Geoethics, food, and water in Latin America: insights from Relational Geoscientific Pragmatism

Enrico Cameron

National Coalition of Independent Scholars and Section of Geoethics and Geological Culture of the Italian Geological Society, Via dei Sedini 11B, 23017 Morbegno (SO), Italy

Email: enrico.cameron@ncis.org

ORCID: https://orcid.org/0000-0002-0192-1202

Abstract. Food is not merely a commodity or a source of nourishment, but a foundational element of human life embedded in extensive social, ecological, cultural, scientific, economic and political relationships. Because food production, distribution, preparation, consumption and waste depend on, and substantially affect, soils, water, climate, biodiversity, energy and other components of the Earth system, food-related decisions and actions have important ethical, and specifically geoethical, implications. This paper examines these implications through Relational Geoscientific Pragmatism (RGP), a framework that integrates geoscientific knowledge, ethical reflection and context-sensitive action. With particular attention to Latin America, the study considers food and water rights, food security and sovereignty, key dimensions of food systems, and the contributions of geoscience and geoscientists to such systems across the Sustainable Development Goals (SDGs). SDG 2 ("Zero Hunger") serves as a principal reference, and the broader interconnections between SDG 2, food systems, and virtually all other SDGs are also addressed. RGP is applied to institutional and personal spheres of decision-making and to the analysis and organization of literature concerning livestock production and related geoethical issues. The paper shows how RGP extends existing approaches, such as sustainable soil management, by advancing a comprehensive, reusable, and structured decision framework; making uncertainty an explicit and integral component of the analytical process; framing geoscientists as contributors to responsible decision-making; requiring that values, rights, and affected actors be explicitly identified and discussed; treating trade-offs and ethical dilemmas as central analytical objects; and explicitly mapping responsibilities across actors, scales, and capacities. Finally, the paper proposes pathways for geoethical action.

Keywords: Food, Geoethics, Relational Geoscientific Pragmatism, Latin America

Geoética, alimentos y agua en América Latina: indicios desde el Pragmatismo Geocientífico Relacional. Los alimentos no son meramente una mercancía o una fuente de nutrición, sino un elemento fundamental de la vida humana, inserto en amplias relaciones sociales, ecológicas, culturales, científicas, económicas y políticas. Dado que la producción, distribución, preparación, consumo y desperdicio de alimentos dependen de los suelos, el agua, el clima, la biodiversidad, la energía y otros componentes del sistema Tierra, y a su vez los afectan de manera sustancial, las decisiones y acciones relacionadas con los alimentos tienen importantes implicaciones éticas y, específicamente, geoéticas. Este artículo examina dichas implicaciones mediante el Pragmatismo Geocientífico Relacional (RGP), un marco que integra conocimiento geocientífico, reflexión ética y acción sensible al contexto. Con especial atención a América Latina, el estudio considera los derechos a la alimentación y al agua, la seguridad y la soberanía alimentarias, dimensiones clave de los sistemas alimentarios y las contribuciones de las geociencias y los geocientíficos a dichos sistemas en el marco de los Objetivos de Desarrollo Sostenible (ODS). El ODS 2 («Hambre cero») constituye una referencia principal, al tiempo que se abordan las interconexiones más amplias entre el ODS 2, los sistemas alimentarios y prácticamente todos los demás ODS. El RGP se aplica a las esferas institucional y personal de la toma de decisiones, así como al análisis y la organización de la literatura relativa a la producción ganadera y las cuestiones geoéticas relacionadas. El artículo muestra cómo el RGP amplía los enfoques existentes, como la gestión sostenible de los suelos, al proponer un marco integral, reutilizable y estructurado para la toma de decisiones; incorporar la incertidumbre como un componente explícito e integral del proceso analítico; reconocer el papel de los geocientíficos en la toma responsable de decisiones; exigir que los valores, los derechos y los actores afectados sean

identificados y discutidos explícitamente; tratar los compromisos entre objetivos en conflicto y los dilemas éticos como objetos centrales de análisis; y explicitar la distribución de responsabilidades entre actores, escalas y capacidades. Finalmente, el artículo propone vías de acción geoética.

Palabras clave: Alimento; Geoética; Pragmatismo Geocientífico Relacional; América Latina

1. Introduction

In food systems, the production, processing, storage, transport, preparation, consumption, and disposal of food depend on continuous flows of energy and materials between human activities and the biosphere, hydrosphere, atmosphere and geosphere. Agricultural production relies on soils, water, climate and nutrients, and, particularly in intensive systems, on substantial external inputs, such as those required to cultivate animal feed. Food availability, including that of products consumed raw, also depends on transport, refrigeration, packaging and market infrastructure, often operating across considerable distances. Cooking introduces additional energy demands and generates gaseous emissions and solid residues; where polluting fuels and inefficient technologies are used, it may also expose households to air pollution and associated health risks. Furthermore, food loss and waste, packaging and organic residues generate additional environmental burdens, which may be amplified in long, highly integrated supply chains.

The cumulative implications of these material and energetic connections are substantial. The global food system relies on large-scale appropriation and degradation of the Earth's natural capital. It occupies approximately 50% of the planet's habitable land, uses more than 70% of available freshwater resources, contributes an estimated 23–34% of global anthropogenic greenhouse gas emissions, contaminates watersheds and coastal seas through nutrient pollution, and extracts aquatic food resources from nearly all rivers, lakes, and oceans (Halpern et al., 2022). Food production accounts for roughly half of humanity's Ecological Footprint, using close to 50% of Earth's biocapacity (Global Footprint Network, 2023). These pressures are not uniform across food types, with livestock, and beef production in particular, being among the most environmentally intensive (Poore and Nemecek, 2018; Halpern et al., 2022).

Moreover, food systems are deeply embedded in social relations and are frequent sources of inequality and conflict. Competition over land and natural resources, labor exploitation, particularly of migrant and seasonal workers, and tensions among agricultural practices, environmental protection objectives, and differing views of the human-nature relationship are widespread. Unequal access to land, technology and markets, along with policy failures, rural depopulation and persistent gender inequalities, further intensify vulnerability. Food systems are also highly politicized, and disruptions to food production and distribution have played central roles in many conflicts and crises (e.g., Teodosijevic, 2003; Magdoff and Tokar, 2010; Agarwal, 2012). At a more fundamental level, food production entails the managed use of living organisms to sustain human life. It is therefore unsurprising that food issues are central to the United Nations Sustainable Development Goals (SDGs) and lend themselves to ethical analysis (e.g., Rawlinson and Ward, 2017).

The main aims of this work are to offer reflections on the relationship between food and geoethics with particular attention to the Latin American context, to examine food production and consumption through the recently developed Relational Geoscientific Pragmatism (RGP) framework (Peppoloni et al., 2025), to explore contributions of geoscience and geoscientists across interconnected SDGs, to assess how RGP may enrich discourse on sustainability and to consider pathways for geoethical action.

The paper first outlines the conceptual foundations of geoethics and RGP (Section 2). It then provides essential context on food, water and agriculture, including a rights-based perspective and references to the Latin American context (Section 3), and examines the contributions of geoscience and geoscientists to food systems across the relevant SDGs (Section 4**).** The analysis subsequently addresses food-related geoethical issues across institutional and personal spheres (Section 5), and discusses the theoretical and practical contribution of RGP (Section 6). In the concluding section, these reflections are situated within the horizons for the future of geoscience proposed by Stewart et al. (2023).

Although this paper focuses on Latin America, some of the data and literature discussed refer to Latin America and the Caribbean, as the consulted sources do not always provide disaggregated information for Latin America alone. Where this is the case, the broader geographical scope is explicitly indicated.

2. Geoethics and Relational Geoscientific Pragmatism

As outlined in the Introduction, human societies, food systems, and the Earth system form an inextricable and nearly all-encompassing web that invites ethical reflection in general and geoethical reflection in particular. This section, therefore, examines at some length the foundations of geoethics and the RGP framework, together with their relationships to systemic awareness, socio-cultural awareness and traditional knowledge. These dimensions are especially relevant to food systems, where decisions concerning land, water, soils, biodiversity, resource use, livelihoods, cultural practices and access to food often involve competing values, unequal distributions of benefits and burdens and uncertainty. They are also highly relevant to Latin America, a region marked by considerable socio-cultural diversity, Indigenous communities, major food-producing landscapes, and persistent tensions among development, environmental protection, rights, and food security and sovereignty (see also the next section).

Geoethics is a field of research and reflection concerned with the principles and values that guide appropriate behaviors and practices wherever human activities interact with the Earth system (Di Capua and Peppoloni, 2023). It integrates scientific knowledge, ethical reflection, and responsibility to promote a critical and informed approach to decision-making and action-oriented toward the common good, and has been proposed as a form of global ethics (Peppoloni and Di Capua, 2020, 2024). Within this framework, human beings are understood as ethical agents embedded in social communities and inseparable from the Earth system. Rather than prescribing rules, geoethics emphasizes the cultivation of moral dispositions such as prudence, integrity, and foresight, while positioning responsibility as the central criterion for action. This responsibility arises from awareness of the far-reaching consequences of human decisions within complex socio-environmental systems, of which humanity is an integral part (Peppoloni and Di Capua, 2022). The foundational principles of geoethics: dignity, freedom, and responsibility, are complemented by aspirational principles of awareness, justice and respect, together guiding ethical conduct across personal, professional, societal and environmental contexts (Peppoloni and Di Capua, 2021).

Within geoethics, ethical judgment and responsible action are inherently contextual, shaped by the specific physical, cultural, and social conditions of human-Earth interactions (Peppoloni et al., 2019). Geoscientific knowledge plays a crucial role by deepening understanding of Earth-system interconnections and enabling informed responses to anthropogenic change among professionals, decision-makers and the wider public. Consequently, geoeducation is a key instrument for fostering critical thinking, environmental awareness and ethical reflection (Bobrowsky et al., 2017). Through the integration of science and ethics, and dialogue among anthropocentric, biocentric, ecocentric and geocentric perspectives, geoethics seeks to reframe humanity's relationship with the Earth, ultimately promoting planetary citizenship grounded in responsibility and solidarity (Peppoloni et al., 2025).

Peppoloni et al. (2025) propose RGP as a holistic methodological framework for geoethics, which serves as the conceptual reference for this paper; its main components are illustrated in figure 1.

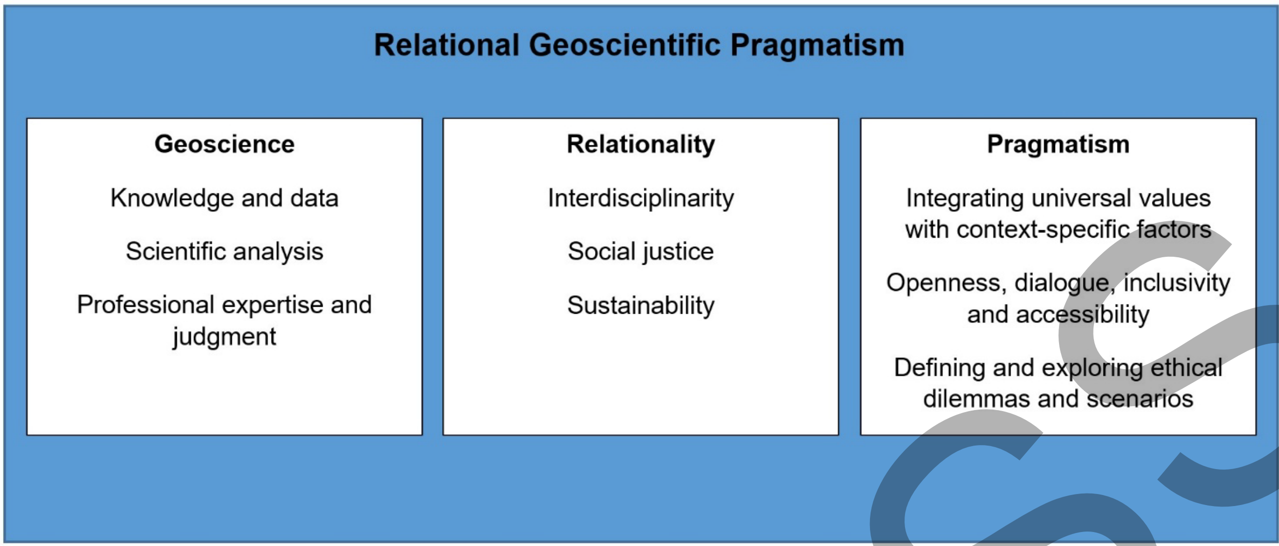

Fig. 1. The main components of Relational Geoscientific Pragmatism (derived from Peppoloni et al., 2025).

The geoscience components of RGP involve the use of robust geoscientific knowledge and objective, verifiable and up-to-date data, combined with rigorous and responsible scientific analysis, professional expertise and judgment, and adherence to appropriate standards. The relationality component emphasizes interdisciplinarity and engagement with communities and individuals, particularly marginalized groups, placing social justice at the center of efforts to address geoethical challenges and foster environmental and intergenerational responsibility. Pragmatism frames geoethics as guided by universal values while remaining action- and solution-oriented and context-sensitive, without implying relativism. Closely linked is an emphasis on openness, dialogue, inclusivity and accessibility, requiring the participation of all relevant stakeholders, such as scientists, policymakers and local communities, in transparent and inclusive decision-making processes. Finally, RGP entails identifying and critically examining ethical dilemmas in human-environment relations, such as balancing economic development and environmental conservation, ensuring intergenerational justice and protecting vulnerable communities (Peppoloni et al., 2025).

The RGP components prompt key questions for addressing geoethical challenges and developing context-specific responses; for example:

- What geoscientific knowledge, data, analysis and expertise are of value in the situation at hand?
- What other scholarly and professional fields should inform decision-making and action?
- Who are the relevant stakeholders and communities?
- What values and principles are relevant, reflecting stakeholder perspectives and concerns, and how compatible are they?
- What ethical issues, dilemmas and choices arise from seeking to integrate or balance these values?
- What possible scenarios could be envisioned to address these issues and/or dilemmas?
- What are the processes through which stakeholder engagement and dialogue should take place?
- How are shared decisions to be made, and action taken, and by whom?

The RGP framework, including the answers to these questions, is non-prescriptive, offering a structured, values-driven pathway for context-sensitive responses to geoethical challenges. It supports decision-makers and other stakeholders in navigating contemporary issues and developing geo-governance models that integrate scientific rigor with ethical and societal considerations (Peppoloni et al., 2025).

The RGP approach entails systemic and socio-cultural awareness. Systemic awareness refers to the capacity to understand how interdependent environmental, social and technical components interact within complex systems, and to recognize the potential consequences of these interactions (Sustainability Directory, n.d.). It enables adaptive, context-specific action by accounting for feedbacks, non-linear dynamics and emergent behaviors, rather than relying on linear prediction or centralized control (Kasdaglis et al., 2014). As argued by Kasdaglis et al. (2014), the cognition underlying such awareness is not confined to a single agent but distributed across multiple agents and their environment (Anderson et al., 2012). Awareness itself can therefore be conceptualized as distributed rather than individually bounded, with information processed in parallel across diverse actors, tools and mechanisms (Kasdaglis et al., 2014). Systemic thinking is essential for addressing complex and potentially wicked sociotechnical problems such as climate change (e.g., Kreuter et al., 2004; Lönngren and Svanström, 2016; Grewatsch et al., 2021).

Socio-cultural awareness (and competence) refers to the ability to understand, appreciate and navigate experiences and perspectives different from one's own, as well as to recognize the complexity of one's relationships and accountability within broader socio-historical dynamics. It entails knowledge of socio-cultural factors shaping interactions and behaviors, respect for multiple dimensions of diversity, effective engagement with individuals whose backgrounds differ by age, culture, disability, ethnicity, gender identity, nationality, neurodiversity, race, religion, or sexual orientation, and the capacity to inform one's own judgment while identifying and appropriately addressing biases in oneself and others (Wesleyan University, n.d.).

Moreover, geoethics and RGP require due consideration of traditional knowledge (TK), understood here as an umbrella term for the cumulative body of knowledge, know-how, practices and representations developed and maintained by people with long-standing interactions with the natural environment (International Council for Science [ICSU], 2002; Houde, 2007; Onyancha, 2024). These sophisticated systems of understanding are embedded in broader cultural complexes encompassing language, naming and classification systems, resource-use practices, rituals, spirituality, and worldviews (ICSU, 2002). TK underpins local-level decision-making across essential aspects of daily life, including hunting, fishing, gathering, agriculture and husbandry, food preparation, conservation and distribution, water location, collection and storage, interpretation of meteorological and climatic phenomena, management of socio-ecological relationships, and adaptation to environmental and social change (ICSU, 2002).

Differences in underlying worldviews (e.g., nonlinear conceptions of time and the relevance of supernatural elements) can complicate relationships between TK and science, but these interactions also offer substantial opportunities. Scientific engagement with well-documented, context-specific TK can broaden empirical foundations and stimulate innovation, while its integration into research and policy can strengthen sustainable development outcomes, particularly in agriculture, conservation and ecosystem management. Moreover, grounding scientific knowledge and technologies in local values and experience enhances their social relevance, acceptance and effectiveness. Through knowledge co-production, scientists and TK holders support mutual learning, methodological innovation and ethical research practices, while enabling flexible, context-sensitive planning that avoids ecological or cultural harm. Finally, linking science education with TK further builds local scientific capacity and allows TK to serve as a foundation for applying scientific knowledge within traditional communities (ICSU, 2002; Ijatuyi et al., 2025).

Applied to food systems, geoethics and RGP combine robust geoscientific knowledge with attention to how access to land and resources, benefits, risks and environmental burdens are distributed across actors, places and generations, and to how values, rights, livelihoods, cultural practices and responsibilities toward vulnerable communities, non-human life and the abiotic world should inform decisions concerning food production, distribution, consumption and disposal under conditions of uncertainty and unequal power. These topics are explored further throughout the remainder of the paper.

Finally, in a section concerning geoethics, it is worth briefly highlighting how theoretical and applied geoethical research is being pursued internationally. The promotion, advancement, and dissemination of geoethics worldwide are led primarily by the International Association for Promoting Geoethics (IAPG), the principal international organization in the field. The IAPG is also at the core of a research infrastructure (Di Capua and Peppoloni, 2025) comprising task groups, boards and committees, national sections, editorial activities, including the dedicated Journal of Geoethics and Social Geosciences, participation in international bodies such as the International Union of Geological Sciences (IUGS), and cooperation with numerous scientific and professional organizations.

Geoethics is a dynamic and expanding field in Latin America. The IAPG has national sections in Argentina, Bolivia, Brazil, Chile, Colombia, Cuba, Mexico, Paraguay, Peru, and Uruguay, and has promoted numerous initiatives, including the first Latin American Symposium on Geoethics, titled "Building Healthy Relationships with the Planet" (Lima, Peru, June 2024). A substantial body of literature has also emerged in the form of articles and books (e.g., Acevedo and Martínez Frías, 2018; Carneiro and de Souza-Fernandes, 2021; Imbernon et al., 2021; Villacorta Chambi, 2022; Villacorta et al., 2024). In 2024, the Chilean section of the IAPG published the Chilean Code of Geoethics, prepared by the Geoethics Group of the Geological Society of Chile with support from the national geoscience community and international collaborators (Sociedad Geológica de Chile, Grupo de Geoética, 2024). These publications do not specifically address the geoethical issues associated with food production and consumption; nevertheless, the objectives of the Chilean Code of Geoethics, including its emphasis on sustainability and sociocultural awareness, largely overlap with the considerations developed in this paper, and the Code is therefore used as one of the reference frameworks for this work.

3. Food, water, food systems

Food, water and food systems encompass a broad and interrelated set of matters that cannot be fully addressed within a single paper. This section, therefore, provides essential context and background to establish a foundation for the geoethical issues examined later, focusing on food as a network, the rights to food and water, food security and sovereignty, and food systems in Latin America. As is typical of geoethical analysis, and as already apparent from the preceding section, the discussion extends beyond the boundaries of the geosciences.

3.1 Food

Szymanski (2017) emphasizes that food is not merely what people eat or a commodity, but a central element of human life and development, embedded in a network of relationships that extends far beyond the basic act of nourishment. This network encompasses food items themselves; the animals and humans who consume or reject them; the living beings and inanimate objects used as food; and the agricultural practices, food sciences and local and global political institutions that regulate production and distribution. It also includes food markets, advertising and media, professional and institutional regimes governing food and health, and cultural practices through which food is acquired, prepared, consumed, preserved, disposed of and transmitted. International organizations responsible for food aid form part of this network as well. Crucially, these relationships span past, present, and, in some cases, future actors, including those affected by the anticipated environmental consequences of food practices.

The right to food is recognized in the Universal Declaration of Human Rights (UN 1948) as part of the right to an adequate standard of living and was reaffirmed in the International Covenant on Economic, Social and Cultural Rights (UN, 1966). This right both underpins and is complemented by the concept of food security, commonly defined through four interrelated dimensions: availability, access, utilization, and stability (FAO, 2006; World Food Programme, 2025). Availability concerns the sufficient supply of food of appropriate quality from domestic production, imports, or food aid. Access refers to individuals' ability to secure adequate entitlements to obtain nutritious food, shaped by legal, political, economic and social arrangements. Utilization denotes the effective use of food through adequate diets, safe water, sanitation and health care, while stability concerns the sustained availability of and access to food over time, without disruption from sudden shocks such as economic or climatic crises, or cyclical events including seasonal food insecurity. Figure 2 shows the prevalence of moderate or severe food insecurity in the total population globally (FAO et al., 2025).

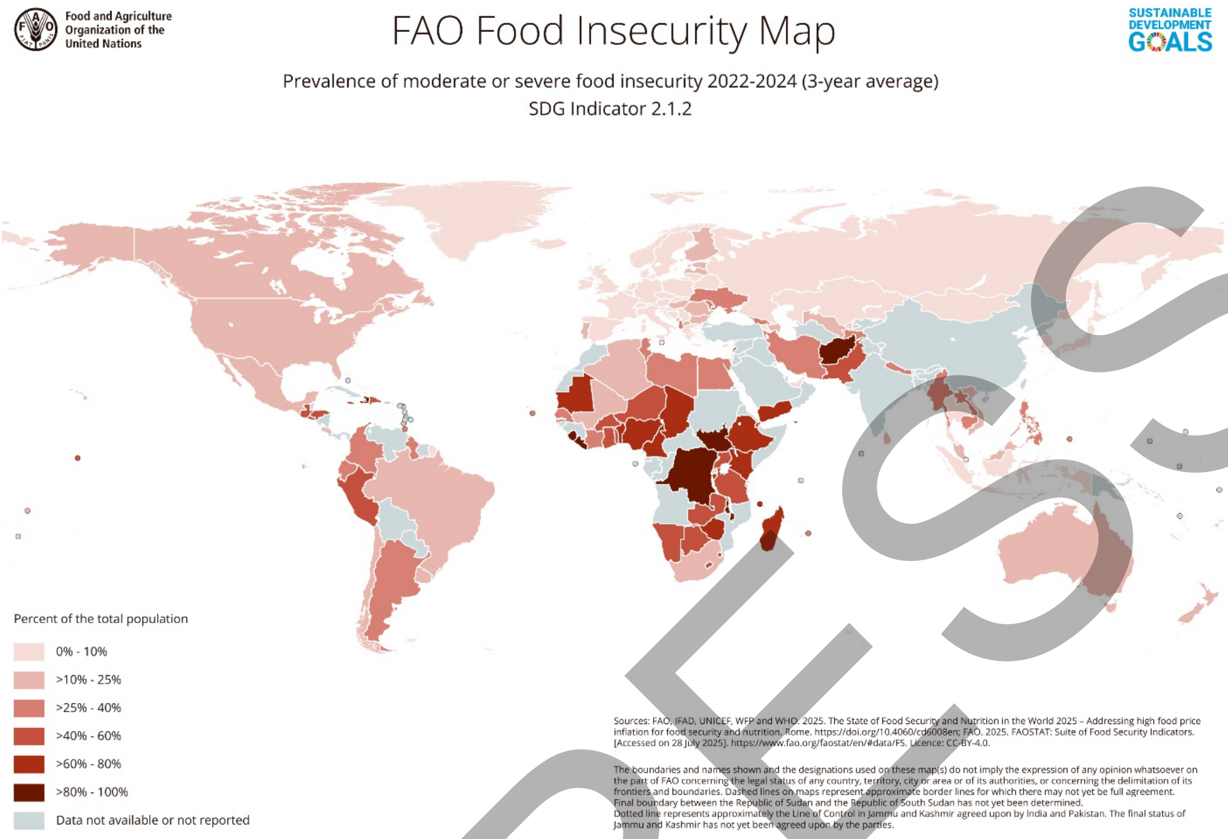

Fig. 2. Prevalence of moderate or severe food insecurity in the global population, shown as the three-year average for 2022–2024 (FAO et al., 2025). The indicator estimates the percentage of people living in households classified as moderately or severely food insecure, that is, households in which at least one adult reported having been exposed, at times during the year, to low-quality diets and may also have been forced to reduce the quantity of food they would normally eat because of a lack of money or other resources (FAO, 2025).

Alongside food security, the cultural acceptability of food has gained increasing prominence. The UN Human Rights Council understands the right to food as encompassing regular, permanent and unrestricted access to food that aligns with the cultural traditions of consumers and ensures, individually and collectively, a physically and mentally fulfilling, dignified life free from fear (Irrera, 2017).

The right to food has been incorporated into the national constitutions of Argentina, Brazil, Colombia, Bolivia, the Dominican Republic, Ecuador, Haiti and Nicaragua (Grisa et al., 2022). More recently, Latin American and Caribbean countries reaffirmed this commitment through the Community of Latin American and Caribbean States (CELAC) Plan for Food Security, Nutrition, and the Eradication of Hunger 2030 (CELAC, 2024). The plan emphasizes strengthening rights-based legal and institutional frameworks while promoting sustainable food production and equitable access to safe and nutritious food, particularly for vulnerable populations. It also prioritizes affordable and healthy diets that respect dietary diversity and food cultures, alongside the development of resilient agrifood systems capable of addressing climate change, biodiversity loss, efficient resource management and climate-related shocks that threaten food availability.

The concept of food sovereignty has gained prominence and is often traced to La Via Campesina's role at the 1996 World Food Summit (Whyte, 2017). Founded in 1993, La Via Campesina is an international movement representing peasants, Indigenous peoples, Afro-descendants, landless workers, small-scale farmers, fishers, pastoralists, migrant farmworkers, rural women and youth worldwide (La Via Campesina, n.d.). It defines food sovereignty as the right of peoples to healthy, culturally appropriate food produced through ecologically sound methods and, critically, their right to define their own food and agricultural systems. Central to this vision are peasant-led agroecological practices, developed over centuries, which seek to ensure healthy food in harmony with nature. La Via Campesina promotes food sovereignty through mobilization for agrarian reform and training in agroecological methods (La Via Campesina, n.d.). For discussions comparing food security and food sovereignty, see, for example, Pachón Ariza (2013), Agarwal (2014), and Jarosz (2014). On food sovereignty, see also the Declaration of Nyéléni (2007), a civil society declaration drafted by representatives from more than 80 countries that advocates food sovereignty, culturally appropriate food, ecologically sound production and people's control over food and agricultural systems.

La Via Campesina, together with other actors, played a central role in developing, in 2018, the United Nations Declaration on the Rights of Peasants and Other People Working in Rural Areas (UNDROP; United Nations Human Rights Council, 2018), which can be seen as a complement to the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP; United Nations, 2007). UNDROP is a non-binding international declaration that articulates specific rights and corresponding state obligations, including access to land, water and seeds, control over food production systems, meaningful participation in policies affecting livelihoods and protection of traditional knowledge, including the right to save, use and exchange seeds, with particular attention to gender inequalities faced by rural women (Kemp et al., 2025). Despite its significance, engagement with UNDROP by global institutions and industry actors has been limited, with references largely confined to the FAO, the Human Rights Council, and the African Development Bank. Nevertheless, it has been invoked in court cases and civil society advocacy in countries such as Argentina, Honduras and Paraguay, and its relevance may increase as connections between climate change, biodiversity, and human rights gain wider recognition (Kemp et al., 2025).

Finally, the United Nations SDG 2, Zero Hunger, together with the other interconnected SDGs, represents one of the principal international frameworks for addressing food security and related challenges and serves as a recurring point of reference throughout this paper.

3.2 Water

The Right to Water and Sanitation was recognized by the UN General Assembly and the Human Rights Council in 2010 and affirmed as a distinct right by the UN General Assembly in 2015 (United Nations General Assembly, 2015). It entitles everyone to affordable, sufficient, safe and acceptable water for personal and domestic use, as well as to sanitation that is safe, hygienic, secure, socially and culturally acceptable, and that ensures privacy and dignity (UN Water, n.d.). Access may be compromised by unaffordability, unreliability, unsafe or unhygienic conditions, poor location, lack of accessibility for children or persons with disabilities, or the absence of gender-appropriate facilities. Marginalized groups, including women, children, refugees, Indigenous and Afro-descendant peoples and persons with disabilities, are disproportionately excluded or discriminated against in service provision. Governments are therefore required to adopt a human rights-based approach that removes legal, social and structural barriers, addresses intersecting forms of discrimination and anticipates broader challenges such as climate change, conflict, migration and population growth. Ensuring universal access to water and sanitation is essential to achieving the SDGs and the 2030 Agenda's commitment to leaving no one behind, as it underpins public health, gender equality, education and economic productivity (UN Water, n.d.).

Latin America is characterized by both abundance and scarcity of water resources. The region holds approximately one-third of the world's renewable freshwater, yet availability is highly uneven across space and seasons, resulting in acute water stress in specific river basins and densely populated or economically dynamic areas, including parts of Mexico, Central America, coastal Peru and Chile, and northeastern Brazil. Agriculture accounts for the majority of water withdrawals and is a major source of pollution, while in some settings, rapid urbanization, governance issues, and underinvestment in infrastructure contribute to challenges such as poor water quality, limited wastewater treatment, high distribution losses, and unequal access to safe water and sanitation. At the same time, improved water management, reduced water footprints in crop production, enhanced pollution control and stronger institutions could substantially reduce consumptive use and contamination, improve equity, and better align the region's significant water endowment with human development and sustainability goals (e.g., World Water Council, 2004; Mejía, 2014; Romano-Armada et al., 2014; Mekonnen et al., 2015).

Water changes state and circulates through different Earth domains, including the biosphere and the bodies of living beings, for whom it is essential to life. These characteristics pose distinctive challenges for water ethics (e.g., Stefanovic and Adeel, 2021) and for enforcing the right to water, and have been invoked both to oppose the commodification and appropriation of water resources and to hinder the constitutionalization of this right (e.g., Ballestero, 2019). Nevertheless, Guatemala, Peru, Costa Rica, Venezuela, Uruguay, Ecuador, Bolivia, the Dominican Republic, Mexico, Honduras, and Cuba have incorporated the right to water into their constitutions (Human Right 2 Water, 2024).

The UN World Water Assessment Programme estimates that producing sufficient food requires 2,000–3,000 liters of water per person per day, with household needs varying depending on whether food is self-produced (Morgera et al., 2020), and agriculture is a cause of water accumulation and related conflicts (e.g., Boelens et al., 2011). Consequently, the human right to water depends on responsible and efficient agricultural water use and is closely linked to the human right to food. While the right to water primarily guarantees access for drinking, sanitation, and personal and domestic uses, it also encompasses water for food and agricultural production through its interaction with other human rights (Morgera et al., 2020).

Finally, SDG 2 (Zero Hunger) is closely linked to water availability, quality and management, since ending hunger, achieving food security and improved nutrition, and promoting sustainable agriculture, depend on reliable water resources. Further connections among SDG 2, water and other SDGs will be explored in greater detail later in the paper.

3.3 Food systems

Food systems and public policies in Latin America vary widely across countries, yet several common trends can be identified (Le Coq et al., 2022). Since the 1990s, food policies have shifted from a narrow focus on hunger eradication to a food and nutritional security (FNS) framework that recognizes food as a human right and emphasizes access, diet quality, social inclusion and environmental concerns. While public interventions have aimed to improve access and support family farming, food systems have been profoundly reshaped by dynamics that reinforce market concentration and the diffusion of low-cost ultra-processed foods, contributing to the coexistence of hunger, rising obesity and diet-related chronic diseases. These trends are further intensified by export-oriented agrarian models dominated by agroindustry, which drive environmental degradation, land concentration, and the marginalization of peasant, Indigenous and other historically rooted peoples and groups, and affect food supply and consumption practices and networks. Although alternative initiatives such as agroecology, short supply chains and urban agriculture have emerged, they remain marginal, resulting in a structural gap between progressive FNS policy frameworks and dominant food system dynamics that continue to produce food insecurity and inequality (FAO et al., 2025).

Two further issues of food systems are considered here. One concerns clean cooking, understood as the use of modern, sustainable fuels and technologies for food preparation (UNDP and FAO, 2025). According to the Joint Declaration "Clean Cooking in Latin America and the Caribbean", adopted during the 55th Meeting of the Ministers of the Latin America Energy Organization (2025), the traditional reliance on charcoal and firewood exposes households to smoke and toxic emissions, with severe health consequences, particularly for women and children in low-income families. It also imposes major time burdens through fuel collection and cooking, constraining access to education, employment and economic independence. The use of these inefficient fuels further contributes to deforestation, ecosystem degradation, air pollution, greenhouse gas emissions and climate change. In Latin America and the Caribbean, around 78 million people, 12% of the regional population, used firewood for cooking and household heating in 2024, and firewood also accounted for 31% of residential final energy consumption in the region, although this share had declined from 43% in 2004 (Organización Latinoamericana de Energia [OLADE], 2025b). Expanding access to clean cooking, one of the commitments of the aforesaid Declaration, is therefore relevant not only to health and social equity but also to the energy transition and greenhouse gas emissions reduction.

The second issue concerns food loss and waste. Both refer to decreases in the quantity or quality of food, but the former results from decisions and actions along the food supply chain from production up to, but excluding, retailers, food service providers and consumers. The latter, by contrast, results from decisions and actions by retailers, food service providers and consumers (FAO, 2019). Food loss and waste in Latin America and the Caribbean has substantial social, economic, and environmental consequences, although available evidence remains uneven across countries and supply-chain stages. Studies reviewed for the region indicate that losses occur mainly in the early and intermediate stages of food supply chains, especially during harvesting, storage, cooling, transport and processing, owing to infrastructural, financial, managerial and operational constraints. These losses reduce food availability and producer income while wasting land, water, energy, fertilizers, and other inputs already used in production. Food harvested but ultimately lost or wasted in Latin America accounts for about 5% of the global water footprint associated with food loss and waste; worldwide, food loss and waste generate approximately 8–10% of annual greenhouse-gas emissions. In Colombia, food loss and waste has been estimated at about 34% of total food production, equivalent to economic losses of roughly US$5.4 billion per year (Hanson et al., 2022; Costa et al., 2024).

3.4 Navigating competing objectives

Food-system interventions can generate both conflicts and synergies across social, environmental and economic objectives. Measures intended to increase productivity, stabilize supplies, or improve affordability may strengthen food security and livelihoods while intensifying pressure on soils, water, biodiversity and climate. Conversely, policies designed to conserve ecosystems, reduce emissions, or limit resource use may impose short-term costs on producers, workers, consumers, or communities whose livelihoods depend on existing practices. Similar tensions arise between export-oriented growth and local access to food and land, between technological modernization and the continuity of traditional practices, and between individual responsibility and the structural conditions that shape consumption, waste and access to cleaner energy. At the same time, some interventions, such as reducing food loss and waste, improving water-use efficiency, or expanding access to clean cooking, can produce benefits across several areas simultaneously. These interactions show that food-system decisions cannot be assessed through a single objective but, in accordance with the RGP approach, require attention to trade-offs, unevenly distributed benefits and burdens, temporal effects, uncertainty, and the differing values and interests of the actors involved.

4. The role of geosciences and geoscientists

The potential role of the geosciences and geoscientists in food systems is wide-ranging; here, we focus on their relevance to the United Nations SDGs. We draw on the approach presented in the UNESCO-AGU publication "Geoscience in Action: Advancing Sustainable Development" (Capello et al., 2023), which associates each SDG with the principal areas of geoscience contribution (Table 1). Building on this framework, Table 2 relates these areas to geoscience topics, applications and representative studies, mainly focused on food systems in Latin America. As already noted, human societies, food systems and the Earth system form an inextricable and nearly all-encompassing web. Accordingly, Table 2 includes all SDGs and areas of geoscience contribution. For the relationship between the geosciences and the SDGs, see also Gill and Smith (2021).

Table 1. SDGs and principal areas of geoscience contribution (Capello et al., 2023).

SDG	Goal	Areas of geoscience contribution
1	End poverty in all its forms everywhere.	Support resource development, increase geoscience participation, and assess geo-risk.
2	End hunger, achieve food security, improve nutrition, and promote sustainable agriculture.	Preserve soil health, manage land use, and monitor erosion.
3	Ensure healthy lives and promote well-being for all at all ages.	Reduce geologic hazards, prepare for natural disasters, and map Earth processes.
4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.	Ease knowledge transfer, promote geoscience in education, and develop visualization skills.
5	Achieve gender equality and empower all women and girls.	Ensure gender equity, eliminate gender bias, and empower minorities.
6	Ensure availability and sustainable management of water and sanitation for all.	Enhance water management, support water regulations, and educate about water cycles.
7	Ensure access to affordable, reliable, sustainable, and modern energy for all.	Increase energy sustainability, foster energy transition, and alleviate energy poverty.
8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.	Insert geoscience in growth plans, augment resource efficiency, emphasize local employment.

9	Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation.	Accelerate geo-technology, enable transformation, share geo-information.
10	Reduce inequality within and among countries.	Practice social and ethical geoscience, promote diversity, prioritize plans and projects.
11	Make cities and human settlements inclusive, safe, resilient and sustainable.	Make settlements resilient and safe, support circular cities, and protect geoheritage.
12	Ensure sustainable consumption and production patterns.	Advance efficiency in natural resources, reduce environmental impacts, promote circular economy mindsets.
13	Take urgent action to combat climate change and its impacts.	Engage in climate mitigation, transition to clean energy, and support decarbonization.
14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development.	Monitor coastal change, identify marine geohazards, and support water management.
15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.	Support habitats and conservation, use resources equitably, and reduce environmental impact.
16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all, and build effective, accountable, and inclusive institutions at all levels.	Promote sustainable development, uphold geoethics, and engage with geo-stakeholders.
17	Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development.	Promote geo-awareness in legislation, strengthen integration, and provide geotechnical support.

Table 2. Geoscience contributions to food systems.

SDGs and areas of geoscience contribution (Table 1)	**Examples of geoscience applications**	**Core food-system function(s) supported**	**Sample papers, chapters, reports and books, mainly focused on Latin America**
2, 3, 12, 15	Soil mapping, fertility assessment, erosion and salinization control, long-term soil evolution	Crop productivity, nutrition, land sustainability	Montaño-Lopez et al. (2021); Poppiel et al. (2025)

SDGs and areas of geoscience contribution (Table 1)	Examples of geoscience applications	Core food-system function(s) supported	Sample papers, chapters, reports and books, mainly focused on Latin America
2, 6, 11, 13	Aquifer characterization, recharge estimation, water quality assessment, sustainable abstraction	Irrigation, food processing, resilience to drought	Salazar et al. (2022); Grondona et al. (2023)
1,2, 13	Climate-hydrology-soil interactions, extreme-event analysis, adaptation planning	Yield stability, risk reduction, long-term resilience	Marengo et al. (2014); Almeida et al. (2020)
1, 2, 11, 13	Hazard mapping, early warning systems, risk-informed land-use planning	Protection of livelihoods, infrastructure, and food access	Meza et al. (2020); Houspanossian et al. (2023)
2, 3	Mapping of micronutrients and toxic elements (e.g., iodine, arsenic, fluoride) in soils and water	Food safety, nutrition, public health	Alves Peixoto and Jadán-Piedra (2022); Costa et al. (2024)
7, 8, 9	Assessment of energy resources (geothermal, hydropower), fertilizer and material supply chains	Mechanization, irrigation, storage, processing	Appleton and Notholt (2002); Guerrero-Lemus and Shephard (2017); IRENA (2019, in particular pp. 20–22)
11, 12, 15	Integrated land-water-ecosystem assessment, geospatial planning tools	Sustainable production, ecosystem services	Estrada-Carmona et al. (2014); Zarbá et al. (2022)
2, 14	Sediment dynamics, coastal geomorphology, seabed and habitat characterization	Fisheries, aquaculture, coastal food security	Rudolph et al. (2009); Vallarino Castillo et al. (2023)
9, 12, 17	Geodata stewardship, remote sensing, long-term environmental monitoring	Decision support across the food system	Galeana-Pizaña et al. (2018); Jennings et al. (2025)
4, 8, 17	Geoscience education, systems thinking, risk communication	Adaptive capacity, innovation, policy uptake	Gibbons et al. (2022); Villacorta et al. (2024); Cerón-González et al. (2025)
5, 10, 16	Gender-sensitive research, inclusive institutions, access to data, and decision-making	Fair access to and governance of food-system resources	Bennett et al. (2005); Solorio et al. (2023); ECLAC (2025b)

SDGs and areas of geoscience contribution (Table 1)	Examples of geoscience applications	Core food-system function(s) supported	Sample papers, chapters, reports and books, mainly focused on Latin America
16, 17	Transparent resource governance, transboundary water cooperation, institutional capacity	Stable and equitable food systems	Siegel and Bastos Lima (2020); Jarquin-Solis and Mauduit (2021); Espíndola and Leite (2022)

According to the Economic Commission for Latin America and the Caribbean (ECLAC), the 2030 Agenda for Sustainable Development has improved millions of lives over the past decade, but progress remains insufficient to achieve its 17 Sustainable Development Goals by 2030. Globally, only 35% of SDG targets are on track or show moderate progress; nearly half are advancing too slowly or only marginally, while 18% have regressed. The situation in Latin America and the Caribbean is slightly more favorable than the global average, but still falls well short of expectations ten years after the adoption of the 2030 Agenda. Of the targets assessed by ECLAC, 64% show positive trends, yet only 23% are likely to be achieved by 2030; 41% require accelerated action, while 36% are stagnating or moving in the wrong direction compared with their 2015 baseline (ECLAC, 2025a). The status of SDG 2 is summarized in Table 3; it is unlikely that at least 50% of its targets will be achieved by 2030 (ECLAC, 2025a).

Table 3. SDG2 targets in Latin America and the Caribbean by likelihood of achievement 2030 (ECLAC, 2025a).

Target	Status
Universal access to safe and nutritious food	The trend is moving away from the target
End all forms of malnutrition	
Ensure sustainable food production systems and implement resilient agricultural practices	
Prevent agricultural trade restrictions, market distortions, and export subsidies	
Ensure stable food commodity markets and timely access to information	
Maintain the genetic diversity in food production	The trend is in the right direction, but progress is
Invest in rural infrastructure, agricultural research, technology, and gene banks	

	too slow for the target to be met
Double the productivity and incomes of small-scale food producers	Insufficient data

What is more, ECLAC (2025b) notes that accelerating progress requires deep structural transformations, including reducing inequality, strengthening social protection and care systems, investing in innovation and digital transformation, and promoting sustainability-oriented practices. Active engagement by civil society, the private sector, academia, local governments and legislatures, along with improved data, monitoring and accountability, is essential. With strong political commitment, enhanced institutional capacity, and renewed regional and multilateral cooperation, the region retains the potential to advance toward more inclusive, resilient, and sustainable development (ECLAC, 2025b). Tables 1 and 2 indicate that geoscience involvement is strategically important for achieving the SDGs and responding to ECLAC's recommendations. This, in turn, requires geoscientists to participate in decision-making and policymaking processes.

It must be noted that Siegel and Bastos Lima (2020), in their analysis of agri-food governance in South America, offer a critique of sustainability, particularly as operationalized through the SDGs, highlighting its conceptual vagueness, political malleability and susceptibility to power capture. They argue that sustainability functions as a flexible and contested signifier capable of accommodating divergent, even contradictory, agendas, enabling actors to claim alignment without substantive transformation. Rather than resolving tensions between economic growth, social equity and environmental protection, sustainability frameworks often depoliticize conflict, obscure trade-offs, and legitimize business as usual, especially in agri-food systems dominated by powerful agribusiness interests. The SDGs' emphasis on inclusiveness is further criticized for lacking enforceable domestic mechanisms, leaving implementation largely shaped by existing institutions, power relations and inequalities. Consequently, sustainability may reinforce rather than challenge marginalization, particularly in contexts of weak democratic institutions (Siegel and Bastos Lima, 2020).

Siegel and Bastos Lima (2020), moreover, identify a practice they term “sustainability metonymy”, whereby selective engagement with a limited set of goals or targets (e.g., productivity or hunger reduction) is treated as compliance with sustainability as a whole, thereby undermining the SDGs’ claim to indivisibility. They also argue that sustainability frameworks insufficiently address global political-economic structures and teleconnections, assigning responsibility primarily to national governments while leaving international drivers of environmental degradation and inequality largely unexamined. Taken together, this critique frames sustainability not as a neutral or inherently progressive concept, but as a deeply political one whose outcomes depend on who defines, implements and controls it (Chappell and Schneider, 2017; Constance et al., 2018).

5. Food and geoethics

Latin America is an important food-exporting region (World Bank, 2025). It has a long, rich and complex food history shaped by Indigenous traditions and successive external influences, closely linked to environmental and cultural diversity. The region is also a major center of crop domestication and agrobiodiversity, having given rise to globally significant food products such as maize, potatoes and tomatoes. These products, together with the dissemination of Latin American dishes and culinary traditions, have influenced food practices worldwide (Lovera, 2005).

As noted earlier, since food is embedded in a network of relationships involving the Earth system as well as social, cultural, economic and political dimensions, every choice and action related to food production and consumption, whether personal or situated in interpersonal, social, or professional contexts, carries ethical, and specifically geoethical, implications. Such choices often arise from the need to balance multiple, sometimes conflicting, objectives, constraints, duties and ethical commitments. The questions prompted by the RGP approach illustrated in Section 2 have been reformulated for application to food systems and to two spheres of decision-making and action, as shown in Table 4.

Table 4. Geoethical guiding questions for food systems across spheres of decision-making and action.

Analytical focus	**Professional, administrative, and political decision-making and action (institutional sphere)**	**Personal sphere**
Knowledge and uncertainty	What scientific knowledge, data, analysis, and expertise are needed to understand consequences for societies and the Earth system, and what uncertainties or limits should be made explicit?	What knowledge should I seek to understand how my food-related choices (e.g., what I eat, buy, waste, or avoid) affect the Earth system and other people, and what uncertainties should I acknowledge?
Other fields and perspectives	What other scholarly, professional, and knowledge fields (e.g., agronomy, ecology, nutrition, economics, social sciences, ethics, knowledge from local or Indigenous and other historically rooted peoples and groups) should inform decisions and actions?	What perspectives beyond my own (scientific, cultural, social, ethical, or experiential) should inform my reflection on this food-related situation?
Affected actors	Who are the relevant stakeholders across the food system, including producers, workers, consumers, local, Indigenous, and other historically rooted peoples and groups, vulnerable groups, future generations and non-human biotic components of the Earth system?	Who may be affected by my food choices, directly or indirectly, including farmers, food workers, communities, vulnerable groups, future generations, animals and other non-human biotic components of the Earth system?
Values and principles	What values, principles, and rights are relevant, reflecting stakeholder perspectives (e.g., right to food and water, food security and sovereignty, sustainability, health, social and environmental justice, equity, cultural diversity, animal welfare)?	What values, principles, and rights are at stake, and how do they reflect my ethical commitments (e.g., right to food and water, …)?
Tensions and trade-offs	How compatible are these values and principles, and where do tensions or trade-offs emerge (e.g., productivity vs. environmental protection)?	Where do tensions arise between these values, such as between convenience, affordability, personal preferences, social justice and care for the Earth system?
Ethical dilemmas	What ethical issues, dilemmas, and choices arise when balancing values, interests, duties and rights within food systems?	What ethical issues or dilemmas emerge when balancing values, interests, duties and responsibilities in my food-related decisions?

Analytical focus	Professional, administrative, and political decision-making and action (institutional sphere)	Personal sphere
Alternatives and consequences	What alternative scenarios or practices could address tensions and trade-offs, as well as ethical dilemmas (e.g., production methods, sourcing strategies, policy options), and what are their likely consequences for human well-being, social justice and the Earth system?	What alternative actions are realistically available to me (e.g., product choices, sourcing, dietary patterns, waste reduction), and what consequences might each entail for others and for the Earth system?
Dialogue and engagement	What processes of engagement, dialogue, and communication are needed to ensure transparency, accessibility, and meaningful participation by affected stakeholders?	How can I remain open to dialogue, learning, and self-reflection regarding food choices and practices, including listening to others and revising my habits when warranted?
Responsibility and action	How should responsibilities be shared, decisions made, and actions implemented, and by whom, to promote social justice and Earth-system integrity, considering legal, regulatory and institutional responsibilities?	What responsibilities am I willing and able to assume as a consumer, household member, or citizen, and how can my food-related actions contribute, however modestly, to social justice, human well-being and Earth-system integrity?

We first examine the institutional sphere. A targeted literature review focused on Latin America was conducted to identify references relevant to the RGP questions listed in Table 4. On this basis, a series of tables was developed to organize how the selected literature addresses each analytical focus in Table 4. Given the breadth of food products and the geoethical issues associated with their production and consumption, a comprehensive treatment is beyond the scope of this paper. The discussion, therefore, focuses on livestock production systems because of their significant direct and indirect environmental impacts, the central role of animal-source foods, particularly beef, in traditional and contemporary Latin American diets, and the region's position as a major livestock producer and exporter (FAO, 2023). The results are presented in Appendix A.

The tables in Appendix A indicate that the literature engages with a broad and heterogeneous set of issues directly relevant to food systems and geoethics in Latin America. The themes that emerge emphasize context-sensitive approaches and relational forms of reasoning attentive to interdependencies among human and non-human biotic actors. They also highlight explicit engagement with trade-offs and uncertainty, shared and differentiated responsibility across actors and scales, and inclusive governance grounded in dialogue. More broadly, the literature points toward the integration of plural knowledge systems and process-oriented transformations in which change is understood as iterative, negotiated and adaptive, rather than as the implementation of fixed technical solutions. As to SDG 2, Table 5 summarizes the main themes identified in Appendix A that are relevant to this goal and links them to the corresponding geoscience contribution areas presented in Table 1.

Table 5. Main themes from Appendix A relevant to SDG2 and areas of geoscience contribution from Table 1.

<table>
<tr><th>Themes</th><th>Areas of geoscience contribution (Table 1)</th></tr>
<tr><td>Land, soil, ecosystem, and climate conditions affecting sustainable and resilient food production.</td><td rowspan="6">• Preserve soil health; manage land use; monitor erosion; assess geo-risk; support habitats and conservation; reduce environmental impact; engage in climate mitigation
• Support resource development; increase geoscience participation; augment resource efficiency; emphasize local employment; ease knowledge transfer; share geo-information
• Use resources equitably; practice social and ethical geoscience; ensure gender equity; empower minorities
• Support habitats and conservation; strengthen integration; engage with geo-stakeholders
• Promote geo-awareness in legislation; uphold geoethics
• Accelerate geo-technology; enable transformation</td></tr>
<tr><td>Agricultural productivity, rural livelihoods, and access to productive resources, knowledge, and services.</td></tr>
<tr><td>Food access, nutrition, health, and the conditions affecting vulnerable populations.</td></tr>
<tr><td>Agrobiodiversity, traditional food systems, Indigenous knowledge, and benefit sharing.</td></tr>
<tr><td>Trade, supply chains, markets, information, standards, and institutional coordination.</td></tr>
<tr><td>Research, monitoring, technology, uncertainty, and science-policy interaction.</td></tr>
</table>

Clearly, addressing the questions in Table 4, and many of the issues presented in the tables in Appendix A, already imply a bias toward geoethics. Political, economic and administrative practices may diverge considerably from the orientations suggested in this paper, as already illustrated by some of the challenges in achieving the SDGs discussed in the previous section, setting aside broader critiques of the SDG framework.

With respect to the personal sphere, Appendix B summarizes, for each analytical focus and question in Table 4, considerations relating to food in general, rather than to livestock alone, since the focus is on an ordinary person consuming a varied diet. Taken together, these considerations outline a reflexive and ethically aware individual who seeks reliable knowledge while acknowledging uncertainty and information constraints, considers scientific, cultural, social, ethical and experiential perspectives, identifies the human and non-human biotic actors affected by food choices, and reflects on the values, rights, tensions, trade-offs, alternatives and consequences involved. Food choices are thus understood not as neutral or purely private acts, but as practices embedded in Earth-system processes, social relations, cultural meanings, economic conditions and power structures. Appendix B encourages context-sensitive and progressively better-informed choices, such as reducing food waste, moderating excessive consumption of resource-intensive or ultra-processed foods where feasible, assessing the reliability of labels and sustainability claims, supporting local or alternative food initiatives when accessible, and remaining open to dialogue, learning and revising established habits. It also acknowledges that personal choices are constrained by income, time, access, cultural norms, marketing and policy environments. Responsibility is therefore shared among institutions, producers, supply-chain actors and public authorities, and individual action should complement rather than replace collective and policy-based solutions. Inevitably, the resulting profile is somewhat idealized: individuals will differ in their awareness, priorities, resources, and willingness to engage, giving rise to differentiated and evolving forms of geoethical practice.

Gradations and tensions may arise between the personal and institutional spheres. Gradations reflect the fact that individuals are embedded in formal and informal groups and networks, beginning with the family, where they assume different roles and possess varying degrees of responsibility and capacity for action. Tensions, and sometimes genuine dilemmas, emerge when personal convictions and commitments conflict with institutional responsibilities, duties or constraints. They may also arise in community settings, for instance when an individual's ethical commitments or dietary practices differ from group norms, such as when a vegetarian or vegan attends a barbecue or other shared meals.

6. Relational Geoscientific Pragmatism and geoethical action

6.1 The contribution of RGP

The RGP approach identifies a set of interrelated pathways through which geoethical orientations can be translated into practice, and it is situated within a substantial and diverse body of literature that already articulates geoethically compatible values and objectives. This raises the question of what this framework adds to existing approaches in terms of interpretation, practice, and scope. To explore this question, we use soil-related issues in Latin America as an illustrative example, given that the vast majority of the food supply ultimately depends on land and soil. The regional scale is adopted here for illustrative purposes, with the understanding that both RGP and its implications require localization in specific contexts. The following considerations on soil conditions in Latin America and the proposed approaches to addressing the identified problems are drawn from the consulted literature (Borras Jr. et al., 2012; Wingeyer et al., 2015; Falcone and Rosenberg, 2022; Ortiz García et al., 2022; Sosa Varrotti et al., 2022; FAO, 2024; Hackfort and Haas, 2025; Neves et al. 2025; Poppiel et al., 2025).

Soils in Latin America face a combination of interrelated challenges, including degradation and declining fertility, loss of organic matter, depletion of key nutrients, erosion, compaction and structural deterioration, expanding desertification, chemical imbalances, loss of biological life, and the conversion of pastures and forests into intensive monocultures. These biophysical processes are reinforced by weak and fragmented soil governance, short-term and extractive land-use practices associated with land leasing and agribusiness expansion, reduced soil water-retention capacity, increased exposure to droughts and extreme rainfall, and the limited integration of soil conservation into agricultural modernization and climate policies.

In response, the reviewed literature highlights solutions that combine on-farm soil restoration with broader institutional reforms. These include integrated soil management practices to enhance fertility and resilience, such as crop diversification, balanced nutrient management and rebuilding soil carbon, alongside land-use regulation to limit monocultures, discourage short-term extractive farming and prevent expansion onto fragile lands. Proposed measures also emphasize strengthening soil governance through coherent legal frameworks, monitoring systems and institutional coordination. They include protecting smallholders, communal and Indigenous people's land ownership rights to support long-term stewardship, as well as integrating soil conservation into climate and energy strategies while avoiding overreliance on weakly regulated carbon markets. In addition, these measures call for sustained public investment in farmer support, technical assistance and agroecological transitions that balance productivity, social equity and ecosystem resilience. Examples of projects aligned with this approach can be found, for instance, on the Initiative 20x20 portal. Initiative 20x20 is a country-led effort that seeks to change land degradation dynamics in Latin America and the Caribbean by protecting and restoring 50 million hectares of forests, farmland, pasture and other landscapes by 2030. Several projects explicitly address soil conditions, including Restoring Soil with Agroforestry Systems in Northern Belize, Building Sustainable Cocoa Agroforestry Systems in Colombia, Restoring the Chihuahuan Desert Grasslands in Mexico, and Revitalizing Landscapes Damaged by Intensive Agriculture in Brazil. Other reforestation, silvopastoral and conservation initiatives can also reasonably be expected to have positive effects on soil conservation and health.

Overall, these solutions align with the principles of sustainable soil management (SSM), understood as an integrated, context-specific approach that restores soil functions while recognizing soils as both ecological and socio-productive resources (FAO, 2024). Beyond biophysical improvements, SSM promotes participatory, locally adapted practices that value community knowledge, strengthen the role of smallholders and family farmers, and support inclusive land governance. In doing so, it delivers multiple co-benefits, including improved productivity, greater resilience to climate extremes, enhanced food security, and positive economic and social outcomes for farmers and rural communities.

The RGP approach integrates and adds to what the literature and, in particular, the SSM framework propose by:

1. advancing a comprehensive decision framework in which biophysical knowledge, governance conditions, ethical considerations, social impacts and long-term consequences are treated as co-equal analytical dimensions rather than as adjacent themes, making explicit that soil management decisions are never purely technical or policy choices but system-wide judgments with ethical and political implications;
2. providing a structured way to assist decisions among practices, policies, and investments when objectives conflict, evidence is incomplete, or consequences are unevenly distributed, by explicitly requiring the identification of uncertainties, trade-offs, alternative scenarios, and responsibility for action;
3. making uncertainty a mandatory and visible component of the analytical process rather than a background limitation, which strengthens transparency and prevents overreliance on indicators or other tools that may mask spatial heterogeneity, social impacts or long-term risks;
4. framing geoscientists as contributors to responsible decision-making through professional judgment, scenario analysis, risk assessment and clear communication of uncertainty;
5. requiring that values, rights and affected actors be explicitly identified and discussed as part of the analytical structure, including future generations and non-human biotic and abiotic systems, which strengthens ethical coherence and helps reveal where technically sound solutions may generate social exclusion, conflict or legitimacy deficits;
6. treating trade-offs and dilemmas as central analytical objects rather than side effects, and encouraging explicit comparison of alternative pathways and their consequences, which supports more defensible and transparent choices, especially where "win-win" narratives are unrealistic;

7. explicitly mapping who is responsible for what, at which scale and with which capacities, thereby helping to diagnose implementation risks, accountability gaps and coordination failures that may explain why even well-intentioned soil policies underperform in practice.

Importantly, the RGP approach allows the same methodological structure to be reused across different domains, problems and scales, from single projects to policy-level decisions. Indeed, a discussion similar to that developed above can be applied, for instance, to livestock production and the associated environmental issues. The consulted literature (Appendix A, in particular Tables A4, A7, and A9), similar to that on soil management, already indicates which good practices should be adopted, including with respect to dialogue and engagement. The RPG, again, integrates and builds upon what the literature proposes, in a manner analogous to what has been discussed above for the SSM. The tables in Appendix A also implicitly point to the necessity of good water management and indirectly reaffirm the close connection and interdependence between the right to food and the right to water, as noted in Section 3. What is more, the RGP even functions as an analytical framework, as illustrated again in Appendix A by structuring the diverse contents and themes via the RGP lens.

6.2 Acting geoethically

The ways in which the RGP questions are addressed and, more broadly, geoethical issues are treated can prompt a spectrum of possible standings and actions for geoscientists, shaped by context, institutional constraints, power relations, personal values, and their role, responsibilities, and capacity to act. Beyond adherence to baseline principles of geoethics and the RGP, the positions outlined here should be understood as context-dependent possibilities.

At one end of the spectrum lies professional integrity, encompassing the production of rigorous geoscientific knowledge, sound analysis, honest communication of uncertainty, and resistance to distortion or strategic simplification of results for political, commercial, or institutional ends. In many contexts, particularly where governance is weak or regulatory frameworks are limited, insisting on methodological rigor, transparency and precaution already constitutes an ethical stance.

A further step involves internal engagement and advisory advocacy, whereby geoscientists raise concerns, highlight risks and propose alternative scenarios within organizations, projects, or policy processes, including escalation to higher technical, managerial or decision-making levels where feasible. This may include advising on long-term consequences, distributive effects or ethical tensions that exceed narrow technical mandates. Although often incremental and constrained, such engagement can meaningfully influence outcomes while remaining compatible with continued professional participation.

Further along the spectrum is selective refusal or boundary-setting, where geoscientists decline to participate in analyses, projects or narratives they judge ethically unacceptable or misleading. This option typically arises when trade-offs become irreconcilable and continued involvement would imply tacit endorsement of harm, injustice or unsustainable practices, particularly where escalation has failed or is no longer possible. It should be understood not as moral absolutism, but as a context-dependent response that weighs effectiveness and the availability of alternative actors or strategies.

Beyond this lies withdrawal, resignation or disengagement, which may occur when institutional environments systematically obstruct ethical action, disregard substantiated concerns or suppress honest communication of risks and uncertainties. Such choices are often costly and unevenly available, especially where professional protections are weak, but may represent a legitimate outcome of responsible reflection when meaningful capacity to act within a system has been exhausted.

At the most demanding and complex end of the spectrum are ethical dissent, whistleblowing, and public critique, including acting as a geocitizen rather than, or in addition to, a professional expert. This may involve engagement with civil society, raising the awareness of local communities through workshops and informative campaigns, support for affected communities, participation in public debate or challenges to dominant narratives around development, resource use or risk, typically after internal avenues have proven ineffective. These actions can entail substantial personal risk and cannot be expected of all geoscientists. Self-protective strategies (e.g., Lewandowsky et al., 2025) may be adopted when academic research is obstructed or discouraged in controlling, or even authoritarian, contexts. Figure 3 presents a conceptual diagram of the actions and positions discussed above.

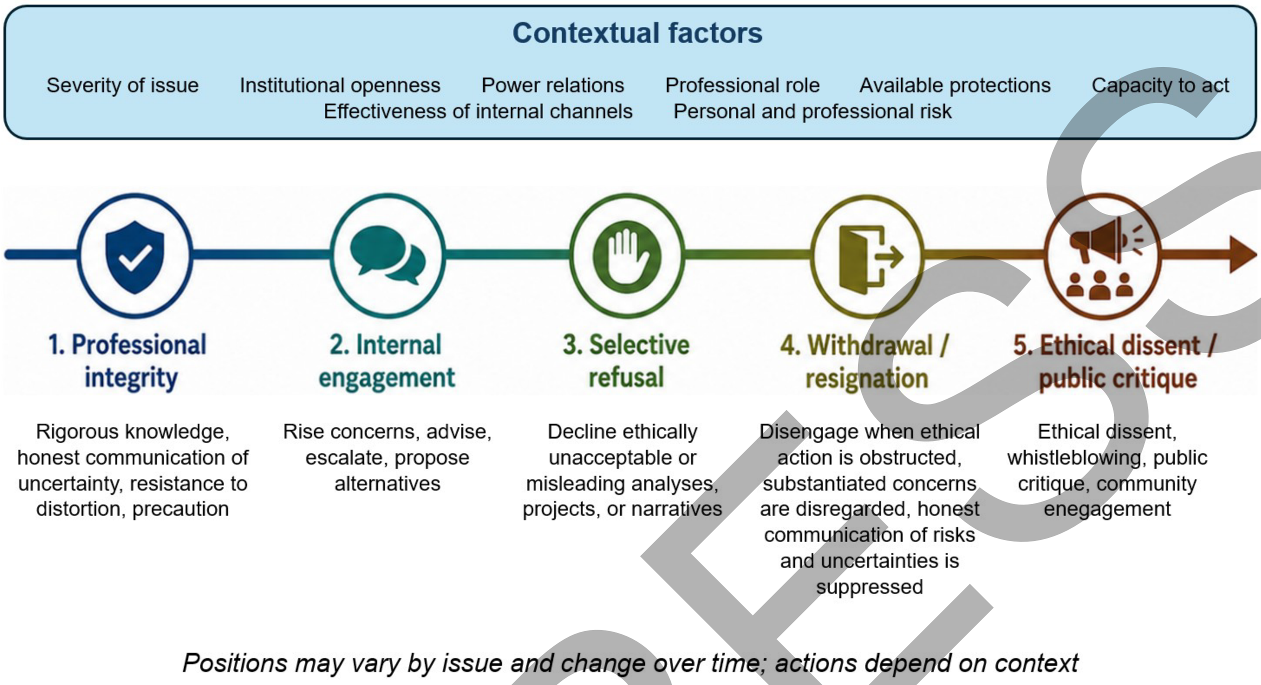

Fig. 3. A possible spectrum of geoethical actions for geoscientists.

Throughout this spectrum of possible actions, geoscientists should avoid positioning themselves as presumptive moral judges. Ethical reflection instead calls for openness to alternative perspectives that may challenge one's own assumptions, and for ongoing critical self-reflection as an integral part of responsible practice. It must be noted, moreover, that institutional obstruction should not always be understood as deliberate or culpable. Some practices may knowingly prioritize organizational interests over geoethical considerations, whereas others may be obstructive because institutions and their employees lack awareness of the relevant Earth-system impacts, ethical implications or consequences for poorly informed individuals. In Latin America, as elsewhere, limited access to geoscientific knowledge, fragmented responsibilities, inadequate training and weak communication between scientific, policy and administrative communities may all contribute to unintentional obstruction. Recognizing this distinction is important because the appropriate response may involve not only accountability, but also education, capacity building, improved information flows and institutional learning.

Even personal food-related decisions and actions are reflective and context-sensitive practices. They involve seeking knowledge to understand how everyday choices such as eating, buying, cooking, disposing of or avoiding food, affect other people and the Earth system. Such actions may include valuing and adopting local and traditional foods and culinary practices, using, if possible, energy-efficient and clean cooking methods, reducing food waste, moderating excessive or resource-intensive consumption, and supporting more sustainable and equitable supply chains by attending to sourcing, labor conditions, animal welfare and environmental claims. Across these dimensions, it is essential to recognize trade-offs shaped by income, access, time and cultural norms, and to acknowledge that responsibility is shared with institutions and collective actors (see also Section 5 and Appendix B).

Finally, conceiving food as a network of relationships and engaging with the questions and orientations of the RGP approach, provides a flexible and effective opportunity for interdisciplinary learning and teaching. One example is considering a specific food product, reconstructing its supply chain and discussing the associated environmental, social, cultural, planning, strategic, economic, and political implications, as well as possible pathways for action and solutions, in light of the RGP questions.

7. Final reflections

As argued in this study, the geoscience, relationality and pragmatism components of RGP, together with the key questions presented in Section 2, provide a flexible framework for addressing geoethical challenges and developing situation-specific responses. The framework can be adapted to virtually any context and has been applied here to food systems across institutional and personal spheres, with particular attention to Latin America. As discussed in Section 6.1, RGP makes a distinctive contribution in terms of interpretation, practice and scope, while also functioning as an analytical framework for structuring diverse themes and bodies of knowledge, as demonstrated by its use in analyzing and organizing the literature in Appendix A.

I believe that future action and research should increase awareness of the role and contributions of geoscience and geoscientists in informed and responsible decision-making. Moreover, geoethics in general, and RGP in particular, should be applied across diverse contexts and decision-making processes, with the resulting outcomes systematically evaluated. A major theoretical challenge is to define what "outcomes" means in different situations. Geoethics and RGP involve dimensions such as interdisciplinarity, social justice, sustainability, the integration of universal values with context-specific factors, openness, inclusivity, accessibility and the identification and navigation of ethical dilemmas. These dimensions may be difficult to translate into clearly defined objectives and measurable criteria, and their assessment must also account for trade-offs and conflicts among competing goals. Nevertheless, we consider this a worthwhile endeavor.

With respect to geoscience, the contents of this paper and the future directions for action and research mentioned above can be situated within the Three Horizons framework proposed by Stewart et al. (2023). The authors observe that geoscience, like other scientific disciplines, is facing growing pressure to demonstrate how it can contribute effectively to major global challenges, including climate change, food insecurity, biodiversity loss, conflict and migration and persistent poverty. At the same time, its historical association with the extraction of natural resources for energy and materials connects the discipline to contemporary concerns about unsustainable human practices. This may be contributing to growing disaffection with geoscience, reflected most clearly in declining enrolment in university geoscience programs in many countries. Against this background, an urgent reframing of the relationship between geoscience and society is explicitly advocated in the opening statement of the Cape Town Declaration adopted at the 2022 World Science Forum (World Science Forum, 2022). This reframing is conceptualized through the "Three Horizons" approach (Stewart et al., 2023).

The H1 horizon represents the dominant business-as-usual configuration of geoscience. It is rooted in a long-established technical curriculum and professional culture that developed alongside industrialization and has been strongly oriented toward the exploration and extraction of energy and mineral resources. Although it also includes applied fields that serve broader societal needs, H1 is sustained by traditional educational structures and career pathways, particularly those linked to mining and energy. Its continued dominance is increasingly challenged by wider environmental, technological, economic and social changes that may reduce its viability over time.

H2 represents the transitional and entrepreneurial horizon in which geoscience responds to the weakening of business-as-usual practices through emerging innovations. These include digital technologies, curriculum reform, the repurposing of established geoscientific expertise for renewable energy, critical minerals, groundwater, remediation, subsurface storage and lower-carbon resource development, as well as closer engagement with industry, policymakers, communities and other disciplines. Such innovations may support deeper transformation, but they may also be absorbed into H1, producing only incremental changes that preserve existing resource- and growth-oriented priorities. H2, therefore, advances decarbonization and sustainability, yet often remains insufficiently attentive to social equity, inclusion and broader conceptions of human well-being.

H3 represents a visionary and transformative horizon in which geoscience is reoriented around the integrated well-being of people and the planet. It envisages a discipline operating within a safe and just space bounded by Earth-system limits and basic human needs, rather than being driven primarily by resource extraction or economic growth. Within this horizon, geoscience contributes more directly to food security, poverty reduction, health, water access, environmental stewardship and sustainable livelihoods, while inclusiveness, equity, social justice, geoethics and community participation become central rather than peripheral. H3 also requires stronger transdisciplinary collaboration and the development of participatory and people-centered capabilities alongside traditional technical expertise.

Stewart et al. (2023) recognize that all three horizons coexist within the present system and that within contemporary organizations, including geoscience departments and programs, H1 thinking is generally dominant, H2 has a weaker influence, and H3 remains marginal. The authors envisage a gradual shift in this balance over time, as H2 and subsequently H3 gain prominence, while only the elements of H1 considered essential are retained. The questions, reflections, approaches, values, and principles considered in this paper are largely consistent with the H2 and H3 horizons. This transition is supported here toward the increasing prominence of H3 and the integration of planetary and human well-being.

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