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Climate change and relational sustainability: a shared future?

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Highlights

- *Climate change requires more than technical fixes and emission cuts.*
- *Relational sustainability values human and nature-centred relationships.*
- *Solutions arise from bridging natural and social sciences and humanities.*
- *Collective awareness and action are key to sustainability transitions.*
- *Communication, inclusion, and shared responsibility drive change.*
- *Sustainable lifestyles grow through empathy, trust, and collaboration.*
- *Rethinking the future starts with how we relate to people and the planet.*
- *Relational approaches promote innovation and holistic climate solutions.*

Graphic Abstract

Abstract

We are living in a time when climate change is one of the most pressing challenges facing humanity and the planet Earth. The response to this crisis must address the root of the problem, the way we live, interact, and relate to the environment, and not be limited to reducing greenhouse gas emissions or developing green technologies. Relational sustainability is a novel approach to the problems caused by pollution. It focuses on human-nature and human-human relationships, moving away from environmental sustainability that focuses on 'physical' approaches. This approach brings together the search for answers on several levels, involving disciplines such as the natural sciences, social sciences, law, economics, philosophy, psychology, and education. It cuts across various scientific, social and humanistic fields. This has enabled sustainability researchers to generate rich insights and significant socio-political work, leading to the development of new ways of thinking about possible solutions to environmental impacts and their consequences. Relational sustainability can be strengthened through collective awareness and action to address environmental challenges. Open communication, social innovation, psychological support, promotion of sustainable lifestyles, inclusion and diversity, and shared responsibility are suggested as possible solutions.

Keywords: Climate Change. Relational Sustainability. Human-nature and Human-human relationships.

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INTRODUCTION

Climate change is one of the greatest challenges of our time, affecting not only Earth's ecosystems but also the very fabric of human societies[1]. Its impacts—ranging from rising temperatures and extreme weather events to biodiversity loss and social inequalities—demand urgent and transformative action. While strategies to reduce greenhouse gas emissions and adopt green technologies are crucial, they address only the symptoms of the crisis. The deeper issue lies in the way humanity perceives and interacts with the environment and with one another.

In this context, relational sustainability is of particular relevance, focusing on what is often missing in responses to the climate crisis: the quality of relationships between people, communities and the environment. This approach offers a profound and regenerative key in a context characterized by increasingly severe ecological crises and growing social and political polarisation.

Indeed, the climate crisis is not only environmental but also relational: it is the result of a model of development that has broken the bonds with nature and weakened the bonds between people[2]. Polarisation, in turn, is an obstacle to the dialogue and cooperation that are essential for the management of complex global challenges[3].

Relational sustainability therefore requires rebuilding trust, empathy and a sense of belonging. It promotes solutions that emerge from confrontation and co-creation. This approach takes the form of bridging different levels of action (personal, communal, institutional) and often separated worlds (scientific, political, spiritual, social)[4].

It is therefore a response that goes beyond technical solutions. It promotes a shift in mindset and culture in which caring, listening and cooperation become key resources for addressing both the ecological emergency and the social divide[5].

In recent years, the concept of relational sustainability has emerged as a promising approach to tackle the root causes of environmental degradation. Unlike traditional frameworks of sustainability, which focus predominantly on physical and technical solutions[6], relational sustainability emphasizes the importance of fostering harmonious relationships between humans and nature and within human communities.

This approach bridges the gap between ecological and humanistic perspectives, drawing on contributions from disciplines such as the natural sciences, social sciences, law, economics, philosophy, psychology and education[7,8].

Relational sustainability can be defined as an integrated approach to sustainability that focuses on the relationships between people, communities, and the environment - seeing them as the foundation for resilience, equity and long-term well-being. Its aim is to regenerate vital connections through practices rooted in care, dialogue, equity, co-responsibility and participation[9]. Integrating natural sciences, social sciences, law, economics, philosophy, psychology and education enables a systemic and transformative approach to the climate crisis. From analyzing ecological interactions and ethical responsibilities, to understanding emotions, cultural constructions, educational and health processes, and creating new imaginaries, regenerative economic models and participatory forms of governance, each discipline has a specific contribution to make.

This review explores relational sustainability's theoretical and methodological foundations, illustrating its multidisciplinary scope and its potential to generate deeper, integrated, cultural and social change responses than traditional environmental sustainability (Fig.1).

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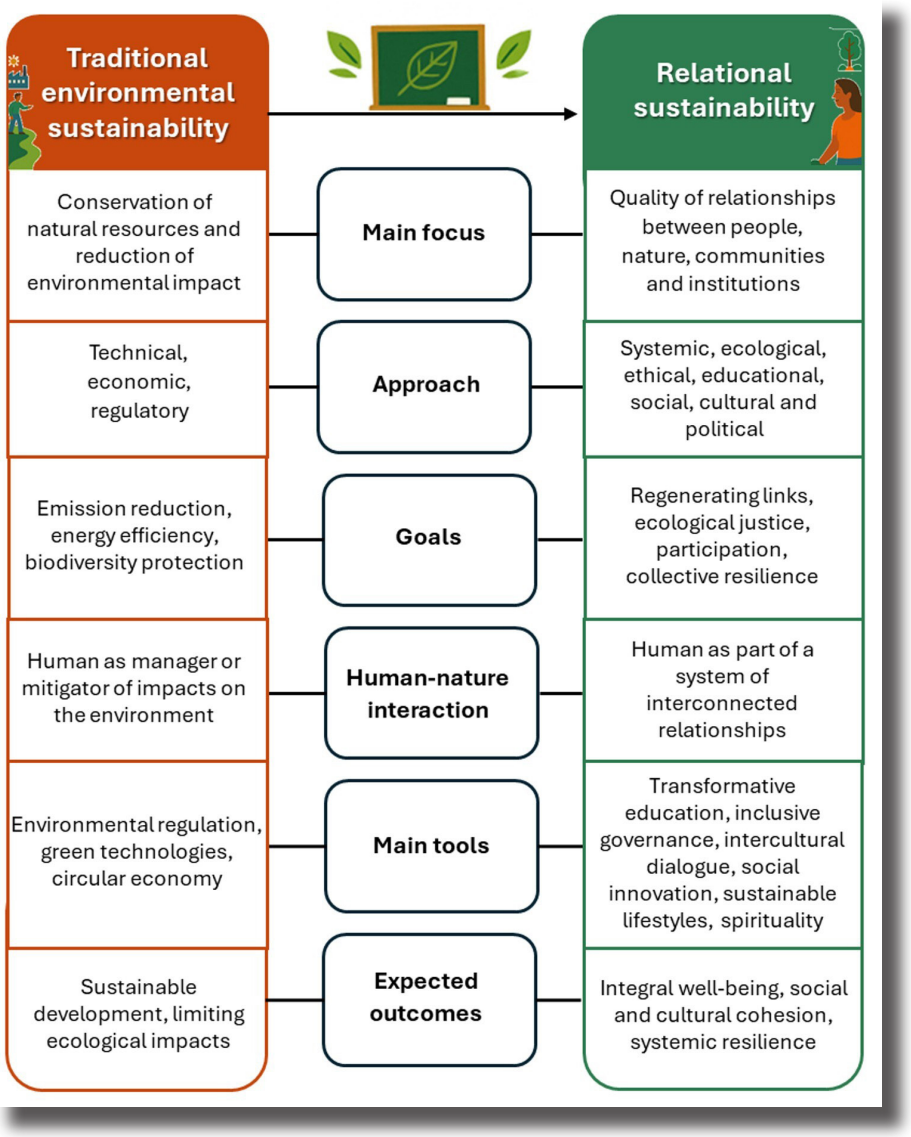

Figure 1 - Comparison between traditional environmental sustainability and relational sustainability.

In this context, interdisciplinarity not only broadens the scope of sustainability analysis but also inspires new research methodologies. Such approaches encourage the crossing of traditional disciplinary boundaries and promote transdisciplinary practices that value the complexity of environmental and human phenomena. Systemic thinking, complex thinking, integral ecology, relational psychology, the ethics of responsibility and reflections on being-with contribute to outlining of more inclusive, dialogical and transformative research models. These include listening to local contexts, interaction with communities, the use of art as a tool for ecological storytelling, analyzing environmental and economic inequalities and the promotion of practices of care and coexistence. In doing so, relational sustainability becomes a methodological laboratory for rethinking the role of science in society and producing knowledge as a collective and generative process.

Relational sustainability proposes that addressing environmental challenges requires not only innovative policies and technologies but also a profound cultural shift. Open communication, collective awareness, and shared responsibility become fundamental in this paradigm. By promoting sustainable lifestyles, encouraging inclusion and diversity, and fostering social innovation, relational sustainability aims to empower individuals and communities to create lasting solutions to the climate crisis.

By examining how human and ecological systems interact, this review contributes to a more integrated understanding of sustainability that prioritizes relationships and shared futures. Promoting practices based on care, dialogue, equity and co-responsibility, relational sustainability aims to regenerate vital connections and bridge the gap between individual actions and systemic changes needed to address the environmental crisis.

METHODOLOGY

This review was developed through the consultation and analysis of various scientific articles, selected for their relevance to the subject. A comparative analysis of the data presented in these studies revealed that climate change significantly impacts ecosystems and individuals' quality of life.

In addition to the traditional approach to environmental sustainability, the concept of *relational sustainability* has gained prominence in recent years. This emerging perspective seeks to address the adverse effects of climate change by strengthening the relationships between humans and the environment.

RESULTS

Ecosystems are changing rapidly, responding not only to changes in temperature but also to variations in atmospheric carbon dioxide, ocean chemistry, frequency and magnitude of extreme events, and water balance. Due to interactions between organisms, stressors, and other disturbances, ecosystems vary in their sensitivity to climate change. These changes affect not only the natural environment but also have a direct and indirect impact on human societies, affecting biodiversity and global food production, and compromising our ability to respond in a sustainable manner. Our environmental and social security is threatened by sudden changes in ecological systems, which are difficult to observe empirically because of their stochastic and unpredictable nature. We are in the midst of accelerating change. Ecological systems are responding differently, with some being more vulnerable than others. Extreme events, such as coral bleaching from intense heatwaves[10] or fires rapidly altering terrestrial ecosystems[11], are particularly devastating, threatening not only biodiversity but also the resilience of human communities.

The growing connections between ecological crises and social imbalances suggest that an effective response must integrate ecological strategies with socio-relational approaches that promote cohesion and cooperation within and between communities[3]. These events highlight the need for collective responses that are grounded on a relational model of sustainability that promotes social ties and collaboration[3,12].

If adopted on a large scale, this approach could transform not only environmental policy, but also models of governance and education, paving the way for forms of participatory leadership, education for ecological citizenship and a culture of shared responsibility for the commons.

Figure 2 shows a flowchart of the human-environment and human-human relationships.

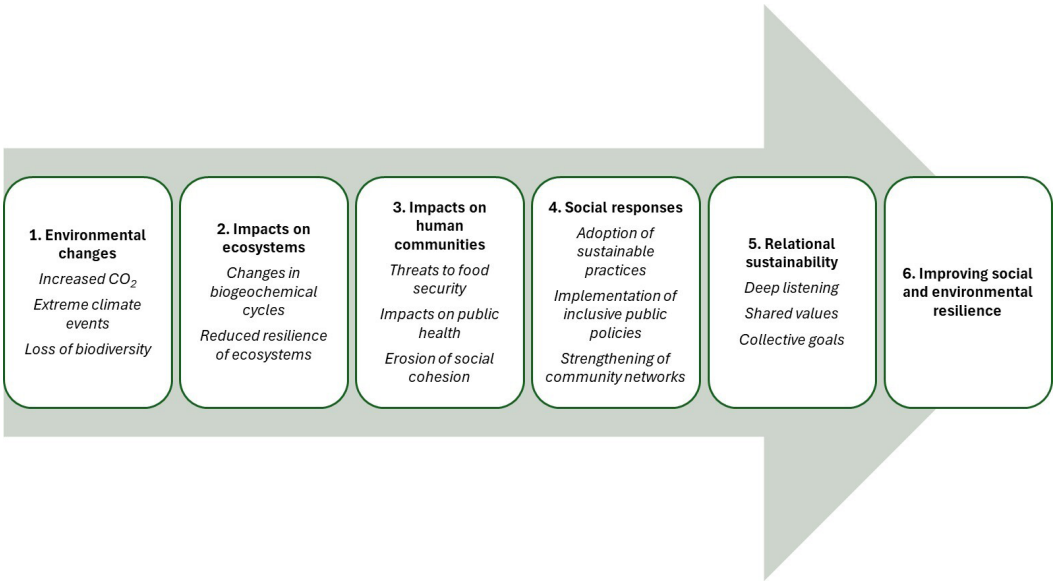

Figure 2 - Flowchart: Human-Environment and Human-Human relationships in relational sustainability.

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Even in the smallest ecological systems, such as the soil, where invisible interactions sustain life on Earth, the importance of relationships is reflected.

Soil microbial communities play a key role in maintaining proper biogeochemical cycles, demonstrating resilience to ecological challenges comparable to that of human communities. Bacteria in soils have fast energy pathways, recycle nutrients and recover quickly from perturbations[13], much like human communities, which adjust dynamically through deep listening, shared values and collective goals. In contrast, fungi, with their slow energy pathways, recycle nutrients slowly[13], symbolizing the need for time to enable balanced and sustainable responses to social and environmental change.

As ecological resilience requires a longer-term perspective, social communities need to be more holistic, considering ecological, economic and relational issues. Our collective commitment to promoting inclusive policies and practices that foster relational sustainability will determine our understanding of ecological and social responses to climate change. Palaeoenvironmental observations of pollen and charcoal in temperate forests have shown that resilience to changes in fire regimes depends not only on ecological factors[14] (such as climate, soil conditions and soil history), but also on the ability of communities to adapt and work together. In some cases, single extreme events can radically alter the composition of ecosystems, in the same way that traumatic social events can reshape societies. Tropical forests, for example, have shifted between long periods of stability and abrupt changes in response to climate change and human activity[15], and so societies need to develop resilience strategies that are timely and cooperative.

Climate change is accelerating the loss of biodiversity and reducing carbon storage in ecosystems. This is partly due to land-use change resulting from the agricultural expansion. Models of biodiversity and carbon loss have shown that this expansion will have a significant impact on biodiversity, especially in hotspots such as Mexico, Congo and the Amazon[16]. In ecosystems with limited water availability, prohibitive temperatures and no nearby replacement species, warming will erode the diversity of terrestrial plant communities[17].

In this context, climate change policies and actions must be considered holistically, incorporating relational sustainability to strengthen the adaptive and mitigative capacities of individuals and communities.

Opportunities for climate change resilience building

Understanding ecosystem responses to global change, where human actions add, subtract, and shift species, populations, and genes, involves fundamental biological processes that continue to evolve even in a human-altered world. Organisms that are well adapted to a changing environment form new ecological communities. However, not only ecosystems are changing: human societies, especially in the most vulnerable regions, must also adapt to promote resilience and ensure long-term sustainability[18]. Climate change exerts its most damaging effects by increasing the intensity and frequency of extreme events rather than by changing average conditions. In this regard, social resilience can be seen as an extension of ecological resilience: both are based upon the ability to regenerate, on diversity, and on mutual dependency between elements[19]. Thus, adaptive policies need to promote cultural and biological diversity, and strengthen nature-society linkages[20]. The impact of climate extremes on post-disaster recovery has been studied in biodiverse tropical ecosystems, such as those of Brazil and Argentina. In these regions, local populations have contributed to biodiversity conservation and mitigation of the devastating effects of floods and droughts through traditional agricultural practices[21]. An example of ecological resilience is the role of dung beetles in the restoration of Brazilian forests[22]. By dispersing seeds and promoting the growth of new plants after an environmental disturbance, these beetles contribute to the regeneration of ecosystems. This is an example of how the actions of small local actors, human and otherwise, may have a systemic impact, promoting regeneration and stability through dynamics of cooperation and interaction with the wider world.

Similarly, human communities that work together and share responsibility can be more effective in dealing with environmental and social crises by strengthening social resilience, inspired by ecological models.

Much of the literature on natural approaches to climate change mitigation and adaptation focuses on terrestrial and coastal ecosystems. However, marine ecosystems, with their high biodiversity,

are crucial for regulating biogeochemical cycles and removing atmospheric carbon. Marine protected areas play a key role in ecological resilience. In South America, the adoption of marine protected areas, for example by the community of Porto Alegre in Brazil, shows how protected areas can strengthen the resilience of both marine ecosystems and coastal communities, and activate an adaptation process grounded in a vision of relational sustainability that integrates ecological, social and economic needs[23].

Atmospheric CO_2 change due to industrialisation

The effects of warming, acidification and sea-level rise can be buffered by invertebrates living in marine sediments. Protecting key areas of a network of marine ecosystems can improve the resilience of a wider area through ecological connectivity[24], a concept that is also applicable at a global scale and consistent with the relational sustainability paradigm. Creating links between protected areas and promoting local approaches in countries such as Brazil and Argentina demonstrate how collective action can transcend regional boundaries to ensure the long-term protection of ecosystems and the well-being of communities[25].

Climate change: increased flooding and acid rain?

Floods and landslides are among the most frequent natural disasters, with devastating impacts on the environment and on the population. In Italy, more than 68% of municipalities are considered to be at high hydrogeological risk. This means that intense rainfall, which is becoming more frequent due to climate change, can cause landslides and flooding, with serious consequences for the social and territorial fabric[26]. The health consequences are short- and long-term: drowning and myocardial infarction, injuries and hypothermia, infections, waterborne infections, mental health disorders, respiratory illnesses and allergies. Rising global temperatures have reduced total precipitation in many regions but increased extreme events, particularly in winter.

This phenomenon is a concern not only for Europe but also globally. In Latin America, cities like Porto Alegre in Brazil and Bahía Blanca in Argentina have recently experienced extreme rainfall and flooding with serious infrastructure, health and social consequences[27,28]. These cases highlight the urgent need to develop local, but interconnected, approaches that combine environmental resilience and social solidarity. The integration of scientific knowledge, traditional practices and active community participation is a strategic lever in the management of the complexity of climate change[29]. Although the phenomenon has been observed in Europe for decades, it is still relevant in many developed regions, such as parts of East Asia, where air, soil and water quality impacts directly affect people's health and well-being[18].

In recent years, the phenomenon of acid rain, attributable to climate change, has had a considerable effect on human health and ecosystems. The principal sources of these gases and pollutants are fossil fuels, industrial plants, wildfires, and motor vehicles.

In Argentina, it has had a devastating impact on agricultural crops and water quality, particularly in cities such as Bahia Blanca. In response, local communities, in collaboration with institutions, have adopted innovative solutions for air filtration and environmental awareness, reducing the negative impacts of acid rain[30]. In Porto Alegre, Brazil, the implementation of a flood monitoring system and a community evacuation plan have reduced damage to people and the environment[31]. In Africa, the Shared Water programme in the desert areas of Mauritania has highlighted the importance of cooperation between different ethnic groups in the management of water resources in the context of climate change and increased resilience to flash floods[32]. Innovative solutions to flooding, such as an improved urban drainage system and awareness-raising on water resource management, were adopted in São Paulo, Brazil. This case represents an initial attempt to apply relational sustainability to foster institutional/citizen cooperation in resource management and climate hazards[33].

The Intergovernmental Panel on Climate Change (IPCC) confirms that global temperatures are rising. This is accompanied by an increase in extreme rainfall episodes, with a high risk of flooding, especially in winter. In Italy, the area affected by floods and landslides has increased due to an increase in short and intense rainfall episodes over the last decade[34].

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In Argentina, similar challenges of flooding and acid rain, particularly after heavy rains in agricultural areas, were faced in the provinces of Buenos Aires and Santa Fe. To mitigate the damage, local communities developed an integrated approach based on traditions of community cooperation. Involving indigenous groups and recognising their traditional knowledge in managing water resources has created a model that, although still in its early stages, has demonstrated the potential of relational sustainability in promoting cooperation between different communities to address the challenges of climate change[35].

Preventive measures need to be implemented in high-risk areas, including the development of emergency and prevention plans, to mitigate the environmental and human health impacts of flooding.

Some studies have shown that stress accumulated during heavy rainfall can lead to death, as well as physical and psychological trauma. Experiencing natural disasters can cause trauma and loss of material possessions, exposing populations to long-term mental and physical health changes[36]. In Asia, "floating villages" built to withstand flooding in Bangladesh have demonstrated how community solutions promote human interdependence and collaboration, reducing material damage and fostering solidarity in a context of extreme climate change[37]. These examples represent a first step towards relational sustainability, as communities work together to adapt to environmental challenges, albeit far from systematic and sustainable solutions.

Acid rain and its impact

Acid rain is a global environmental problem with devastating effects on ecosystems and human health, caused by rapid industrial development and increased greenhouse gas emissions. In Latin America, especially in Mexico, acid rain is an important issue that threatens food security and public health. Solutions adopted in these regions, such as the adoption of sustainable agricultural practices and the planting of acid-resistant trees, have contributed not only to environmental improvement, but also to the strengthening of the social fabric through community engagement[30].

Similarly, in Brazil, where rapid urbanization and industrial expansion have significantly increased pollution emissions, local communities - especially in coastal areas such as Santos - have taken initiatives to reduce the impact of acid rain. In an attempt to apply a relational sustainability approach, communities, government institutions and NGOs are working together to plant trees with high CO_2 and SO_2 absorption capacity, such as mangrove forests. These ecosystems represent a first step towards cooperation between the environment and people, as they not only absorb pollutants, but also provide a safe habitat for many local species[38].

In Argentina, industrial cities like Rosario face serious air pollution problems, leading to increased acid rain. To address this, the region's agricultural communities, heavily reliant on soybean cultivation, have begun working with local universities to develop sustainable agricultural techniques that limit atmospheric pollutant emissions. This collective effort has led to the adoption of organic farming practices. This has reduced the use of chemical fertilizers and improved environmental quality.

While these initial examples are a good starting point, they are still evolving and need to be strengthened to ensure full relational sustainability[39].

Asia also faces serious problems of air pollution and acid rain, particularly in countries like China and India. In response, local communities in the Yangtze River Delta region have developed community-based solutions. These include creating urban gardens and planting trees, which act as natural filters for air pollutants. While these projects are important, full collaboration between different urban and rural areas is a process that needs to be further developed, thus, they represent preliminary efforts of adaptation to the challenges posed by acid rain[40].

To summarize the main findings of this study, Table 1 provides an overview of the key issues discussed, highlighting their implications and providing relevant examples.

These impacts underscore the need for global strategies for resilience building through the integration of environmental, social and governance dimensions.

Table 1 - Summary of Key Findings on Climate Change and Ecosystem Resilience.

Location	Topic	Key Findings	Exemples	Source	Relation to the Relational Dimension	Explanatory Notes
Great Barrier Reef in Australia; San Diego, California	Ecosystem Changes	Ecosystems respond to multiple stressors beyond warming. Different sensitivities between terrestrial and marine ecosystems.	Coral bleaching, forest fires, and droughts affecting terrestrial and marine ecosystems.	Hughes TP, 2021[10]; Scalingi PL, 2021[11]	Responses impact community life and require an integrated approach between social and ecological sustainability.	Events such as fires and droughts alter local economies and social dynamics.
White Mountain National Forest in New Hampshire, United States	Microbial Communities	Soil microbes facilitate ecological regeneration and nutrient cycling, contributing to long-term resilience.	Bacteria contribute to rapid nutrient recycling, while fungi provide resistance by slowing responses.	Isobe K, 2022[13]	Strengthen ecological awareness and foster supportive relationships between humans and nature.	Microbes are key, but invisible, actors in ecological resilience.
Peatlands of the Italian Alps	Fire and Forest	Fire regimes influence tree composition based on climate and soil history.	Pollen and charcoal studies indicate long-term resilience depends on climate and soil history.	Furlanetto G, 2023[14]	Forest communities need to develop collaborative forms of fire adaptation and prevention.	Requires local historical knowledge and shared governance.
Alto Vale do Itajaí region, Santa Catarina, Southern Brazil	Biodiversity and Carbon	Agricultural expansion reduces biodiversity and carbon storage capacity, affecting ecological hotspots.	Biodiversity hotspots are particularly vulnerable.	Lacerda AEB, 2020[21]	It is urgent to engage communities in biodiversity conservation and local ecological economies.	Loss of biodiversity also undermines social cohesion.
Paraná region, southern Brazil	Resilience Strategies	Conservation and restoration efforts can enhance resilience to climate change.	Natural actions (e.g., seed dispersal, fish grazing) promote spontaneous ecosystem regeneration.	Simões-Clivatti TRO, 2022[22]	Local traditional practices integrated with science strengthen resilience and social bonds.	Nature-based solutions work best when based on local knowledge.
Marine Protected Areas (MPAs), Brazil	Ecossistemas Marinhos	Marine habitats are critical for global biogeochemical cycles and carbon regulation.	Oceans regulate global carbon cycles and require an expansion of protected areas (from 10% to 30%).	Patrizzi NS, 2025[23]	Cooperation between states and coastal communities is essential for safeguarding common goods.	Shared goals in the UN Decade for Oceans.
Canada, Mexico, Artic regions, South and East Asia	Direct Climate Impacts	Extreme precipitation events increase the frequency of floods and landslides.	Recent floods in Europe and Latin America caused major damage and loss of life.	ISPRA, 2021[26]; Giglio VJ,2018[27]; World Weather Attribution, 2025[28]	Collective responses are crucial for resilience: social networks, infrastructure, and participation.	Disasters accelerate or undermine social cohesion.
Bahía Blanca, Argentina; Porto Alegre, Brasile; Mauritanian desert, Northwestern Africa; São Paulo, Brasile	Acid Rain	Acid rain is a global issue caused by industrialization and fossil fuel combustion.	Affects soil fertility, plant health, and accelerates forest decline.	Martínez L, 2018[30]; Portocarrero A, 2019[31]; Jansen H, 2021[32]; Santos P, 2019[33]	Prevention requires public policies and intergenerational collective commitment.	One of the most neglected but still active global issues.
Global	Human-Nature Relationships	Anthropogenic impacts are reshaping sustainability perceptions and strategies.	Emphasis on relational sustainability, integrating ecological and humanistic approaches.	Sachs JD, 2020[7]; Barragan-Jason G, 2025[8]	Human-nature interaction is at the core of future strategies: education, participation, and dialogue between knowledge systems.	Integrating scientific and humanistic approaches is essential.

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Relational sustainability

Our planet, characterized by widespread environmental degradation and growing concerns about climate change, is experiencing anthropogenic impacts of unprecedented magnitude.

Despite efforts over the past decades to develop technological, political and behavioral solutions, the failure to respond effectively to the complexity of the environmental crisis has led to widespread feelings of helplessness and diminished willingness to take action[2]. Against this background, it is crucial to rethink sustainability strategies to address current challenges.

Perceptions of the future have a profound impact on the scope for action, as they shape individuals' understanding of their role in shaping tomorrow[41]. The idea that the future is created in the present suggests that our choices today are critical to building a world in which society and nature can coexist in harmony[42,43].

The quantification and objective analysis of phenomena[2] is the dominant scientific paradigm in sustainability strategies. However, as this approach often describes future scenarios with a deterministic and fatalistic character[44,45], it may contribute to a reduced capacity for action. In spite of the importance of governance and policy in the management of sustainability, these aspects are still under-researched in the scientific literature[46].

A new way of looking at these issues could be provided by relational sustainability. It moves away from environmental sustainability, which focuses on 'physical' approaches, and instead focuses on human-nature and human-human relationships.

By viewing these relationships as cooperative pairings that maintain individual identity, a new understanding emerges of the link between humans and the environment, as well as among people themselves. This is where ecological and humanistic approaches converge. Fields such as ecology, philosophy, and psychology are united in this framework. Through this integration, sustainability researchers have produced rich insights and significant socio-political contributions, fostering new ways of thinking about solutions to environmental impacts and their consequences.

Several studies have emphasized the significant changes in human-natural relationships and the growing recognition of the interconnectedness of human and environmental well-being[47,48]. Interdisciplinary research highlights the importance of 'nature connectedness' as a key factor in the promotion of pro-environmental behaviors and the improvement of mental and physical health[49,50]. Furthermore, urbanisation and industrialisation have changed people's interactions with the environment, reducing direct experiences with nature and negatively affecting both perceptions and values of ecosystems[51].

A team of researchers has identified three key elements of collective visioning of relational sustainability pathways, essential to coordinate local action[52]: 1) the capacity for in-depth listening opens up the possibility of revising one's own beliefs; 2) shared values provide a common basis for interaction between stakeholders; 3) the definition of concrete steps to achieve goals creates a creative tension that stimulates change. The effectiveness of these practices can be measured by indicators such as: levels of citizen and institutional confidence; levels of public participation in policy-making; levels of cooperation and solidarity; quality of cross-cultural dialogue; perceptions of connectedness to nature; perceptions of fairness in environmental decision-making; and strength of sense of belonging.

A sustainable future requires a radical redefinition of the human-environment relationship, with changes in values, worldviews and institutions that regulate social behavior, according to Bennet *et al.*[53]. The key challenge is to understand how such transformations can be deliberately activated[54].

In contexts where many believe their view is the only correct one, dialogue and active listening can facilitate perspective shifting and consensus building around collective values[55,56].

The reductionist paradigm that has dominated knowledge production has led to a situation of paralysis of analysis, where reflection continues without a real will to act. However, in order to open the heart and mind to new perspectives, deep listening is the first step. Moreover, when a shared vision is based on collective values, collaboration becomes more effective and the capacity to act is strengthened.

Tools such as questionnaires on perceived well-being, qualitative interviews on social cohesion, metrics on engagement in local projects, indicators of cross-sectoral collaboration and psychometric tools to assess empowerment and collective self-efficacy can be used to monitor the effectiveness of these dynamics.

Therefore, clearly defining the goals and the changes needed in current systems allows aspirations to be translated into concrete actions. These principles are not arbitrary, but are supported by psychological studies that highlight the role of a sense of belonging in promoting individual and collective resilience[57], by organizational research emphasising the power of agency in driving change

processes, and even by social quantum physics, which provides a perspective on the interconnections between social and natural agents and underlines how relational dynamics can influence complex systems[58]. To test Social Quantum Physics theory empirically in sustainability projects, methods could be developed to analyse the nonlinear and interconnected dynamics between social and environmental actions using systems modelling and participatory observation. The adoption of approaches that monitor the interactions between individuals, groups and ecosystems could provide indicators of how social and environmental relationships influence each other, and thus test the validity of the theory in sustainability initiatives.

One of the major challenges at present is to institutionalise these emerging concepts of transformation towards relational sustainability. Addressing this challenge requires an interdisciplinary approach and a rethinking of current governance models so that solutions move beyond theory and translated into effective and sustainable practices.

Future developments

There are several ways in which climate change can affect relational sustainability, as we have seen. At an individual and community level, extreme climate-related events such as natural disasters can strain human relationships, becoming sources of emotional stress or anxiety. In addition, the need to cope with economic challenges can cause financial strain due to the loss of homes, property, and personal assets, which can affect relationship dynamics. Disasters can force people to evacuate or migrate. This creates challenges in adapting to new environments and affects social and neighborhood relations.

In addition, the management of resources such as water and food can become another source of tension and conflict. Water resources, in particular, are becoming increasingly critical, and management strategies must include water conservation, the use of efficient technologies, and the promotion of sustainable agricultural practices[16]. Furthermore, climate-related health problems such as neurodegenerative diseases, tropical diseases, or heat stress can affect people's ability to care for themselves and their dependents, impacting relationships. However, the sustainability of relationships can be strengthened through collective awareness and action to address climate change.

Solutions to Address Relational Sustainability Challenges

Strategies that strengthen social ties, promote equity and support adaptation to environmental and social change are essential to address the challenges of relational sustainability. The following context-specific solutions can be applied at different scales and promote meaningful change:

- **Open communication:** Creating spaces to talk about environmental issues to help understand each other. At the local level: neighborhood meetings and citizen workshops; at the national level: education campaigns; at the global level: forums and digital platforms. First steps: community listening tables, social campaigns, accessing environmental information.
- **Social innovation:** Encouraging sustainable solutions through collaboration between individuals, communities and organizations. At the local level: circular economy and urban regeneration; at the national level: civic incubators; at the global level: transnational partnerships. First steps: co-designing workshops, encouraging public-private partnerships.
- **Mental health support:** Provision of psychological support to address stress related to environmental crises. At the local level: community psychological help desks; at the national level: integrated health-environment policies; at the global level: support networks and common guidelines. First steps: training of mental health professionals, integration of mental health into climate change agendas, creation of safe spaces.
- **Promotion of sustainable lifestyles:** Encouraging daily choices that improve human relationships and the environment. At the local level: educational initiatives in schools and neighbourhoods; at the national level: tax incentives; at the global level: multilateral agreements on responsible consumption. First steps: awareness raising campaigns, incentives for virtuous behavior, networks of critical consumers.
- **Inclusion and diversity:** Recognition and integration of diversity in public policies and decision-making processes. At the local level: involvement of minorities and vulnerable groups; at the national level: inclusive policies; at the global level: promotion of participation from underrepresented communities. First steps: representative advisory committees, intercultural interventions, a 'no one excluded' principle in governance.
- **Shared responsibility:** Promoting a culture of co-responsibility. At the local level: active citizenship practices; at the national level: educational programs; at the global level: multilateral agreements and joint initiatives. First steps: educa-

tion pathways on ecological responsibility, citizen monitoring platforms, collective narratives of co-responsibility.

Limits of Relational Sustainability

Notwithstanding its transformative potential, the relational sustainability paradigm faces several challenges and limitations that complicate its implementation. A primary challenge involves the inherent unpredictability of relational elements, such as trust, a sense of community, and the quality of dialogue. These elements are inherently qualitative, dynamic, and context-dependent, rendering them more challenging to quantify and compare than physical or technical indicators. Furthermore, relational sustainability necessitates extended periods of development and an unwavering dedication to mediation and attentive listening, which frequently stands in opposition to the accelerated logic of public policy and market-driven economies. The issue of relationships being accorded systematic recognition in sustainability strategies remains unresolved. This is a key factor contributing to the marginalisation of relationships. From a pragmatic standpoint, relational sustainability faces challenges in coordinating actors who may have competing interests. The adoption of relational approaches necessitates the active involvement and consent of multiple stakeholders, who frequently possess divergent perspectives on the management and prioritization of resources. In politically unstable or socially polarised contexts, achieving balance among diverse groups can be a highly complex undertaking. Furthermore, the constraints posed by limited financial resources and institutional infrastructures, which do not always facilitate the establishment of long-term spaces for dialogue, can act as impediments to the sustainability of relationships. This approach necessitates sustained investment in training, mediation, and the development of local capacity, which are frequently deficient in the most vulnerable contexts. In situations marked by social inequality, conflict, or widespread mistrust, establishing strong and inclusive relationships is especially challenging. These contexts often demand prior engagement in processes of social justice and reconciliation.

Future Research Directions

Building on these insights, several potential research directions could deepen our understanding of relational sustainability and its applications:

- **Empirical Validation of Relational Sustainability:** future studies could evaluate the effectiveness of relational approaches through the analysis of behavioral changes within communities and organizations by means of longitudinal research to track transformations over time.
- **Measuring the impact of deep listening:** the development of methodologies capable of assessing the influence of relational practices, such as deep listening, on ecologically responsible attitudes and behaviors, is imperative.
- **Psychological and Behavioral Dimensions:** further exploration is necessary to understand the cognitive and emotional mechanisms that motivate sustainable behavior. Of particular importance is the study of how empathy, shared values, and common goals influence participation and cooperation.
- **Public policy analysis:** it is vital that research is conducted in order to identify and analyse policies that already incorporate elements of relational sustainability, such as co-design and community participation, at local, national and international levels.
- **Comparative Studies on Governance Models:** through the comparison of governance models that integrate relational sustainability across various sociopolitical contexts, it is possible to identify inclusive and long-term best practices.
- **Interdisciplinary Approaches to Climate-Induced Social Disruptions:** collaborative studies have the potential to explore relational strategies with a view to mitigating tensions and strengthening community resilience within contexts affected by migration, resource scarcity or environmental shocks.
- **Technological Innovations for Social Cohesion:** emerging technologies such as digital platforms and the blockchain could be leveraged to enhance participatory governance and promote new models of collaboration and resilience.
- **Social quantum physics in sustainability:** theoretical exploration of the implications of social quantum physics may offer novel perspectives on human interconnection and the emergence of collective behaviors within complex systems.
- **Mental Health and Climate Change Resilience:** the investigation into the dynamic interplay between mental health, climate impacts, and social resilience has the potential to yield interventions that will enhance communities' capacity to cope with environmental stress and trauma.
- **Cultural and Ethical Dimensions of Sustainability:** an analysis of the manner in which cultural narratives, ethical frameworks, and local knowl-

edge can enhance relational practices might facilitate the development of sustainable models that are inclusive and grounded in local contexts.

• **Educational Frameworks for Relational Sustainability:** there is an evident necessity to devise and evaluate educational curricula that incorporate relational sustainability, aiming to empower citizens and leadership figures with the competencies to integrate ecological responsibility with the cultivation of relationships.

• **Corporate and Organizational Applications of Relational Sustainability:** Research could explore the potential of businesses and institutions to adopt relational sustainability as a component of their strategies for social responsibility, contributing to systemic change, even within the private sector.

CONCLUSION

The prevailing environmental crisis and the effects of climate change demand a paradigm shift in sustainability. The prevailing model, which is based primarily on quantitative analyses, has frequently engendered a sense of powerlessness. Relational sustainability provides a complementary perspective that integrates a range of disciplines, emphasizing the interdependence between human relationships and the environment. It acknowledges that climate challenges are not solely environmental issues, but also social and cultural ones. Adopting this perspective can facilitate the development of more effective and sustainable solutions that take into account social, cultural and economic dynamics in addition to ecological considerations. It is imperative that immediate action is taken, in order to overcome the inertia that typifies a considerable number of sustainability initiatives. The practice of deep listening, the alignment of shared values, and the establishment of collective goals have been demonstrated to be effective catalysts for change.

The consequences of climate change are twofold, impacting both the physical environment and social structures and relationships. The phenomenon of forced migration, in addition to conflicts over resources, has been shown to engender social tensions. In order to address these challenges, an interdisciplinary approach is required that promotes social cohesion and governance innovations.

The transition to relational sustainability is characterized by the adoption of participatory governance models and inclusive policies, which promote dialogue, mental resilience, social innovation and sustainable lifestyles. The integration of natural and social sciences, through a relational approach, has the potential to stimulate more action-oriented research, promoting practical and shared solutions to address climate challenges. The proposal to address environmental challenges through the lens of relationships paves the way for the use of mixed methods (quantitative and qualitative), co-creation of knowledge with communities, and the valuing of local knowledge and individual experiences in climate models. The focus on issues such as mental health, communication, social innovation and inclusion can guide future research to assess not only the environmental but also the relational and cultural impacts of climate policies.

This approach, therefore, proposes an interdependent vision, in which ecological well-being is intrinsically linked to social and relational well-being.

In order to ascertain its validity and practicability, experimental and evaluative processes may be initiated in real contexts. These processes may then be compared with those obtained through purely technical-economic approaches. The establishment of living laboratories – wherein citizens, researchers, institutions, and associations engage in the formulation of objectives and instruments – engenders an environment conducive to mutual learning and continuous adaptation. Consequently, this methodological approach has the potential to shape future research initiatives, facilitating a more holistic and interconnected comprehension of environmental and social issues.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

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