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Sustainable Land Governance for Water–Energy–Food Systems: A Framework for Rural and Peri-Urban Revitalisation

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Abstract: This research paper addresses the need for an adaptable theoretical framework in the context of sustainable land governance for Water–Energy–Food (WEF) systems, bridging the gap between international guidelines and contextual realities. The novel framework is useful to effectively tackle the intricate challenges of rural and peri-urban revitalisation in the Global South by providing a holistic approach that considers the multi-dimensional interactions of land with water, energy, and food systems. The proposed framework encompasses three main objectives: (1) a top-down approach involving policy review and legal framework analysis to contextualise and inform the decision-making process; (2) a bottom-up approach based on case studies, enabling ground-level insights, stakeholder identification, and participatory mapping to empower rural and peri-urban communities; (3) a geospatial approach utilizing GIS and spatial analysis to study the implications of land within WEF systems. Drawing on mixed methods, including a literature review, a policy review, interviews, surveys, focus group discussions, and participatory action research grounded on case studies, this research emphasises the need to integrate both top-down and bottom-up approaches for comprehensive sustainable land governance. Over the course of 2018 to 2023, 22 master's theses were supervised, each addressing the framework's research objectives in 14 countries in Africa, Asia, the Middle East, and Latin America. Sixteen capacity building workshops in 11 countries engaged 851 participants, fostering knowledge exchange; 6 participatory action research (PAR) projects involved the installation of projects to advance food sovereignty in small communities in the Global South, following needs assessments. We showcase in this paper the PAR successfully implemented in Gitaraga, Rwanda, to validate the practical application of the proposed framework. The methodology has been useful for determining transversality, sustainability, inclusivity, adaptability, evidence-based decision-making, and policy integration as the core principles of sustainable land governance for WEF systems. The research contributes valuable insights to inform future interventions and policies that promote rural and peri-urban revitalization while addressing the ever-evolving challenges of WEF systems in the Global South.

Keywords: sustainable land governance; WEF systems; framework

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1. Introduction: Forging a Path to Sustainable Land Governance for Water–Energy–Food Systems

In recent decades, rural areas in the Global South have witnessed significant transformations, leading to disparities with urban centres and a growing diversity within the "rural" category. These changes stem from the interplay of socio-economic processes, demographic dynamics, and climate/environmental shifts, which have reshaped the layout of sustainable development. Consequently, the need for targeted policies and instruments has arisen to address territorial disparities between remote rural regions and more accessible areas. Simultaneously, the exploration of territorial impacts resulting from policies has garnered increased attention in the field of formal policy assessment and evaluation research. Recognising this evolving landscape, this research endeavours to contribute a novel theoretical framework on "Sustainable Land Governance for Water–Energy–Food

(WEF) Systems" that goes beyond traditional siloed approaches and prioritises rural and peri-urban revitalisation in the Global South.

While various frameworks offer different perspectives and approaches to sustainable land governance, they may not fully capture the complexities and interactions between water, energy, and food systems grounded on land. The Integrated Land and Water Resources Management Framework [1–3] emphasises the integration of land and water resources management to achieve sustainable development outcomes. It recognises that land is the fundamental basis for water and food production, as well as energy generation. ILWRM promotes coordinated planning and decision-making processes that involve stakeholders from different sectors and levels of governance to develop strategies that ensure the sustainable use and management of land and water resources. However, it may not comprehensively address the interdependencies between land, water, energy, and food systems.

Similarly, the Land System Archetypes Framework [4–6] categorises different land systems based on their characteristics, such as land use patterns, governance structures, and resource management practices. It recognises that land systems can vary significantly across regions and scales, and that understanding these variations is essential for effective governance. The framework helps identify the strengths and weaknesses of different land systems and provides insights into potential pathways for WEF systems [7], but it may not fully account for the intricate relationships between WEF elements.

The Ecosystem Services Framework [8–11] focuses on the provisioning, regulating, and supporting of the cultural services provided by ecosystems. By valuing and incorporating ecosystem services into decision-making processes, policymakers and practitioners can develop sustainable land governance approaches that optimise resource use, enhance resilience, and promote biodiversity conservation [12]. However, it may lack a holistic approach to encompass the multiple interconnections between land and the WEF systems.

The Adaptive Co-management Framework [13,14] highlights collaborative and adaptive governance processes that involve multiple stakeholders in the management of land. It recognises that complex socio-ecological systems require flexible and inclusive approaches that can respond to changing dynamics and uncertainties. Adaptive co-management promotes learning, knowledge exchange, and collective decision-making, allowing for the integration of diverse perspectives in the identification of context specific solutions [15,16], but it may not explicitly address the integration of water, energy, and food systems grounded on land.

Thus, the central problem that this paper addresses is the need for a comprehensive theoretical framework that accounts for the interdependence and intricate interactions between water, energy and food systems, grounded on land. The proposed framework will offer an integrated approach that recognises land as the crucial bonding element connecting water, energy, and food systems. By exploring the transversal relationship between land and the WEF systems, this framework aims to enhance decision-making, policy coherence, and sustainable land governance in diverse territorial contexts.

The primary objective of this research is to propose an innovative and integrated methodology for sustainable land governance, encompassing: (1) a top-down approach, including literature and policy reviews, as well as legal framework analyses, (2) a bottom-up approach informed by Participatory Action Research and supported by stakeholder identification, mapping and engagement, interviews, surveys, and focus group discussions, and (3) a geospatial approach utilising a spatial analysis. The research demonstrates the relevance of land governance in WEF systems and how it influences resource management, territorial impacts and food sovereignty.

To do so, this research paper adopts a qualitative research approach to develop a novel theoretical framework—sustainable land governance for WEF systems (hereinafter SLG)—for rural and peri-urban revitalisation in the Global South. To showcase the practical application of the proposed methodology for SLG, the PAR involved the installation of WEF projects in small rural and peri-urban communities, designed and implemented after needs assessments, and guided by the Theory of Change (ToC) [17–19]. The ToC aligns

seamlessly with the sustainable land governance (SLG) Framework due to its capacity to capture the interconnected and comprehensive nature of the research. By providing a structured approach to delineate causal pathways, accommodate diverse contexts, and promote participatory engagement, ToC serves as a fitting mechanism to substantiate the complex relationships between land governance, resource management, and rural revitalisation within the SLG framework. To highlight the framework's efficacy in supporting food sovereignty, community empowerment, and sustainable land governance in challenging territorial contexts, the research showcases the installation of a solar-powered irrigation pump in the rural village of Gitaraga in Rwanda (see Section 5), as one of the multiple case studies assessed (see Section 4.1) to develop the SLG framework. While other case studies could provide additional insights into the different phases of the methodology, the deliberate selection of this example serves to demonstrate the practical application and transformative potential of the proposed approach. Gitaraga village was chosen due to its representation of a critical agro-ecological zone, characterised by its vulnerability to climate change, its dependence of rain-fed agriculture, the challenges of land fragmentation, inadequate irrigation infrastructure, and limited access to credit and resources. Focusing on the sustainable management of land, water, energy, and food systems as an integrated whole, our research aimed to develop practical solutions that improve agricultural productivity, enhance local livelihoods, and foster resilience. Additionally, by delving deeply into a single case, such as the one in Rwanda, we were able to scrutinize the intricate interplay between land, water, energy, and food systems within a specific socio-cultural and environmental backdrop. This focused approach allowed us to not only provide an in-depth analysis of the practical implementation and outcomes of sustainable land governance principles but also to demonstrate the effectiveness of our proposed framework in addressing real-world challenges. The Rwanda case study acts as a comprehensive exemplar that demonstrates the transversal application of the SLG framework's principles, objectives, and methods, thereby validating the framework's adaptability and relevance in diverse contexts.

2. Theoretical Framework: Sustainable Land Governance for WEF Systems—Unravelling the Connections

The theoretical framework of this research establishes that Land Governance is the vital bonding element within Water–Energy–Food (WEF) systems, acknowledging its central role in interconnecting these three sectors.

Land lies at the core of social, environmental, economic and cultural sustainability and resource management. Land governance is the ground where a number of transversal and multidisciplinary challenges and solutions take place, including: water management (in)tangible cultural assets, environmental risks, food security/sovereignty, gender issues, legal frameworks, nature-based solutions, mining (formal, informal, artisanal, for fossil fuels, for minerals needed for renewable energies), rural and urban development, transition towards clean energies, waste management, smart city interventions (machine learning, artificial intelligence, remote sensing, passive systems), land administration, land information infrastructures, and more [20–24].

The concept of Nexus Governance has been investigated before [25–29] in the sense of the integrated governance of water, energy, and food systems, while Bizikova et al. stress the "need to focus on actual actions—such as innovative solutions and investments—and resource governance, such as regional and transboundary water and land governance" [30]. This research goes beyond to explore the role of land governance as the foundation upon which WEF systems occur and develop. For example, land use decisions can have a significant impact on water resources, as certain land use practices can lead to soil erosion and runoff, which can degrade water quality and reduce resource availability for agriculture and urban development. Similarly, land use decisions can affect energy production, as the extraction of the minerals needed for the energy transition (i.e., copper, cobalt, lithium, and nickel) can have substantial impacts on ecosystems and local communities [31]. Therefore, this research understands that a transversal approach to Land Governance mechanisms

would ensure the participation of cross-sectoral stakeholders for more sustainable WEF systems: (1) in the understanding of contextual bio-cultural structures, (2) in the formulation, monitoring and enforcement of land policies and decision-making processes, and (3) in the equitable distribution of land and other resources.

The proposed transversal approach to land governance promotes sustainable and equitable use of land resources by effectively managing interlinkages between land use, water, energy, and food, supporting sustainable development. Recognising land as the bonding element connecting the WEF sectors underlines its influence on resource management, territorial impacts, and food sovereignty. This SLG framework addresses challenges arising from competing land uses, aiming to balance competing interests, engage stakeholders, and improve land governance in rural and peri-urban communities. Guided by a set of core principles, the SLG framework is designed to be adaptable to diverse contexts, considering specific socio-cultural, economic, and environmental conditions. Through the synthesis of international guidelines and frameworks, rigorous case studies, and empirical validation, this research offers an empirically tested framework for sustainable land governance for WEF systems, enhancing understanding of land governance complexities and supporting informed decision-making for sustainable development.

2.1. Land as the Bonding Element: Exploring the Dynamic Interplay with WEF Systems

Using land as the bonding element, all possible relations between water, energy and food in a transversal approach to WEF systems can be expressed as Land + Water–Energy–Food (L + WEF), and be understood as follows:

1. Land–Water (LW): Land provides the foundation for water-related activities such as irrigation, rainwater harvesting, fishing, and groundwater recharge, supporting agricultural production and enhancing water availability. However, land degradation and deforestation can lead to biodiversity loss, reduced water retention and increased soil erosion, affecting water quality and availability for both agriculture and human consumption. Improper land management practices may result in water pollution from agricultural runoff, pesticides, and fertilisers, impacting water ecosystems and human health [32]. Also, land-use changes can alter hydrological cycles, leading to changes in local water availability and exacerbating water scarcity in certain regions [33]. For example, deforestation and land conversion in the Amazon rainforest for agricultural expansion in Brazil have resulted in significant consequences for land and water resources [34]. Vast areas of the Amazon have been cleared for agriculture, particularly for cattle ranching and soybean cultivation, leading to the loss of crucial forest cover and disruption of important ecosystems, impacting biodiversity, Indigenous land rights, and climate [35]. This removal of trees and vegetation has also disturbed the water cycle in the region, altering rainfall patterns, reducing water availability, and increasing the risk of droughts and floods. The use of pesticides and fertilisers in agriculture has contaminated nearby water bodies, posing risks to aquatic life (e.g., frugivorous fish in charge of dispersing seeds along the riverbanks) and human health, while conflicts over land rights and dispossession of Indigenous communities have also emerged [34,36]. The LW relationship in the Amazon rainforest is being studied in the framework of our research project ForestFisher (https://www.amazon-fish.com/forestfisher accessed on 28 July 2023), in partnership with other international institutions.
2. Land–Energy (LE): Land plays a significant role in energy production, especially concerning renewable energy sources like solar and wind. Land is required for the installation of solar panels, wind turbines, and other clean energy infrastructure [37]. Additionally, land serves as a site for mining activities, particularly in the extraction of minerals and fossil fuels required for energy generation. On the other hand, competing land uses for energy production (e.g., solar farms, wind turbines) can displace agricultural activities, potentially affecting food production and food security [38]. In addition, extractive activities, such as mining for fossil fuels or minerals used in

renewable energy technologies, can lead to habitat destruction and ecological damage, affecting biodiversity and ecosystem services [39]. The Democratic Republic of Congo possesses abundant reserves of cobalt and lithium, essential for battery production in industries like electric vehicles and renewable energy. However, their extraction has led to significant environmental and social challenges. Large-scale mining operations have caused habitat destruction and biodiversity loss, disrupting ecosystems and displacing wildlife. Furthermore, human rights violations, including forced evictions and poor labour conditions, have been reported in some mining areas, impacting local communities. Environmental damage, such as soil and water contamination, poses health risks to nearby populations and affects agricultural resources. Additionally, child labour has been associated with cobalt mining. The DRC's struggle to regulate and monitor mining activities, particularly in artisanal mining, has resulted in illegal practices and inadequate environmental protection [40–42].

3. Land–Food (LF): Land is the primary resource for agricultural production, providing the space and conditions for growing crops and raising livestock to ensure food supply and security. Conversely, the expansion of agricultural land for food production can lead to deforestation and loss of natural habitats, diminishing biodiversity and ecosystem resilience [43]. According to FAO's Global Remote Sensing Survey, "agricultural expansion drives almost 90 percent of global deforestation. [. . .] Worldwide, more than half of forest loss is due to conversion of forest into cropland, whereas livestock grazing is responsible for almost 40% of forest loss" [44]. In Borneo, the competition between intensive palm oil production and traditional food systems poses significant challenges for sustainable land governance and food sovereignty. The rapid expansion of intensive palm oil plantations has led to the conversion of extensive areas of natural forests and peatlands into monoculture plantations. This land-use change has resulted in deforestation, loss of biodiversity, and habitat destruction, impacting the region's ecological balance and contributing to greenhouse gas emissions. The displacement of traditional agricultural practices and local communities has affected food security. Additionally, the extensive use of agrochemicals in palm oil plantations has further contaminated water resources, leading to environmental degradation and potential health risks for nearby communities [45–48].
4. Land–Water–Energy (LEW): Land acts as a nexus between water and energy, facilitating hydropower generation, water-intensive energy production processes, and integrated energy-water management. Though, competition for water resources between agriculture, energy production, and domestic use can lead to conflicts over water allocation and distribution. Moreover, energy-intensive water extraction methods, such as groundwater pumping for irrigation, can deplete water resources, leading to water scarcity and affecting both agriculture and energy production [49]. For example, in the Salar de Atacama, Chile and Salar del Hombre Muerto, Argentina, lithium extraction has become a major driver of economic development due to the increasing demand for lithium-ion batteries in renewable energy technologies and electric vehicles [50]. However, the extraction of lithium requires vast amounts of water, putting immense pressure on local water resources. This has had severe consequences for nearby Indigenous communities who rely on these water resources for their cultural heritage, traditional farming practices and livelihoods. As water is diverted for lithium extraction, it results in reduced access to water for the people that survive in the desert [51]. Moreover, the extraction process and associated infrastructure disrupt natural ecosystems and biodiversity in the area, leading to environmental degradation [52–54].
5. Land–Water–Food (LWF): Land plays a pivotal role in connecting water and food systems by creating an environment conducive for irrigation and crop growth, essential for sustaining food production. Unsustainable agricultural practices, on the other hand, such as excessive water abstraction for irrigation, can lead to the depletion of water resources, jeopardising good production and food security. Moreover, pollu-

tion from urban, industrial and agricultural activities can contaminate water sources, posing health risks to both humans and aquatic ecosystems [55,56]. In the Mekong Delta, Vietnam, rice cultivation plays a pivotal role in food security and the economy. "The delta's unique waterscape—with its maze of canals, extensive horizons of rice fields, village orchards and aquaculture farms—is the result of natural forces such as rain, floods, sedimentation and tides, and of human constructions such as canals and dikes" [57]. The expansion of rice fields faces challenges due to altered river flow from upstream dams and water diversions, impacting the delta's hydrology and water availability for crops. Intensive rice practices contribute to soil salinization and subsidence, affecting yields [58].

6. Land–Energy–Food (LEF): The interaction between land, energy, and food systems highlights the impact of land use on energy-intensive agricultural practices, food-processing industries, and the demand for energy in the food supply chain. Additionally, agrivoltaics involves the dual use of land for both agriculture and renewable energy production [59]. Also, increased demand for bioenergy crops can lead to land-use changes, potentially competing with food crops and contributing to price volatility [60,61]. Additionally, energy-intensive food processing and distribution systems can exacerbate carbon emissions and environmental degradation. For example, in Ethiopia, the increasing demand for biofuels has led to land use conflicts, contributing to food insecurity. The cultivation of jatropha and castor beans for biofuel production has resulted in the conversion of agricultural land into large-scale plantations in the Gamo Gofa region, displacing local communities from their traditional farmlands and altering their agricultural practices [62,63]. However, when the transformation has taken place at a small scale, with rotations between food versus fuel (cash) crops, food security can increase significantly [64,65].
7. Land–Water–Energy–Food (LWEF): Land forms the basis for the interconnectedness of all three elements as it supports integrated land use planning, resource management, and sustainable development. Yet, conflicting land uses, such as converting agricultural land for energy production can lead to food insecurity and displacement of farming communities [66]. Furthermore, large-scale mining activities can lead to land displacement and evictions of local communities, disrupting traditional livelihoods and food production [67]. Pollution from mining activities can contaminate water sources, affecting both water quality and the availability of water for agricultural processes. In Tete Province, Mozambique, coal mining activities have led to significant challenges concerning land rights, water availability, and food security. The exploitation of coal reserves has triggered involuntary resettlement, displacing communities from fertile lands along the Revuboe River to remote locations like Mualadzi. This displacement has resulted in the loss of agricultural lands and disrupted traditional livelihoods, leading to food insecurity for affected communities. Moreover, the resettlement process has often provided inadequate compensation and insufficient consideration for the impact on local livelihoods and access to water resources [68–71].

The situations exposed above call for improved governance mechanisms to address the complexities arising from land's interplay with water, energy, and food systems, to ensure the protection of communities' land rights, access to water and energy, and food security. Therefore, the framework for sustainable land governance for WEF systems (SLG) is necessary due to the intricate and interrelated challenges faced in managing land, water, energy, and food resources. Conventional sector-focused strategies frequently overlook the interconnected dynamics between L + WEF, resulting in conflicts, inefficiencies, and unsustainable resource utilisation. Through the integration of a holistic framework, we aim to address these intricacies and advance solutions that optimise resource management, social fairness, and ecological sustainability.

2.2. Building Bridges to Sustainable Land Governance: State of the Art Review of International Frameworks

The development of an effective and comprehensive SLG framework necessitates a thorough exploration of existing frameworks and indicators that address the complex governance interactions between land, water, energy and food. In this literature review, we examine several key frameworks and indicators that have been applied to land and water governance, each offering unique perspectives on sustainability, equity, and environmental considerations for some of the WEF relationships with land.

The World Governance Indicators (WGIs) by the World Bank provide a comprehensive dataset of governance, capturing six dimensions: Voice and Accountability, Political Stability and Absence of Violence, Government Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption. The WGIs aim to measure and assess the quality of governance in over 200 countries and territories, using data from a variety of sources, including surveys, expert assessments, and other quantitative data, to produce annual updates on governance indicators. The WGIs play a crucial role in land governance by providing insights into the broader governance context in which land decisions are made. For instance, it helps researchers, policymakers, and practitioners understand the quality of governance and institutional frameworks that shape land use, land tenure, and land management policies, offering a foundation for understanding the political, social, and economic dynamics that shape land use decisions and resource management [72].

The Voluntary Guidelines for the Responsible Governance of Tenure (VGGT) by the Food and Agriculture Organization (FAO) of the United Nations is a set of international guidelines that promote responsible and sustainable governance of tenure over land, fisheries and forests. They provide a framework for governments, civil society, and other stakeholders to design and implement policies, laws, and practices that respect and protect the legitimate tenure rights of individuals and communities, particularly vulnerable and marginalised groups. The VGGT contribute significantly to land governance and sustainability by emphasising tenure security for all, promoting gender equality in land rights, advocating for sustainable land use practices, encouraging inclusive decision-making, providing mechanisms for conflict resolution, and addressing responsible land investments. By adopting and implementing the guidelines, countries and stakeholders can enhance tenure security, promote sustainable land use, and contribute to poverty reduction, food security, and environmental sustainability [73].

The Tenure Responsive Land Use Planning (TRLUP) by the Global Land Tool Network (GLTN) of the United Nations Settlements Programme (UN Habitat, Nairobi, Kenya) is a significant tool that contributes to land governance and sustainability by addressing land use planning and tenure security challenges in tandem. This approach enables local communities to actively participate in their development vision through a more inclusive, gender-sensitive, and tenure-responsive process. By utilising practical, locally adapted methods, the TRLUP strengthens the capacity and knowledge of communities, empowering them to make informed decisions. One of the key contributions of TRLUP to land governance is its focus on enhancing tenure security. By taking a participatory approach and involving local people in land use planning, the approach ensures that land rights are recognised and protected, reducing the risk of land grabs and conflicts over resources. This, in turn, promotes sustainable land management practices as communities are incentivised to invest in and manage their lands more responsibly. Its emphasis on coherent and informed decision-making helps governments and policymakers evaluate land use policies and strategies to enhance tenure security, leading to more equitable and sustainable land governance practices [74–76].

The Land Degradation Neutrality (LDN) framework, established by the United Nations Convention to Combat Desertification (UNCCD), is a tool aimed at halting and reversing land degradation by promoting responsible land management and restoration efforts. LDN contributes significantly to land governance and sustainability by providing a comprehensive approach to addressing the degradation of land resources. By adopting

this framework, countries can enhance their land governance policies and strategies, ensuring that land resources are sustainably managed and protected for current and future generations. LDN encourages the integration of environmental, social, and economic considerations to land-use planning and decision-making processes, leading to more balanced and resilient ecosystems and landscapes. It promotes climate change mitigation, biodiversity conservation, and poverty alleviation by fostering collaboration between various stakeholders, including governments, local communities, and the private sector [77,78].

The Principles for Responsible Investment in Agriculture and Food Systems by the Committee on World Food Security (CFS-RAI) provide a vital framework for promoting sustainable land governance and responsible agricultural investments. These principles seek to ensure that land investments contribute to food security, poverty reduction, and social and environmental sustainability. The CFS-RAI principles include food security and nutrition, sustainable and inclusive economic development and the eradication of poverty, gender equality and women's empowerment, empower youth, tenure of land, fisheries and forests, sustainable management of natural resources, cultural heritage and traditional knowledge, safe and healthy agriculture, transparent governance structures and processes, and promoting accountability. These principles emphasise the need for inclusive and transparent decision-making processes, ensuring that all stakeholders—particularly small-scale farmers and vulnerable communities—have a voice in land-related investments. This approach fosters more equitable land governance and helps prevent land grabs and displacement of local populations. Moreover, the CFS-RAI principles prioritise sustainable and environmentally friendly land use practices, promoting responsible agricultural investments that conserve biodiversity, protect ecosystems, and enhance soil health [79].

The Good Practice Guidance for Land Use, Land-Use Change and Forestry is a comprehensive set of guidelines developed by the Intergovernmental Panel on Climate Change (IPCC-LULUCF). The guidance aims to enhance transparency, consistency, and accuracy in reporting emissions and removals from the land sector, enabling countries to effectively address climate change mitigation and sustainable land management. By offering scientifically robust methodologies and best practices, the IPCC-LULUCF facilitates the accurate accounting of greenhouse gas emissions and removals from land-use activities, enabling countries to develop informed and evidence-based climate change mitigation strategies. This supports more effective land-use planning and decision-making, ensuring that land-based actions align with climate goals and promote sustainable practices. The guidelines also promote transparency and comparability of data, fostering trust and collaboration among countries in addressing climate change challenges. This collaborative approach can lead to enhanced cooperation on sustainable land management practices, knowledge sharing, and capacity building, further contributing to global efforts to mitigate climate change and promote sustainable land governance [80].

The Guiding Principles on Large Scale Land-Based Investments in Africa developed by the African Union (AU) and the United Nations Economic Commission for Africa (UNECA), provide a comprehensive framework to promote responsible and sustainable land governance in the context of large-scale investments. While primarily focused on Africa, they could serve as an inspiring model for the broader Global South. These principles aim to enhance land tenure security, protect the rights of local communities, and ensure that investments contribute to social and economic development while safeguarding environmental sustainability. By emphasising principles such as transparency, inclusivity, and respect for customary land rights, the guidelines foster improved governance and regulatory frameworks, promoting equitable and sustainable land-use practices. These principles contribute to land governance and sustainability by promoting responsible investment practices that prioritise the well-being and rights of local communities and vulnerable populations. They provide guidance to governments, investors, and other stakeholders in ensuring that large-scale land investments adhere to social and environmental standards, mitigating the risks of land grabbing, displacement, and environmental degradation. By encouraging participatory decision-making and respecting the knowledge and perspec-

tives of local communities, the principles support more inclusive and sustainable land-use planning and management [81].

Finally, the Sustainable Development Goals (SDG) are a set of 17 goals adopted by all United Nations Member States in 2015 as part of the 2030 Agenda for Sustainable Development. The SDGs provide a comprehensive and universal framework that addresses various global challenges, including those related to land governance and sustainability (e.g., Goal 15 "Life on Land"). By promoting sustainable land management, responsible land use planning, and equitable access to land, the SDGs stress the importance of fostering harmonious relationships between land, water, energy, and food systems. These goals encourage countries to develop and implement policies and practices that ensure the conservation of natural resources, the protection of ecosystems, and the enhancement of biodiversity. The SDGs also underscore the significance of inclusive participatory approaches to decision-making, involving local communities, stakeholders, and Indigenous populations in land governance processes. By advocating for social equity and tenure security, the SDGs aim to protect the rights of the vulnerable populations and foster sustainable land use practices that benefit present and future generations [82].

A summary of the existing international frameworks, along with their descriptions and contributions to sustainable land governance is presented in Table 1.

Table 1. Summary of existing international governance and WEF frameworks.

Framework/Guideline	Description	Contributions to SLG
World Governance Indicators (WGI)	World Bank's comprehensive governance dataset measuring governance quality in various countries.	Provides insights into broader governance context influencing land decisions and resource management.
Voluntary Guidelines for the Responsible Governance of Tenure (VGGT)	UN FAO guidelines promoting responsible governance and sustainability.	Emphasises tenure security, gender equality, sustainable land use, and inclusive decision-making.
Tenure Responsive Land Use Planning (TRLUP)	UN Habitat's approach addressing land use planning and tenure security.	Enhances tenure security, participatory land use planning, and responsible land management practices.
Land Degradation Neutrality (LDN)	UNCCD framework for halting and reversing land degradation.	Provides a comprehensive approach to land resource degradation, integrating environmental, social, and economic considerations.
Principles for Responsible Investment in Agriculture and Food Systems (CFS-RAI)	The Committee on World Food Security's principles promoting responsible agricultural investments.	Ensures investments that contribute to food security, poverty reduction, gender equality, and sustainable land use.
Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC-LULUCF)	IPCC's guidelines for accurate greenhouse gas emissions accounting.	Enhances accurate accounting of emissions from land-use activities, aligning with climate goals and sustainable practices.
Guiding Principles of Large Scale Land-Based Investments in Africa	AU and UNECA principles promoting responsible and sustainable large-scale investments in Africa	Ensures investments protect local rights, promote inclusive decision-making, and adhere to social and environmental standards.
Sustainable Development Goals (SDGs)	UN's comprehensive global goals for sustainability, included those related to land governance and use.	Encourages sustainable land management, equitable access to land, and inclusive decision-making.

The comprehensive review of diverse guidelines in this section provides valuable insights into land governance and sustainability, contributing to the development of the proposed theoretical framework on SLG. The principles derived serve as the foundational pillars of the proposed SLG framework, addressing the complex interactions between land and the WEF systems. By integrating and harmonising these principles, the SLG framework will offer a multidimensional and holistic approach to guide sustainable land use practices that balance environmental conservation, social equity, and economic development, fostering rural and peri-urban revitalisation.

The forthcoming sections sill outline the detailed methodology used to identify, validate and refine the principles for sustainable land governance for WEF systems in diverse urban and peri-urban settings. These experiments address specific land governance challenges and opportunities, aiming to enhance livelihoods, food sovereignty, and water and energy access in these areas. The results will demonstrate the applicability of the SLG framework, highlighting its potential for transformative changes to revitalise rural and peri-urban settings. The principles derived from this research will be presented as a comprehensive and empirically tested framework in the Results section.

3. Methods: Integrating Transversal Approaches for Sustainability

The development of the SLG framework is guided by a multidisciplinary approach, drawing on perspectives from geography, anthropology, law, environmental engineering, sustainable resource management, and political science.

The research uses a mixed-methods approach (including case study analysis, field observations, stakeholder mapping, interviews and surveys, policy reviews, and participatory action research) to offer insights and recommendations that are grounded in empirical research and informed by a deep understanding of the local contexts and frameworks in which land use decisions are made. Overall, the research methods seek to explore the complex relationships between land use, land tenure, and governance, and extract insights from a range of disciplinary perspectives. To achieve this, a set of three interconnected objectives is pursued:

Objective 1: "From the Ground Up: Stakeholder Analysis" involves a broad data collection on selected case studies, consisting of field visits, stakeholder identification, mapping of stakeholder roles, responsibilities, and interests. Interviews, surveys, and focus group discussions were used to gain insights into stakeholders' perspectives, needs, and understanding, which enabled us to assess stakeholder awareness, knowledge, and engagement in the pertinent land-related issues. In addition, literature reviews and participatory action research (PAR) [83] using the Theory of Change [17–19] approach were useful for determining the rationales behind land claims.

Objective 2: "Down to the Ground: Policy Review" focuses on analysing existing land policies and reports on land claims, contrasting them with insights from local stakeholders. A categorised literature review, spider method [84], and interviews with key stakeholders are utilised to search for policy options that align with local insights.

Objective 3: "Observing the Ground: Geospatial Approach" involves gathering geospatial data through Remote Sensing, Geoportals, GIS, Photographic surveys, field visits, and observations. Spatial analysis is conducted to identify patterns and overlapping land use, land rights, and land claims.

The case studies approach is used to examine the governance mechanisms in place and their impact on WEF systems in specific regions of Africa, Asia and Latin America. It is driven by a collaborative research approach, in which the supervision of PAR theses includes the implementation of a desired change with iterative processes that is complemented by monitoring activities. This involves collecting and analysing data on land use, water, energy, and food systems, as well as examining policy and governance frameworks using Q Methodology. Field observations are used to gain better understanding of the local contexts and to identify opportunities and challenges for sustainable and equitable use of land resources. This involves visiting different sites and interacting with

the identified local stakeholders, including community members, government officials, and industry representatives.

Stakeholder structured surveys and open-ended interviews are used to gather perspectives and insights from different actors involved in land governance and WEF systems, and to identify areas of improvement. These interviews help to inform policy and governance recommendations. When relevant (and when funds are available), a specific project is implemented with a participatory approach and/or with demand-driven capacity building activities. Geospatial analysis is used for gathering, displaying and manipulating geographic data, involving the use of Remote Sensing, spatial analysis and Geographic Information Systems (GIS) to capture, store, manipulate, analyse, and display spatial data. It is used to study patterns of human behaviour. Finally, policy reviews are used to examine the governance mechanisms and the legal framework.

The proposed theoretical framework for sustainable land governance for WEF systems has been rigorously tested and refined through extensive practical applications and collaborative research. Over the course of this research (from 2018 to 2023), 22 master's theses were supervised by the author, each of which constituted an individual study. These theses were meticulously structured, incorporating their own literature reviews, stakeholder analyses, policy reviews, interviews with key stakeholders, etc. Moreover, each thesis addressed at least one of the three specified research objectives, providing in-depth exploration and refinement of the framework's principles in diverse geographical and socio-cultural contexts in 14 countries in Africa, Asia, the Middle East, Latin America and North America. Furthermore, 16 capacity building workshops in 11 countries (either in presence, online or hybrid) were successfully facilitated as focus group discussions, engaging a total of 851 participants and fostering knowledge exchange for the development of the framework's principles. To further validate and enrich the framework, 6 Participatory Action Research projects were implemented in Mexico, Germany, Rwanda and Nepal, allowing for iterative improvements based on real-world experiences. Showcased in this research paper is a solar-powered irrigation system following a land consolidation process in Gitaraga, Rwanda.

All these efforts have been underpinned by 4 large-scale research projects with third-party funds, exclusively focused on the different dimensions of land governance, sustainability, and WEF systems. This extensive practical experience, combined with rigorous research and collaboration, has culminated in a robust and empirically tested framework that addresses the complexities and challenges of sustainable land governance in WEF systems in various regions and situations.

4. Results: Case Studies and Capacity Building

The results section presents a detailed exploration of the master's theses and capacity building workshops, which lay the ground for the formulation of the core principles of the SLG framework.

4.1. Case Studies: Exploring Diverse Frontiers for SLG and L + WEF Systems

This section delves into the empirical findings obtained from a series of case studies, meticulously designed to align with the research objectives of the SLG framework. The case studies, derived from 22 master's theses, provide a critical foundation of the proposed theoretical framework, grounded on literature reviews, stakeholder analyses, policy reviews, and interviews. Spanning diverse urban, rural and peri-urban settings in Africa, Asia, the Middle East and Latin America, these investigations shed light on the complex interplay between land use, water, energy and food.

As we delve into the comprehensive table summarizing the master's theses (Table 2), a coherent pattern emerges to delineate the core principles of the framework, which provide a multidimensional and holistic understanding of land governance challenges.

Table 2. Summary of master's theses on sustainable land governance: Objectives, Methodology and Stakeholder Engagement.

Thesis Title	Country	Name	Year	Objectives Addressed [1]	L + WEF	Literature Review	Stakeholder Analysis	Policy Review	Interviews	PAR
Exploring mining conflicts based in land rights in Zambia: Bottom-up centred stakeholder analysis	Zambia	Beinhofer	2023	2	LEF	Yes	Yes	No	Yes	No
Analysing Indigenous agriculture techniques in Cuetzalan, Mexico for sustainable food systems	Mexico	Bianco	2023	1, 2	LWF	Yes	Yes	Yes	Yes	Yes
Breaching the gap between the local and the global: the impact of community-based resource management on water security across development, policy and science	Mexico	Navarrete	2023	1, 2, 3	LWF	Yes	Yes	Yes	Yes	Yes
Stakeholder engagement around water governance: 30 years of decision-making in the Bogotá River basin [85]	Colombia	Salamanca	2023	1	LW	Yes	Yes	Yes	No	No
Cost-benefit analysis of green-grey infrastructure for coastal protection. A case study in Guyana and Cuba	Guyana and Cuba	Saldarriaga	2023	3	LW	Yes	Yes	No	Yes	No
A tale of two Megacities: Comparing approaches to managing extreme heat in Ahmedabad and New York City	India and USA	Schmidhammer	2023	2	LE	Yes	Yes	Yes	No	No
Evaluation of the impacts of farmstays—a sustainable ecotourism-based program on cultural landscape management, local community development & women empowerment	India	Sur Roy	2023	2	LWF	Yes	Yes	Yes	Yes	Yes
Agrivoltaics for food security: the WEF nexus approach in Bugesera, Rwanda	Rwanda	Udhaya Kumar	2023	2, 3	LWEF	Yes	Yes	Yes	Yes	No
Participatory approach to strengthen food sovereignty based on a Theory of Change: the case of Barrio de Jesús Tlatempa, Mexico	Mexico	Becker	2022	1, 2	LF	Yes	Yes	Yes	Yes	Yes
Feasibility study of adaptation of Climate Smart Agriculture in Rwanda in the context of WEF nexus system at the farm level	Rwanda	Devadas	2022	1, 2, 3	LWEF	Yes	Yes	Yes	Yes	Yes
Land use strategies in the touristic municipality of San Bartolomé de Tirajana, Gran Canaria	Spain	Rojas Rivero	2022	1, 2, 3	LG	Yes	Yes	Yes	Yes	No
Stakeholder analysis for the WEF Nexus in Ethiopia: implications for Nexus Governance, Land Degradation Neutrality and food security	Ethiopia	Harb	2022	1, 2	LWEF	Yes	Yes	Yes	Yes	No

Table 2. *Cont.*

Thesis Title	Country	Name	Year	Objectives Addressed [1]	L + WEF	Literature Review	Stakeholder Analysis	Policy Review	Interviews	PAR
Analysing land policies for food sovereignty of Indigenous people from a gender perspective. The case of the Wayúu community, Colombia	Colombia	Mantilla Álvarez	2021	1, 2	LWF	Yes	Yes	Yes	Yes	No
Policy integration of nature based solutions for coastal risk reduction in the Caribbean [86]	Mexico	Moreno	2021	1, 2	LW	Yes	Yes	Yes	Yes	No
Growing artificial glaciers as a strategy for agricultural growth and tackle climate change in Nepal	Nepal	Ghimire	2020	2	LWF	Yes	Yes	Yes	Yes	No
The Metropolitan Region of Bogotá: opportunity for sustainable land use management	Colombia	González Aparicio	2020	1	LW	Yes	No	Yes	No	No
Investigation of Peikao-gentrification for socio-spatial development in China: a case study of Town M.	China	Liu	2020	3	LG	Yes	Yes	No	Yes	No
An emergency response strategy based on the Good Governance Principles. The case of Tochimilco, Mexico	Mexico	Baldenhofer	2019	2, 3	LWF	Yes	Yes	Yes	Yes	Yes
A water management strategy based on Participatory Planning for the Kathmandu Valley to improve the conditions of Bagmati River [87]	Nepal	Gigl	2019	1, 2, 3	LW	Yes	Yes	Yes	Yes	No
Developing a monitoring plan to assess the water quality of Bagmati River in Kathmandu Valley, Nepal [87]	Nepal	Kreutzer	2019	1, 3	LW	Yes	Yes	No	Yes	No
Land management strategy to improve the socio-spatial quality of an informal settlement from its causes: the case of Wadi Al-Mashari in Damascus	Syria	Sallam	2019	1, 3	LG	Yes	Yes	No	No	No
The influence of the built environment on cultural identity: the case of Kibuga in Kampala, Uganda [88]	Uganda	Tusiime	2018	1, 3	LG	Yes	Yes	Yes	No	No

[1] 1 stands for Objective 1 "From the Ground Up: Stakeholder Analysis", 2 stands for Objective 2 "Down to the Ground: Policy Review", 3 stands for Objective 3 "Observing the Ground: Geospatial Approach".

The examination of the 22 master's theses provides valuable insights into the different connections of land with WEF systems. The identified Land + Water–Energy–Food relations (L + WEF, as developed in Section 2.1) have been explored as follows: 6 cases of Land–Water (LW), 1 of Land–Energy (LE), 1 of Land–Food (LF), 0 of Land–Energy-Water (LEW), 6 of Land–Water–Food (LWF), 1 for Land–Energy–Food (LEF), 3 for Land–Water–Energy–Food (LWEF) and 4 for Land Governance (LG). Regarding the three primary research objectives, 14 theses were addressing multiple objectives simultaneously: hence, of the 22 theses 14 addressed Objective 1, focusing on stakeholder analysis and engagement, emphasising inclusive decision-making and recognising the complexities of the competing interests in land management. An equal number of 14 theses centred on Objective 2, conducting policy reviews to highlight the significance of coherent governance frameworks and evidence-based planning for sustainable land use. Additionally, 11 theses aligned with Objective 3, adopting geospatial approaches to understand spatial patterns and land use changes, stressing the need for adaptive strategies in addressing land-related challenges. Furthermore, in views of the methodology followed, 100% of the theses conducted an extensive literature review. This comprehensive examination if existing scholarly work provides a strong theoretical foundation and context for the respective case studies on SLG. A high level of adherence (21 out of 22 theses, representing 95.5%), a thorough and in-depth stakeholder analysis was conducted, firmly grounded on contextual issues. This process involved identifying and engaging relevant stakeholders to understand their roles, interest, and power dynamics. A policy analysis was conducted in 17 out of the 22 theses (approximately 77.3%), delving into the existing international land governance frameworks, and scrutinising relevant national, regional and local policies, regulations, and legal instruments to assess the policy gaps and strengths. An equal number of 17 out of the 22 theses (approximately 77.3%) involved interviews with key stakeholders and/or surveys incorporating both closed and open-ended questionnaires. By engaging with stakeholders from diverse backgrounds, including local communities, government officials, and industry representatives, the theses aimed to capture multiple viewpoints and nuances related to land use, tenure and resource management. Through structured surveys and open-ended interviews, the research delved into stakeholders' awareness, knowledge, and participation in land-related decision, empowering the process of inclusive and participatory governance. Finally, six out of the twenty-two theses (27.3%) were developed through a Participatory Action Research (PAR) project. The PAR approach enabled the formulation, design and monitoring of WEF projects in direct collaboration with local communities, ensuring their active involvement and ownership throughout the process. Following the Theory of Change approach, these projects were meticulously designed to address the specific needs and priorities of the communities they serve, fostering a participatory and inclusive decision-making process. By engaging stakeholders directly in the implementation of these projects, the theses aimed to promote sustainable and equitable outcomes that resonate with the local context, culture, and practices. Moreover, the PAR approach facilitates meaningful and enduring changes, as the communities take ownership of the projects, ensuring their continuity and sustainability beyond the research period.

4.2. Capacity Building Activities for SLG

In addition to conducting case studies research to validate and refine the proposed SLG framework, capacity building activities played a pivotal role in empowering stakeholders and advancing knowledge exchange [89,90]. These capacity building workshops and training programs (displayed in Table 3) served as opportunities for focus group discussions, which offered diverse opportunities for individuals and organisations to enhance their understanding of land governance, sustainability, and the WEF systems [91]. By bringing together participants from various regions, backgrounds and disciplines, these activities provided a platform for collaborative learning and the exchange of best practices.

Table 3. Summary of capacity building activities and objectives addressed for sustainable land governance.

Workshop Title	Location	Year	Objectives Addressed [1]	Focus Area	Recipient [2]	Participants
Participatory mapping and planning to empower Amaleys of Ladakhi villages	Phyang, India	2023	1, 3	Participatory frameworks and Socio-cultural heritage	HIAL	14
Training Program on land governance for the youth	Online	2022	1, 2, 3	Land Governance and Participatory frameworks	YILAA	25
Research Writers Workshop	Chaminuka, Zambia	2022	1	Education	NELGA Southern Africa	30
ADLAND Curriculum Needs Assessment	Online	2022	2	Stakeholder engagement and Education	NELGA Southern Africa	7
Ice Stupa Project in Ladakh and the Alps	Munich, Germany	2022	1, 3	WEF systems	Nexus@TUM, HIAL	10
Monitoring and Promoting Policy Changes for a Gender-Equitable Governance of Tenure through Stakeholder Engagement	Kumasi, Ghana (hybrid)	2021	1, 2	Stakeholder engagement	GIZ	70
Land Management and Land Tenure	Online	2021	1, 2	Land governance	TUM Alumni	150
Blockchain Technology and Applications for Secure Land Rights	Kumasi, Ghana (hybrid)	2021	1, 2, 3	Land governance and Land rights	KNUST, NELGA	300
Urban and Landscape Design	Beijing, China (hybrid)	2021	3	Socio-cultural heritage	Tsinghua University	50
Book Edition and Publishing on Sustainable and Smart Spatial Planning	Harare, Zimbabwe (hybrid)	2020	1, 2	Spatial Planning and Education	NELGA Southern Africa	20
Research Development on Responsible Land Management and Land Governance	Zanzibar, Tanzania	2019	1, 2	Land governance	NELGA	15
Research Development on Responsible Land Management and Land Governance	Addis Abeba, Ethiopia	2018	1, 2	Land governance	NELGA and GIZ	30
Research Writing Workshop on Urban and Rural Development	Windhoek, Namibia	2018	1, 2	Spatial planning and Education	NELGA and NUST	12
Research Writing Workshop on Urban and Rural Development	Dar es Salaam, Tanzania	2018	1, 2	Spatial planning and Education	NELGA and Ardhi University	18
Digital Teaching and e-Learning Tools on Responsible Land Management	Kampala, Uganda	2018	2, 3	Land governance and Education	NELGA and EALAN	40
Resilience beyond Emergency	Cholula, Mexico	2018	1, 2, 3	Stakeholder engagement, Environmental risk management and Participatory frameworks	UDLAP	60

[1] 1 stands for Objective 1 "From the Ground Up: Stakeholder Analysis", 2 stands for Objective 2 "Down to the Ground: Policy Review", 3 stands for Objective 3 "Observing the Ground: Geospatial Approach". [2] HIAL stands for Himalayan Institute of Alternatives Ladakh, YILAA stands for Youth Initiative for Land in Africa. NELGA stands for the Network of Excellence on Land Governance in Africa. GIZ stands for the German Agency for International Cooperation. TUM stands for the Technical University of Munich. KNUST stands for Kwame Nkrumah University of Science and Technology. NUST stands for Namibia University of Science and Technology. EALAN stands for Easter Africa Land Administration Network. UDLAP stands for Universidad de las Américas Puebla.

A total of 16 workshops across 11 countries were organised and facilitated during the research journey, encompassing both in-person and online formats, engaging a diverse group of 851 participants, ranging from land professionals to young practitioners, students and farmers. Notably, 13 out of the 16 workshops tool a comprehensive approach by addressing multiple objectives simultaneously. Among the workshops, 13 focused on achieving Objective 1, which emphasised stakeholder analysis and engagement, while 12 workshops centred on Objective 2, delving into policy reviews and implications. Additionally, 7 workshops specifically targeted Objective 3, employing a geospatial approach to analyse land use and its impact on sustainability. The capacity building workshops covered a range of focus areas, with a total of 9 out of 16 addressing multiple themes simultaneously. The diverse topics included participatory frameworks (three workshops), land governance (six workshops), education (six workshops), stakeholder engagement (three workshops), Water–Energy–Food systems (one workshop), land rights (one workshop), socio-cultural heritage (two workshops), spatial planning (three workshops), and environmental risk management (one workshop). By combining multiple focus areas, we ensured a holistic and transversal approach to SLG.

The amalgamation of these results displays the applicability of our proposed SLG framework and underlines it potential to contribute to rural and peri-urban revitalisation and promote sustainable land governance globally. They also contributed to the formulation of the core principles of sustainable land governance for WEF systems.

5. Discussion: Interpreting Transformative Approaches through PAR

This section delves into the transformative potential of participatory approaches by conducting an in-depth analysis of one of the case studies listed in the results section. Focusing on the case study in Rwanda, this analysis aims to comprehensively interpret the outcomes and evaluate the efficacy of the SLG framework. Employing Participatory Action Research (PAR), the study gains deeper insights into how local communities actively contribute to developing holistic and context-specific solutions, thus addressing the complexities of sustainable land governance and WEF systems.

The study explores the impact and lessons learnt from engaging local stakeholders in decision-making processes. Moreover, it presents the core principles for SLG, which have emerged as a result of the research process (encompassing the literature review, the analyses of the 22 master's theses that include policy reviews, interviews with key stakeholders, focus group discussions during the capacity building activities as previously described). The principles have been validated and calibrated across the case studies listed above, providing robust evidence of their effectiveness. In particular, we explore their application in the context of a rural community in Gitaraga, Rwanda, showcasing how these principles align with real-world challenges and opportunities in land governance and WEF systems. This examination serves as a testament to the versatility and transformative potential of the SLG framework in diverse contexts, underpinning its capacity to drive positive changes and foster sustainable development.

5.1. Case Study: Empowering a Rural Community through Climate Smart Agriculture in Rwanda

In this case study, we conducted a rigorous exploration of Land + Water–Energy–Food (LWEF) systems in the rural Gitaraga village in Bugesera District, Rwanda (Figure 1), shedding light on multiple objectives (1, 2, and 3) of the SLG framework.

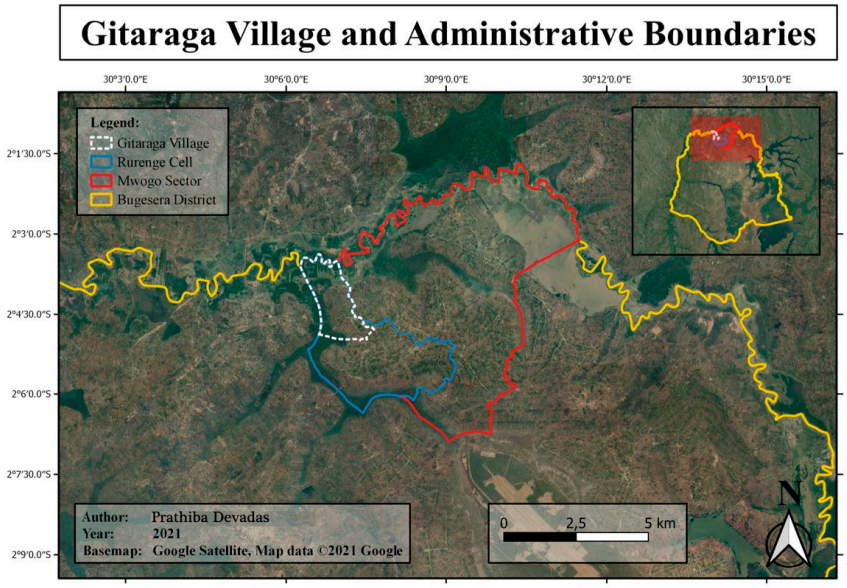

Figure 1. Gitaraga village and Administrative boundaries. Source: Devadas [92].

The case study area, located in the heart of Rwanda, offers a typical representation of the country's diverse landscape and agricultural practices. Nestled within the Central Plateau at an average elevation of 1400 m above sea level, this region is characterised by the presence of volcanic mountains. One of the distinctive features of this landscape is the prevalence of small, scattered land plots, averaging around 0.3 hectares in size, spread across plateaus and hills with varying slope gradients [93]. These land characteristics mirror the broader agricultural practices in Rwanda, where smallholder farming is the norm. Within the mosaic of small-scale agriculture, the intricate interplay of WEF systems becomes evident. Rain-fed agricultural practices, while essential for crop cultivation, introduce challenges related to water availability. After the rainy season, farming plots situated uphill often grapple with water scarcity, affecting not only crop production but also household water supply. This underscores the critical importance of sustainable water management and efficient energy use in pumping and distributing water resources for both agricultural and domestic needs. Furthermore, Rwanda's ambitious development goals, including expanding access to clean energy and improving food security, make the study area a microcosm of broader national efforts. The quest for clean and reliable energy sources to support both rural and urban areas is closely tied to land use decisions. For instance, the extraction of conflict minerals, such as coltan [94] and tin, which are essential for electronic devices and renewable energy technologies, has implications for both land management and energy production. Food security is deeply intertwined with land governance and the efficient utilisation of available resources. The study area's agricultural practices, primarily rain-fed, highlight the need for innovative approaches to enhance agricultural productivity while conserving water resources and promoting sustainable land management.

During our research in Gitaraga, we engaged 48 families of smallholder farmers who willingly participated in a land consolidation project. Land consolidation, a process that involves combining and reorganising fragmented parcels, was implemented to bring together their previously dispersed plots into a more manageable 7-hectare area. This initiative aimed to facilitate improved land use efficiency, agricultural operations, and overall land management [95,96]. To do so, we employed a geospatial approach that harnessed GIS and remote sensing to make informed decisions based on data analysis and spatial information. The geospatial approach consisted of an assessment of the landscape, using GIS to map the scattered land plots held by the participating families. Through the integration of high-resolution satellite imagery and ground-based data collection, we identified the locations of the dispersed parcels and gained insights into the conditions of

the land. We analysed the slope of the terrain, considering the topographical features of each parcel. This analysis helped us identify areas with slopes conducive to Climate Smart Agriculture and irrigation, ensuring that the consolidated land would support efficient farming practices while minimising erosion risks. Furthermore, we assesses soil conditions using geospatial data, allowing us to pinpoint regions with soil profiles suitable for various crops. By factoring in soil fertility and composition, we were able to strategically allocate land parcels based on their agricultural potential, promoting optimal crop selection and yields. In addition to slope and soil assessments, our geospatial approach incorporated an evaluation of land availability and spatial proximity. We used GIS to identify contiguous land parcels that could be seamlessly combined while minimising the need for excessive land clearing or infrastructure development. Remote sensing is being used to monitor land-use dynamics over time, tracking changes in vegetation cover and land productivity. This real-time information ensures adaptability to evolving environmental conditions.

Additionally, we conducted a stakeholder identification, analysis, and mapping process. The identified stakeholder groups include the Rwanda Governance Board, Bugesera's district and local authorities, service providers, capacity building partners, investors/donors, research institutions, site owners, and Gitaraga farmers. Their levels of power and interest, along with their roles in the PAR project (supporter, neutral, blocker), are illustrated in Figure 2.

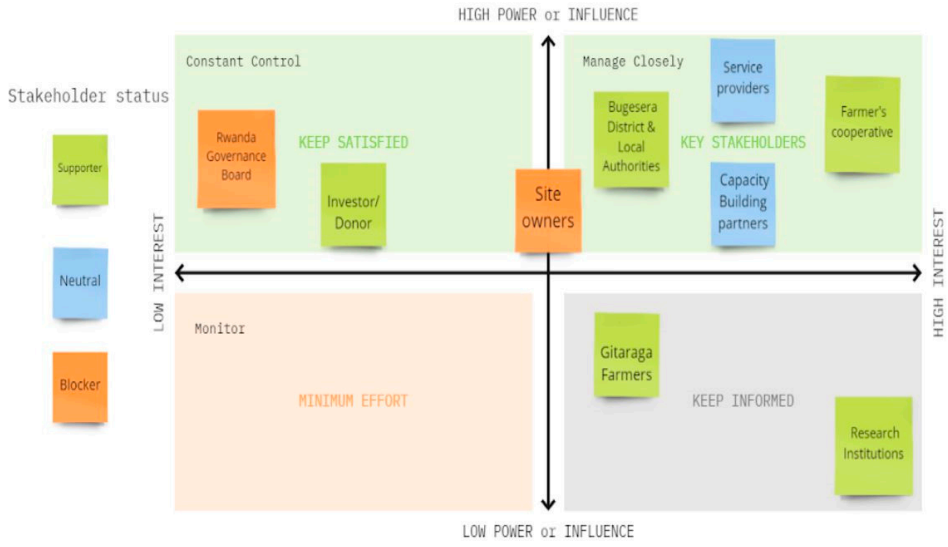

Figure 2. Stakeholder influence matrix. Source: Devadas [92].

To identify and evaluate the needs, gaps, challenges, and requirements of the local community, we performed a needs assessment. This assessment involved collecting primary data through household surveys, using questionnaires containing both open-ended and closed-ended questions regarding sociodemographic characteristics, climate change, population growth, income generation, significant agricultural issues, crop yields, irrigation practises, and baseline data on their lifestyle and economic activities. Furthermore, we conducted focus group discussions and performed field observations to assess plot sizes and land uses. Random and purposive sampling were used to reduce sampling bias. The needs assessment revealed the arduous daily journey farmers undertook to harvest water from the swamp downhill, using 10-L water bottles—making up to 300 trips per day in temperatures reaching 30 °C. The survey indicated that 36% of respondents used diesel pumps for irrigation before the installation of the project, while 33% relied on water cans for watering their crops. Additionally, 53% of the farmers depended on rainwater, and 55% stated that they had never used irrigation methods before.

These aspects highlight the high vulnerability of the region to climate change variability, particularly for smallholder farmers living in these critical agro-ecological zones.

Prolonged droughts and frequent floods exemplify the persistent risk of climate change disasters [97]. However, the presence of a reliable hydrological network consisting of rivers, swamps, lakes and basins provided the foundational resources for the installation of our solar-powered pump, making a significant impact on water availability and crop productivity. In Gitaraga, Climate Smart Agriculture (CSA) [98] practices, in the form of the solar-powered pump, yielded multiple benefits encompassing climate change mitigation, adaptation, and improved food security. The most commonly produced agricultural products included onions, cabbage, tomatoes, sweet potatoes, beans, groundnuts, and other vegetable crops. Cereal crops such a maize and sorghum were the second most commonly produced agricultural products.

For the implementation of the PAR project, the research team focused on various aspects of infrastructure design, planning, implementation, and management of irrigation systems, as well as economic, environmental, and community needs. Advisory meetings were held with the Bugesera district headquarters Directorate of Agriculture and Natural Resources, responsible for CSA and natural resource management. Subsequent meetings with local partners and stakeholders implementing irrigation systems in the area further informed the research. We conducted 48 semi-structured interviews with various respondents, providing each household head a questionnaire. To ensure effective data gathering, enumerators were employed to assist respondents who faced language barriers, as the majority were unable to read or write in English or Kinyarwanda. Furthermore, we conducted 15 focus group discussions with farmers, each involving three to five individuals, and 10 discussions with the entire cooperative of farmers at different stages of the project design and implementations. Additionally, we conducted multiple interviews (over six to seven times) with cooperative leaders, irrigation personnel, and Bugesera district representatives, based on the status and design of the planned irrigation system.

The data were analysed following a thematic method, allowing for the identification of relevant issues and sub-themes in participant's responses. Microsoft Excel version 2016 was the primary tool used in this process, where transcribed text were organised for coding purposes. Passages from the coded transcripts were tracked and collated using Microsoft Excel. An in-depth textual analysis of interview transcripts was conducted to identify recurring themes and patterns. A plausible outcome was the Theory of Change for CSA based on stakeholder engagement and participation (Figure 3).

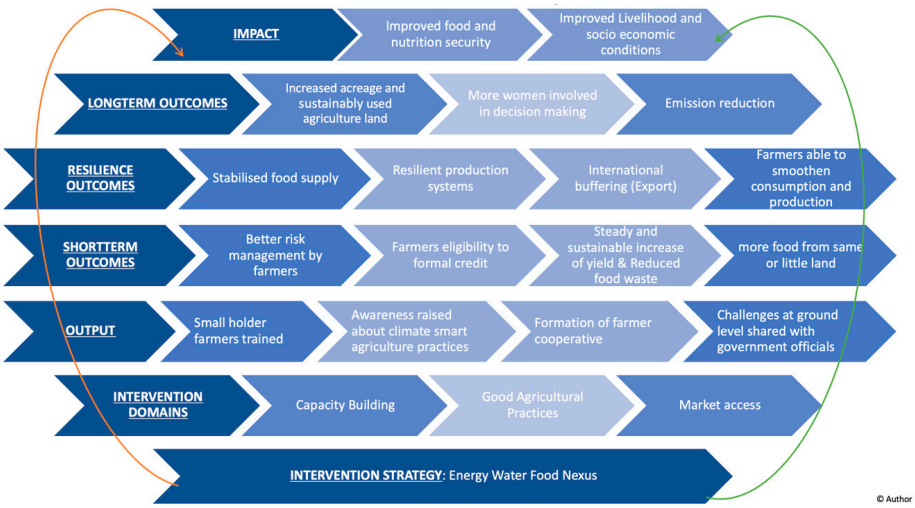

Figure 3. ToC for CSA based on surveys and stakeholder involvement. Source: Devadas [92].

Based on the ToC, a small-scale irrigation project was designed using a mixed methods approach to address the L + WEF interconnections. The farmers gained reliable access to water resources, resulting in increased crop productivity and expanded market opportunities. This transformative project facilitated the transition of smallholder farmers from

subsistence to commercial agriculture, enabling them to cultivate both self-consumption and cash crops (in the form of contractual farming for peppers), even during periods of insufficient rainfall.

The implemented CSA methods and techniques to enhance their agricultural practices improved varieties for higher yields, drought-resistant varieties, legume integration, intercropping, and push-pull crops. Farmers also expressed their engagement with crops varieties tolerant to droughts, pests, and diseases, as well as those that require fewer nutrients and less water, to better adapt to climate changes and variability. Planting dates for these varieties are adjusted throughout the cropping season to accommodate changing rainy season patterns and temperatures, contingent on factors such as credit availability for purchasing seeds and fertilisers. Additionally, incorporating nitrogen-fixing crops like peanuts, legumes and cowpeas was found to improve soil fertility and subsequent crop nutrient supply. Crop diversification over time served as a safety net for farmers' incomes in case one crop was significantly impacted by climate extremes.

Based on the policy review (Table 4), interviews, field observations, and survey data, key recommendations were proposed for the irrigation project's design and implementation in Gitaraga village. Firstly, enhancing access to credit and long-term loans for small farmers is vital to alleviate poverty and boost productivity. Secondly, strengthening agricultural irrigation cooperatives fosters collective responsibility and problem-solving for the community's benefit. Finally, aligning with government policies enables better access to essential approaches to CSA, ensuring improved efficiency and productivity. These recommendations offer valuable insights for a successful and transformative irrigation initiative in the rural region.

Table 4. Policy documents in favour of small-scale irrigation projects implementation. Source: Devadas [92].

Policy Instrument	Approach	Policy Drivers	Policy Initiative/Orientation
National Development Vision & Strategies Vision 2020, Vision 2050 and NSTI 2017	Policy transfer, learning	Global agendas, donor requirements, and practises in the Global North	Promotion of knowledge-based economy, predefined development priorities, vision for Rwandan agriculture
National Policies 2018 National Agriculture Policy and 2011 National Industrial Policy	Policy transfer, learning	Regional plans, sub-regional plans, national plans, and sectoral and cross-sectoral plans	Promotion of agri-technologies, establishment of research programs
Sector strategies Strategic Plan for Agriculture Transformation IV (2018)	Policy transfer, learning and evidence-based policymaking	National priorities and local conditions	Promotion of agriculture technologies, specialised research and technology transfer programs, market diversification
Local strategies 2008 CIP-Crop Intensification and Program and LUC-Land Use Consolidation Act	Policy transfer, learning, and evidence-based policymaking	Donors' requirements, national priorities and local conditions	Promotion of agri-technologies (improved seeds, processing, etc.), community-based technology transfer tools

Although adopting a small-scale irrigation technology has proved to be an effective solution for mitigating the effects of climate change and is contributing to increased income for farmers through the sale of agricultural products, we encountered several challenges during the PAR process. Challenges included identifying relevant stakeholders promoting CSA, their associated technologies, and services. Additionally, the geographical dispersion of stakeholder project villages presented travel difficulties. The language barrier also hindered our effective communication with the community. To overcome this last challenge, we developed and distributed hand-illustrated textless educational comics to

inform community members about the social and economic benefits of the solar-powered pump for irrigation for food security (Figure 4).

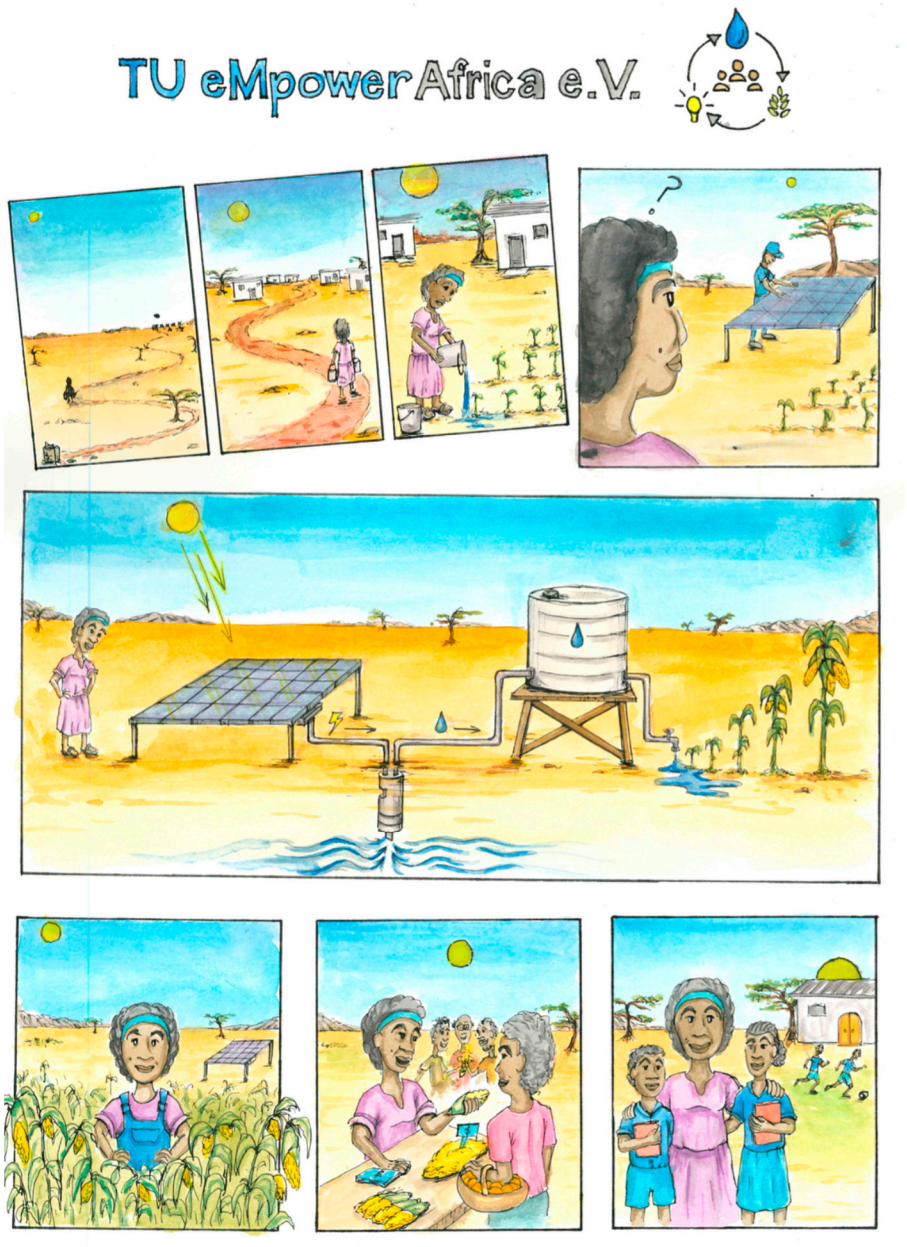

Figure 4. Hand-illustrated textless educational comic for solar-powered irrigation system. Source: TU eMpower Africa e.V., in Devadas [92].

The comics effectively transferred the knowledge without need for verbal communication, though the level of literacy, educational background, and age of the participants influenced the ability to comprehend the information presented. Participants over the age of 50 faced more challenges in understanding and engaging with the material compared to younger and more literate participants. Similarly, those who had not attended school demonstrated difficulty recognising narrative and continuity constraints in the illustrations. These insights underscore the importance of tailoring communication approaches to different stakeholders to ensure effective knowledge transfer and engagement.

Anyhow, all farmers revealed unanimous agreement on the benefits of using pumping systems to enhance crop production and increase their income. Moreover, recognising the potential of small-scale irrigation technology that this PAR proved for Gitaraga village,

the Rwandan government introduced a subsidy program, covering up to 50% of the technology's total cost. Overall, this success story showcases the transformative impact of small-scale irrigation technology, CSA, and participatory methods for sustainable land governance in WEF systems.

5.2. Transformative Insights from Participatory Approaches: Defining the Core Principles of SLG in WEF Systems

The case study in Gitaraga, Bugesera District in Rwanda is a compelling example of how the SLG framework effectively addresses its three core objectives:

Objective 1: "From the Ground Up: Stakeholder Analysis". The case study in Gitaraga demonstrates how to engage the most vulnerable stakeholders in CSA practices through a WEF project, utilising stakeholder identification and analysis as part of the broader strategy to empower the local community. The involvement of 48 families of smallholder farmers, along with interviews, surveys, focus group discussions, and even hand-illustrated textless educational comics, enabled a thorough understanding of stakeholder roles, interests, awareness, and knowledge related to land management and CSA practices. The Theory of Change approach was employed to explore the underlying rationales behind land claims, ensuring a holistic understanding of the local context.

Objective 2: "Down to the Ground: Policy Review". The case study effectively addresses policy review by analysing existing land policies and integrating insights from local stakeholders and land claim reports. Through a categorised literature review and interviews with key stakeholders, the research identifies policy options that align with the needs and perspectives of the local community, which ensures a contextualised and inclusive approach to land governance.

Objective 3: "Observing the Ground: Geospatial Approach". The Rwanda case study incorporates a geospatial approach to gather relevant data on land use, land rights, and land claims. It also dives deep into the geophysical matrix (topography, hydrology), land delimitation and boundaries for land consolidation, and land information systems for the registration of the land under communal tenure. The remotely sensed information was corroborated with field visits to identify potential land conflicts. The geospatial analysis aids in understanding the physical distribution of land resources and informs decision-making regarding land management and sustainable agriculture practices. It was also crucial to design the solar-powered irrigation system.

Furthermore, the case study takes a transversal approach to WEF systems by considering the interconnections and interdependencies among land, water, energy, and food components. In this context, land serves as a bonding element that links these various components together:

Land–Water: The study addresses the challenge of water availability in the Bugesera District, which has a hilly topography and relies heavily on rain-fed agriculture. By implementing a solar-powered irrigation system, the project ensures a more reliable and sustainable water supply for farming activities.

Land–Energy: The traditional practice of using diesel pumps for water irrigation contributes to environmental issues like CO_2 emissions and poses health risks. By transitioning to a solar-powered irrigation system, the project not only reduces greenhouse gas emissions but also provides a sustainable energy solution that is vital for pumping water.

Land–Food: The fragmented land structure in the region has limited farmers' ability to cultivate crops in a synchronised manner, leading to decreased crop productivity and food insecurity. Through land consolidation and the use of solar-powered irrigation, the project enables farmers to improve crop yields and diversify their food production.

In summary, the case study in Rwanda takes a transversal approach to WEF systems by recognising the interactions and synergies between land and other components. The project's emphasis on land consolidation and CSA practices has improved farmers' livelihoods significantly. By increasing agricultural productivity and income from the sale of agricultural products, the project enhances the overall standard of living for the farming

community. This could only be achieved by addressing challenges in water availability, energy use, and food security through sustainable land governance principles with an integrated approach to WEF systems.

By effectively addressing these three objectives and the L + WEF interconnections of the SLG framework, the Rwanda case study demonstrates the framework's utility and potential to guide transformative changes in land governance, supporting sustainable development and improved livelihoods in the region.

5.3. Regulatory Mechanisms Shaping Land Governance for WEF Systems

Land governance within the intricate web of WEF systems is underpinned by a myriad of regulatory mechanisms encompassing legal, institutional, and policy frameworks. These mechanisms play a pivotal role in guiding sustainable and equitable land use practices that harmonise the often complex interplay between land, water, energy, and food resources.

Land Tenure Systems constitute a fundamental pillar of these regulatory mechanisms. By elucidating and safeguarding land ownership, land rights, and land tenure arrangements, these systems ensure secure and equitable access to land resources for diverse stakeholders, including smallholder farmers, indigenous communities, and investors. The assurance of tenure security is paramount in preserving social equity within WEF systems.

Integral to the regulatory framework are Land Use Planning and Zoning strategies. These mechanisms are instrumental in the allocation of land for specific purposes, be it agriculture, urban development, or conservation. Well-structured zoning practices mitigate conflicts over land use, promoting efficient resource allocation within the broader context of WEF systems.

Environmental Regulations form another vital facet of land governance mechanisms. These regulations focus on the environmental repercussions of land use practices. They encompass directives for soil conservation, protection of water quality, and the conservation of biodiversity. Environmental considerations are pivotal in attaining the sustainability goals within WEF systems.

A corollary of land governance in in the domain of Water Rights and Management, especially pertinent in contexts where land and water resources are interlinked. These mechanisms ensure not only the judicious utilisation of water resources for agriculture and energy production but also the protection of aquatic ecosystems.

Energy Policies, often integral to the dynamics of land use, come into play when addressing energy production facilities such as solar farms or hydropower plants. Regulatory mechanisms within the energy sector take into account land requirements and the potential environmental ramifications of energy infrastructure.

Mining Regulatory Mechanisms govern the exploration and extraction of minerals and resources, often intersecting with land use practices. Effective mining regulations seek to mitigate environmental impacts, protect local communities, and ensure responsible resource extraction.

In the realm of agriculture and food security, regulatory mechanisms encompass policies aimed at supporting sustainable agricultural practices, preserving arable land, and fortifying food security. Food Security and Agricultural Policies within the regulatory framework guide land use practices and influence the allocation of land for food production.

Land Registration and Land Information Systems provide the technological infrastructure necessary for transparent and efficient land governance. They are instrumental in documenting land transactions, arbitrating land disputes, and granting stakeholders access to comprehensive land-related information.

Additionally, within the regulatory framework, the protection of Indigenous Land Rights ensure that Indigenous communities retain control over their ancestral lands, preserving their cultural heritage and traditional knowledge. The recognition and protection of Indigenous land rights are integral to fostering sustainable and inclusive land governance within WEF systems.

Moreover, regulatory mechanisms promoting Women's Land Rights are indispensable, as they aim to rectify gender-based disparities in land ownership and tenure. By ensuring equitable access to land for women, these mechanisms contribute to gender equality and empower women as key stakeholders in WEF systems.

Lastly, regulatory mechanisms advocating Community Engagement and Participation are indispensable in the equitable management of land resources. Inclusivity in decision-making processes empowers local communities and ensures that their voices are heard and their interests protected.

These diverse regulatory mechanisms orchestrate the complex interrelationships between land, water, energy, and food systems. Understanding their role and effectiveness is essential for elucidating the dynamics of land governance within WEF systems and, subsequently, fostering sustainable and equitable resource management.

5.4. Core Principles of Sustainable Land Governance for WEF Systems

As demonstrated throughout the research, the proposed framework holds significant implications for addressing the multifaceted challenges arising from competing land uses and the interplay of these resources. It aims to facilitate the crucial task of balancing the diverse demands placed on land, such as agriculture, renewable energy installations, and mining activities [25,99]. By seeking a harmonious equilibrium among these uses, the SLG framework strives to avert conflicts and optimise the benefits of each sector, while safeguarding the integrity of the environment. Furthermore, the SLG framework plays a pivotal role in enhancing policy coherence by seamlessly integrating policies across the domains of land, water, energy, and food in both rural and peri-urban regions [100]. This integration ensures that decisions taken in one sector do not undermine objectives in another, thereby fostering more effective and sustainable outcomes [101]. By predicting (and consequently preventing) potential contradictions between policies, the SLG framework facilitates a comprehensive approach to resource management, reducing redundancy, and increasing policy impact in rural and peri-urban contexts.

Moreover, the SLG framework promotes a culture of empowerment in both rural and peri-urban settings by prioritising participatory approaches. By engaging local communities, stakeholders, and experts from diverse backgrounds in the decision-making process, the framework ensures inclusivity in governance. Diverse perspectives and interests are considered, leading to the development of context-specific solutions that are both socially acceptable and environmentally responsible [102,103]. This inclusive governance structure strengthens social cohesion and promotes equitable development, ensuring that the needs and aspirations of all stakeholders in both rural and peri-urban areas are acknowledged and addressed. Finally, the SLG framework underscores the significance of ecosystem considerations in sustaining the delicate balance of land, water, energy, and food systems. By adopting ecosystem-based approaches into decision-making processes, the framework prioritises biodiversity conservation, enhancement of ecosystem services, and bolstering resilience against environmental changes [104–106].

Hence, the SLG framework's significance lies in its capacity to navigate competing land uses, foster policy coherence, empower stakeholders, and prioritise ecosystem considerations in both rural and peri-urban contexts. By embracing these fundamental principles, the SLG framework provides a robust structure for enhancing sustainable land governance and promoting rural and peri-urban revitalisation in the context of complex and interconnected WEF systems.

The multidimensional approach of the research, encompassing the literature review of existing frameworks, policy analyses, expert consultations, capacity building workshops, and case study findings based on the master's theses and PAR, allows for a comprehensive and evidence-based identification of the core principles that underpin the proposed SLG framework, presented in Table 5. The core principles of the SLG framework have been tested and refined across case studies to ensure their relevance, applicability, and effectiveness in

promoting sustainable land governance and addressing the challenges presented by the interconnections between land, water, energy, and food systems.

Table 5. Core principles of the sustainable land governance for Water–Energy–Food systems (SLG) framework.

Core Principle	Definition and Purpose
Transversality	Recognises and addresses the interconnectedness of land, water, energy, and food systems. By promoting integrated strategies that transcend sectoral boundaries, transversality ensures that policies and interventions consider the interdependencies between these systems, leading to more holistic and effective resource management.
Sustainability	Ensures the long-term sustainability of land resources and ecosystem services. It advocates for a balance between meeting present needs and safeguarding the needs of future generations. By considering ecological health and biodiversity, sustainability emphasises responsible land use practices that do not compromise the well-being of future generations.
Inclusivity	Emphasises the active engagement of stakeholders at all levels of governance. By empowering local communities and marginalised groups, inclusivity promotes social equity and ensures that decision-making processes incorporate the needs and priorities of all stakeholders, including the most vulnerable population.
Adaptability	Recognises that solutions for land governance should be flexible and tailored to specific socio-cultural, economic, and environmental contexts. It acknowledges the diversity of challenges and opportunities across different regions and encourages adaptive approaches that can respond effectively to changing conditions.
Evidence-Based Decision-Making	Emphasises the importance of data-driven policies and interventions. By drawing on sound research, participatory action, and geospatial analysis, decision-makers can make informed choices that are more likely to result in positive and impactful outcomes.
Policy Integration	Seeks to encourage collaboration and coherence across the land, water, energy, and food sectors. Integrated policies enable synergies between these sectors, avoiding conflicting objectives and promoting a holistic approach to resource management.

The core principles of the sustainable land governance for Water–Energy–Food Systems (SLG) framework work together synergistically to enhance rural and peri-urban revitalisation. Through their integrated and adaptable approach, these principles empower local communities, promote sustainable land use practices, and ensure evidence based decision-making, all contributing to the overall well-being and transformation of rural and peri-urban areas. By adhering to its core principles, the SLG framework can guide policymakers, researchers, and practitioners in developing comprehensive and context-specific strategies that support resilient and equitable development.

6. Conclusions: Implications and Opportunities for SLG

This research introduces a novel sustainable land governance (SLG) framework, focusing on rural and peri-urban revitalisation within Water, Energy, and Food (WEF) systems. We uncovered the intricate connections between land and WEF elements, emphasising land's pivotal role. The SLG framework embodies three core objectives: top-down, bottom-up, and geospatial approaches, culminating in six core principles—transversality, sustainability, inclusivity, adaptability, evidence-based decision-making, and policy integration. We have tested and refined these elements through 22 master's theses, 16 capacity-building workshops, and 6 participatory action research projects across diverse global contexts.

- Land as the Bonding Element: Unveiling the Interconnections with WEF Systems (L + WEF)

Through the exploration of the dynamic interplay between land and the elements of WEF systems, this research shed light on the critical relationships that underpin rural and peri-urban revitalisation. The case study in Rwanda served as a remarkable example of how land, as a foundational element, intricately interacts with water availability, energy utilisation, and food production. By implementing sustainable land management practices, such as solar-powered irrigation systems and participatory land use planning, we observed tangible impacts on water resources, crop productivity, and food security. The in-depth analysis of these interconnections deepens the understanding of how integrated strategies can foster resilience, ensure sustainable resource management, and strengthen land governance.

- Unlocking the SLG Framework: The Three Core Objectives

The SLG framework thrives on three core objectives: bottom-up, top-down, and geospatial approaches.

From the bottom-up: We connected with local stakeholders, from smallholder farmers to Indigenous groups, gathering insights through interviews, surveys, and focus group discussions. This grassroots approach uncovered their unique views, needs, and land governance challenges.

Down to the ground: We conducted a comprehensive policy review across Global South case studies. This systematic analysis revealed policy gaps, inconsistencies, and best practices. Through interviews with policy-makers, government officials, and experts, we assessed how well national and regional governance aligned with sustainable land management.

Observing the ground: This approach provided a spatial perspective using advanced tools like GIS and remote sensing. It helped visualize complex land dynamics, including land use changes, resource distribution, and areas at risk of degradation. This spatial insight informed evidence-based decisions and targeted interventions.

By blending these three objectives, our framework grounded recommendations in solid evidence. The bottom-up approach ensured inclusivity and responsiveness to local contexts. Top-Down alignment with policies and regional strategies added breadth. The Geospatial dimension offered a precise understanding of land's role within broader systems. Integrating evidence from these diverse methods empowered us to tackle real-world challenges within context-specific, sustainable solutions.

- Revealing the Core Principles of SLG

The SLG framework is underpinned by a set of core principles meticulously formulated through a comprehensive and multi-faceted research approach. Drawing insights from a rigorous literature review of existing international frameworks, policy analyses, and stakeholder engagements, we carefully identified and designed the principles of transversality, sustainability, inclusivity, adaptability, evidence-based decision-making, and policy integration.

- Concluding Reflections

In wrapping up our research, we want to emphasise the significance and innovative nature of the SLG framework in the context of rural and peri-urban revitalisation. While international frameworks offer vital guidance, the distinct strength of the SLG framework lies in its multi-level governance approach. This approach bridges the gap between high-level policy goals and practical on-the-ground actions, injecting global guidelines with context-specific strategies that resonate with local realities.

By tailoring our methods to specific socio-cultural, economic, and environmental conditions, the SLG framework adeptly addresses the diverse complexities of land governance challenges. We have carefully crafted a theoretical framework supported by methods

aligned with our three core objectives. This alignment ensures the SLG framework can effectively address intricate land governance issues while promoting sustainable transformations.

- The versatile SLG framework

The adaptability of the SLG framework has proven transformative, transcending traditional governance boundaries. Its interdisciplinary and inclusive approach ushers in an era of holistic resource management, seamlessly integrating land, water, energy, and food systems. Through active engagement with stakeholders at all governance levels, including local communities and marginalised groups, the SLG framework empowers previously unheard voices, reinforcing social equity and amplifying our research's impact.

- Recommendations for future research

This research represents a crucial step advancing the SLG framework, and we encourage future studies to build upon our findings and expand its application. Further research into adapting SLG principles to diverse socio-cultural and geographical contexts, implemented by land management practitioners beyond academia, would enhance its versatility and impact. Additionally, conducting longitudinal studies to assess the long-term effects of SLG interventions on community well-being and ecological health could provide valuable insights.

Moreover, further research on financial mechanisms to systematise the implementation of participatory action research projects would benefit local communities, policy-makers, and researchers alike. Collaboration with other relevant frameworks could uncover synergies and optimise resource management efforts. Ultimately, we envision the SLG framework as a catalyst for transformative change, making significant strides toward Sustainable Land Governance and rural and peri-urban revitalisation worldwide.

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