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Congratulatory Remarks

Distinguished scholars and scientists, ladies and gentlemen,

I would like to thank all the participants for their academic interests and efforts in helping to make this conference a fruitful one, especially those who have participated remotely and taken valuable time from their very busy schedules to attend this international conference. As the President of the Unification Thought Institute International, I am expected to play a key role in accomplishing the ideal of uniting sciences based on unification thought. Permit me to give a few remarks on the unity of sciences and unification thought.

In recent centuries, science has had astonishing success in providing explanations of a wide range of natural phenomena. Such is this success that it would seem to be foolish and reactionary to resist the physical claims that eventually all phenomena, including even the most subtle of human thoughts and actions, will be completely explained scientifically.

Concerning the movements for the unity of science, we know scientists have tried to carry out the task of accomplishing the ideal of science for a long time. To sum up the history of that movement, the first attempt to realize the ideal of the unity of sciences along with developing science was the movement of the school of encyclopedia based on the philosophy of the Enlightenment in 17th-century Europe. They compiled an encyclopedia based on the empirical philosophy of the Enlightenment and mechanical materialism, the predecessor of the Encyclopedia Britannica, and are enhancing its reputation even today.

The second attempt was the unity of science movement centered on the Vienna Circle in the 1930s. The Institute for the Unity of Science was set up on this basis. Its slogan, "unity of science," was created by the living dynamo, Neurath [Otto Neurath, 1882–1945], and was taken up by other members, in particular Carnap [Rudolf Carnap, 1891–1970], Reichenbach [Hans Reichenbach, 1891–1953], Hempel [Carl Gustav Hempel, 1905–1997], Frank [Philipp Frank, 1884–1966], physicist Bridgman [Percy Williams Bridgman, 1882–1961], biologist Wald [George Wald, 1906–1997], statistician von Mises [Richard von Mises, 1883–1953], logician Quine [Willard Van Orman Quine, 1908–2000], psychologist Skinner [B. F. Skinner, 1904–1990], the young linguist Noam Chomsky [Noam Chomsky, b. 1928], and various sympathizers of logical empiricism in England, Germany, Austria, Poland, France, and the United States.

They began publication of the International Encyclopedia of Unified Science, which laid the foundation for a new methodologically unified approach to cognitive assertion in general.

Their original thesis of the unity of science was based on the belief that all scientific concepts are definable, in the strictest sense, in the language of sense data, by terms belonging exclusively to the positivistic language, namely, physical language. Carnap originally formulated the thesis of extensionality as one of the main theses of the unity of sciences.

Today, the claims of the Vienna Circle look rather naive. Most of the logical empiricists came to realize that most terms in scientific theories are neither definable by nor reducible to the so-called positivistic language. The Institute for the Unity of Science has recently dissolved. That its aims have been achieved might well be doubted. The original positivist manifesto has been abandoned.

Contrary to positivism, unification logic, or unification thought, recognizes the a priori sphere of the subjective condition as the foundation for the possibility of positive experience and as the control of all empirical conditions. Accordingly, from the viewpoint of unification logic, the foundation for proper science can begin with neither empirical positivity alone nor subjective a priori alone. It is unification logic, which is being promoted as an alternative to formal logic, which was invented by Aristotle and has been the basis of most academic endeavors.

Unification thought intends to systemize sciences in an appropriate order. Unification thought is presented as a system that can offer a solution to the confusion affecting the human sciences and social sciences, the natural sciences, and the arts. The unity and harmony which it brings to the various theories competing in this field must be based on fundamental principles of the universe. Finally, Unification Thought aims to realize a world in which all humankind can serve God as one great family and bring about a peaceful world.

Thank you very much.

Dr. Jin Sung Bae
Chairman of HyoJeong Academic Foundation

Congratulatory Remarks

Distinguished guests, ladies and gentleman, good morning.
I am Moon Sung-jae, President of Sun Moon University.
It is my great pleasure to offer my heartfelt congratulations on the opening of the 7th International Conference of Hyojeong Academy.
I would like to express my deepest respect and gratitude to Dr. Pyun Young-sik for his dedicated efforts in preparing this conference. I also extend my sincere thanks to the co-chairs of the organizing Committer of the 7th international conference of Hyojeong Academy: Dr. Takahiro Hiroi, Dr. Chul-Hee Han, and Dr. Kazuhiro Aoki. The discussions at this international conference, centered around the theme of "Coexistence, Co-prosperity, and Universal Values," embody our shared commitment to realizing a peaceful ideal world where all of humanity lives together as one family.
Distinguished guests, ladies and gentlemen, I kindly ask that this conference serves as a meaningful platform to explore new values and practical solutions for the sustainable prosperity and peace of humankind.
I would also like to express my gratitude to all the scholars presenting their research for their valuable participation and hard work, and I wish this conference every success. May heavenly blessings be with all of you in attendance today.

Thank you very much.

Dr. Moon Seong-Jae
President of Sun Moon University

Section 1

Universal Values and Unity of Sciences

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Beyond SMART: A Holistic Ecological Framework for Goal Achievement: Integrating Cognitive, Axiological, and Systemic Dimensions of Human Creation

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Abstract: Despite the prevalence of goal-setting frameworks in management literature, failure rates for complex, long-term objectives remain high. Traditional models (e.g., SMART, OKRs) predominantly focus on cognitive specificity and output measurement, often neglecting the systemic, emotional, and axiological dimensions of human agency. This conceptual paper introduces the **Holistic Ecological Framework of Creation**. We propose that sustainable goal achievement is a function of: (1) Cognitive-Behavioural Alignment, (2) Social Resource Integration, (3) Generative Interaction, (4) Axiological Resonance, (5) Systemic Stakeholder Equilibrium, (6) Adaptive Capacity Building, and (7) Dynamic Feedback Sensitivity. These universal principles are drawn from the ontological structure of the first chapter of the Divine Principle—namely the Principle of Creation—and parallel insights from Aristotelian teleology and Systems Theory. We argue that these "7 Principles of Creation" are not merely religious tenets but observable phenomenological laws of high-performance human agency. The framework exposes two critical insights. First, it systematizes the implicit logic of common sense into a rigorous structure. Second, it establishes an ontological constancy: the fundamental principles of goal achievement remain unchanged regardless of the task. As complexity rises, success depends not on new mechanisms, but on a deeper, more conscious application of these seven principles.

Keywords: Goal Setting Theory, Holistic Management, Axiology, Systems Theory, Unification Thought, Organizational Behaviour, Management Practice, Human Resources, Values, Eastern Philosophies

1. Introduction

For decades, the landscape of goal-setting literature has been dominated by the mechanistic paradigms of the industrial age. Locke and Latham's Goal Setting Theory [1] established the gold standard, demonstrating that specific, difficult goals lead to higher performance, while frameworks like SMART [2] provided the tactical checklist for execution. While these models excel at defining *what* the goal is, they often fail to address the complex, human ecosystem of *how* creation actually occurs. They tend to treat the goal-setter as a solitary cognitive processor, isolated from their emotional depths, their social ecology, and their need for transcendent meaning.

Despite the prevalence of these frameworks, failure rates for complex, long-term objectives remain high. In an era characterized by "quiet quitting" and a global crisis of workplace engagement, there is an acute need for a framework that honours the human search for meaning. This paper proposes the Holistic Ecological Framework of Creation. The framework derives seven secular constructs directly from the outline of the Principle of Creation. These

"7 Principles of Creation" are not merely religious tenets but observable phenomenological laws of high-performance human agency. By highlighting these principles, this framework moves beyond the mechanics of production to address the mysteries of existence, bridging the divide found in modern management theory.

2. Literature Review and Theoretical Background

Contemporary goal-setting scholarship is dominated by two strands: formal prescriptive heuristics (like SMART) and theoretically driven psychological models (Goal-Setting Theory, Self-Efficacy, Self-Determination Theory). While each makes contributions regarding specificity and effort intensity, they share blind spots regarding the systemic interactions required for long-term attainment.

2.1. Critique of Dominant Models

Locke and Latham's theory [1] is primarily an individual-level, task-motivational account. It explains how "what is set" changes effort, but pays less attention to the broader ecology—including bodily embodiment and stakeholder dynamics. Similarly, the SMART heuristic [2], while practical, creates brittle systems. Recent empirical work suggests SMART goals do not always outperform open goals, particularly in domains requiring creativity [3]. Practically, SMART tools emphasize measurability but omit the developmental processes and values alignment necessary to sustain goals when ambiguity arises.

2.2. Self-Efficacy and Self-Determination Theory (SDT)

Bandura's self-efficacy [4] introduced the crucial element of belief in one's capability. However, efficacy remains an intra-psychic resource; it reduces the question to "Will I do it?" rather than "How will my network and meaning-system support the doing?". SDT [5] extends this by identifying basic needs for autonomy, competence, and relatedness. Yet, SDT generally treats relatedness as a psychological feeling of support rather than a structural resource ecology. It addresses why people are motivated but stops short of specifying the multi-level system dynamics that amplify or extinguish that motivation.

2.3. The Management, Spirituality, and Religion (MSR) Shift

A growing body of scholarship argues that performance-driven models insufficiently account for the human search for existential coherence. MSR research reframes the worker as a meaning-seeking agent whose energy is tied to narrative coherence and values alignment. Mitroff and Denton's foundational study [6] revealed that employees across industries express a desire for work that feels intrinsically worthwhile and connected to something greater than themselves. However, most spiritual leadership models still operate at the level of leadership style or psychological states, rather than embedding spirituality into a wider ecological system of goals, resources, and embodied enactment. The Holistic Ecological Framework builds on these advances by conceptualizing meaning not as an isolated variable, but as a systemic, energizing principle.

3. The 7 Principles of Creation

The Holistic Ecological Framework posits that the fundamental principles of human agency remain consistent across time and scale. The framework operationalizes common sense into a rigorous seven-step heuristic.

3.1. Cognitive-Behavioural Alignment (The Principle of Mind and Body Unity): What is my goal, and is my body ready to move?

Definition: A dual state of congruence consisting of Unambiguous Teleological Vision (Cognitive Clarity) and Executive Behavioural Readiness (Embodied Action).

Traditional theory emphasizes cognitive clarity (vision), but the proposed framework argues this is insufficient without somatic readiness. Drawing from Implementation Intention research by Gollwitzer [7], mere intention is less effective than an aligned state where a cognitive plan is linked to a specific behavioural cue. In the absence of this alignment, goal pursuit remains trapped in cognition. The mind may have a clear vision, but if the body is not prepared to execute specific actions, the result is "action paralysis".

Proposition 1: The relationship between Goal Intention and Goal Performance is moderated by Cognitive-Behavioural Alignment. High Goal Specificity (Vision) will only predict high Performance when paired with high Executive Readiness (Embodied Implementation Intentions).

3.2. Social and Material Resource Integration (The Principle of Dual Characteristics—of Diverse Contributions): What resources and people might help me achieve this?

Definition: The structural identification and acquisition of a heterogeneous ecology of assets—human capital, material infrastructure, and political authority—required to bridge the gap between capability and requirements.

This is the static/architectural principle. Significant goal achievement is rarely a solitary event; it requires integrating diverse contributions. This aligns with Social Capital Theory [8], which argues that who you know provides access to resources that what you know cannot. This involves:

- Human Resource Ecology: Integrating diverse viewpoints to overcome bounded rationality.
- Material Ecosystem: A rigorous audit of physical tools and funding.
- Vertical Integration: Securing political sponsorship to unlock resources.

Proposition 2: Social Resource Integration moderates the relationship between Task Complexity and Goal Achievement. As complexity increases, the effect of individual capability diminishes, while the effect of Resource Heterogeneity increases.

3.3. Generative Interaction (The Principle of Give-and-Take Action—of Dialogue—to Generate Energy): What are the proximal steps and communication strategies that will generate momentum?

Definition: The dynamic process of communicative exchange that converts latent resources into kinetic momentum through energy-generating dialogue and the decomposition of distal goals into proximal small wins.

While Principle 2 provides the "network," Principle 3 provides the "engine". It moves beyond communication as information transfer to communication as energy generation. This relies on High-Quality Connections (HQC) [9], where distinct forms of interaction generate relational energy. This includes "Reflexive Dialogue" (values clarification), "Strategic Dialogue" (alignment), and "Affective Dialogue" (psychological safety). Crucially, this principle involves breaking large goals into "small wins" [10] to unify the team and create a sense of progress, which Amabile and Kramer [11] identify as the strongest driver of motivation.

Proposition 3: Generative Interaction mediates the relationship between Resource

Integration and Perceived Progress. Possession of resources does not predict velocity; the appropriate use of energy-generating communication does.

3.4. Axiological Resonance (The Principle of Love and Beauty): Why am I doing this? How does this align with Truth, Goodness, or Beauty?

Definition: The extent to which a goal aligns with the agent's intrinsic orientation toward the Transcendentals—Truth, Goodness, and Beauty—functioning as a renewable, internal source of motivational energy.

Standard motivational theories are transactional ("I do X to get Y"). This framework suggests that when a goal aligns with Truth (validity), Goodness (ethics), or Beauty (aesthetic harmony), it becomes autotelic. Meaning is not an incidental preference but an ontological requirement. This echoes Fry's Spiritual Leadership Theory [12] and Benefiel's work on organizational transformation [13], which link vision and altruistic love to intrinsic motivation. Goals that lack this resonance risk becoming instrumental and emotionally inert. Without the "metaphysical why," the system lacks its internal fuel tank.

Proposition 4: Axiological Resonance moderates the impact of External Adversity on Goal Persistence. Individuals with high Transcendental Alignment will exhibit significantly lower attrition rates under difficulty than those motivated by utility.

3.5. Systemic Stakeholder Equilibrium (The Principle of Being the Centre of Harmony): Who do I need to respect to maintain harmony?

Definition: The homeostatic management of goal pursuit within a broader social ecology, ensuring resource extraction does not violate the support thresholds of key stakeholders, thereby preventing systemic recoil.

This construct draws from Stakeholder Theory [14] and Work-Family Enrichment Theory [15]. Goal setters act as nodes in a network. A common failure mode is sub-optimization, where success in one area (e.g., career) destroys the supporting system (e.g., family). If the goal extracts too much energy without returning value, the network withdraws support. This applies equally to macro-economic supply chains; extracting value from suppliers without fair return creates systemic recoil. Sustainable creation requires a resource-respecting strategy.

Proposition 5: There is an inverted-U relationship between Goal Intensity and Long-Term Goal Viability, moderated by Systemic Stakeholder Equilibrium. High-intensity pursuits that violate stakeholder thresholds will experience Systemic Recoil.

3.6. Adaptive Capacity Building (The Principle of Personal Growth): What do I need to learn to achieve this task?

Definition: The deliberate integration of learning goals alongside performance goals, creating a dual-process mechanism where the agent actively upgrades internal competencies to match the objective.

Personal growth is not a byproduct but a prerequisite creation principle. This aligns with Dweck's [16] distinction between Learning and Performance goals. In complex environments, setting specific performance goals can induce anxiety and tunnel vision; setting learning goals leads to superior outcomes [17]. This mirrors the Dynamic Capabilities framework [18]. Agents must conduct a "Competency Audit" and engage in Deliberate Practice [19] to identify and fill missing skills.

Proposition 6: In high-uncertainty environments, goals framed with a Learning Orientation

(Adaptive Capacity) will outperform goals framed strictly as Performance Outcomes.

3.7. Dynamic Feedback Sensitivity (The Principle of Vitality Elements): How can I learn from my successes and mistakes in real-time?

Definition: The cybernetic control loop through which an agent continuously harvests "vitality elements" (energizing data) to reduce the discrepancy between the mental map and reality.

This principle is grounded in Control Theory [20], representing the feedback loop seeking to reduce discrepancy. It prevents the "planning fallacy" and "escalation of commitment". Without frequent, energizing feedback, the mental map diverges from the physical territory, and Cognitive-Behavioural Alignment degrades. Importantly, feedback must be vitalizing; meta-analytic reviews [21] indicate that poorly calibrated feedback interventions can actually decrease performance.

Proposition 7: The relationship between Goal Specificity and Performance is mediated by Feedback Sensitivity. Highly specific goals without appropriate feedback loops increase the risk of escalation of commitment to a failing course of action.

4. Discussion and Theoretical Implications

This paper shifts the paradigm from "Creation Dynamics" to "Creation Ecology". We argue that humans are not merely achievers but creators. The integrative structure of the framework demands that all seven principles be present; when one is weak, the system develops fault lines.

The model integrates findings that have historically been siloed. Locke and Latham [1] established the necessity of Specificity (Principle 1); Bandura [4] identified Self-Efficacy (Principle 6); SDT [5] illuminated Relatedness (Principles 3 and 4). The Holistic Ecological Framework proposes that these are not competing theories but distinct dimensions of a unified ontological act.

5. Practical Application: Diagnosis and Intervention

The Holistic Ecological Framework provides a diagnostic map that transcends the traditional managerial focus on strategy and effort. Because the "7 Principles" are derived from the ontological structure of human agency itself, the model possesses high transferability across the spectrum of human activity—from organizational strategy to personal development.

5.1. Implications for Organizations: Measuring the Health of the Creation Process

Perhaps the most transformative implication is the shift from measuring only output to assessing the health of the creation process itself. Outputs are often downstream lagging indicators of deeper systemic dynamics. By evaluating goal pursuits through the lens of the seven principles, organizations can identify fragilities early, mitigate burnout cycles, and cultivate environments where goals are pursued with vitality rather than depletion.

Consequently, we propose that organizations adopt a "Process Health Dashboard." This instrument would integrate indicators such as learning trajectory (Principle 6), relational vitality (Principle 3), stakeholder equilibrium (Principle 5), and meaning alignment (Principle 4) alongside traditional financial KPIs. This approach ensures that high performance is achieved sustainably and humanely, fostering long-term flourishing.

5.2. Implications for Organizations: Reframing Performance Reviews

The framework suggests a fundamental restructuring of performance management. Reviews should pivot from purely retrospective metric analysis ("Did you hit the target?") to diagnostic inquiry regarding the agent's ecosystem.

A process-based review would utilize questions such as:

- *Social Integration:* "Who did you collaborate with to bridge capability gaps?" (Principle 2).
- *Adaptive Capacity:* "What specific competencies did you acquire during this cycle?" (Principle 6).
- *Axiological Resonance:* "In what ways did this goal align with your sense of meaning or values?" (Principle 4).

This shift transforms performance management from a compliance exercise into a shared diagnostic process. It enables leaders to identify whether underperformance is a failure of volition or a failure of the supporting ecosystem, allowing for highly personalized employee and leadership development.

5.3. Implications for Teams: Project Alignment and Management

We suggest that the framework be integrated into the project lifecycle from the initiation phase. By explicitly discussing the seven principles during kick-off, teams can align their "whole person" capabilities with the task at hand. This acts as a preventative alignment mechanism. Rather than waiting for friction to emerge, teams can proactively map their Social Resources (Principle 2) and agree on Generative Interaction protocols (Principle 3). This ongoing dialogue allows for agile modifications across the life of the project, ensuring that the team remains a "centre of harmony" rather than a source of entropy.

5.4. Implications for Teams: Forensic Project Analysis

When projects fail or underperform, the framework provides a rigorous heuristic for forensic analysis. Instead of generic attributions of blame, teams can pinpoint the specific ontological fracture.

For example, a post-mortem might reveal:

- *Axiological Resonance Deficit:* Was the goal framed solely as cost reduction, neglecting the human need for craftsmanship or innovation (Truth, Goodness, and Beauty)?
- *Systemic Disequilibrium:* Did the intensity of the timeline violate the resource thresholds of the team's external stakeholders (family, health), leading to predictable "systemic recoil" in the form of resignations?

5.5. Implications for Universal Systems

Because the framework asserts ontological constancy—that "humans are always being human"—its application extends to all dyadic and social systems, including marriages, non-profits, and civic institutions.

For instance, a marital unit functions as a goal-achieving system that requires the same equilibrium as a corporate team: mutual respect (Systemic Equilibrium), the creation of shared beauty (Axiological Resonance), and dialogue that generates rather than drains energy (Generative Interaction). Reflection on these principles enhances the agency of any actor, regardless of the context.

5.6. Wider Sociological and Spiritual Implications

Because goal setting is such an intrinsic part of human life, our model has implications for many fields of study. For example, the model engages with the theological and philosophical discourse regarding the nature of human agency. While theologians have debated the extent of the "fall of man," our model suggests that the structural capacity for creation—the ability to utilize these common-sense principles—has always remained intact.

The seven principles appear to be embedded in the "subconscious" of the universe; they are accessible mechanisms that yield results for agents of both benevolent and malevolent intent. However, the framework helps explain the eventual collapse of malevolent goals. When intentions are corrupt, they inevitably violate Principle 4 (distorting Truth and Goodness) and Principle 5 (disregarding stakeholder well-being). These violations eventually trigger systemic correction or collapse, suggesting that sustainable creation is inextricably linked to ethical alignment and inner personal well-being.

5.7. Limitations and Future Research

The framework is currently grounded in ontological reasoning and lacks empirical validation. Future research should operationalize the seven principles using established scales (e.g., Work-Family Enrichment Scale [15], Work and Meaning Inventory) to test the proposed mediation and moderation effects. Additionally, the framework's universal claims must be tested across different cultural contexts, where constructs like Axiological Resonance may be interpreted differently.

Table 1. Proposed Instrumentation for Empirical Validation

Principle	Core Construct	Recommended Measurement Scale	Rationale for Selection
1. Cognitive-Behavioural Alignment	Implementation Intentions & Clarity	Implementation Intentions Scale [6] + Goal Specificity Scale [1]	Captures the dual necessity of mental clarity (Vision) and the behavioural "if-then" plans (Readiness) described in the framework.
2. Social Resource Integration	Network Diversity & Capital	Resource Generator Scale [22] or Bridging Social Capital Scale [23]	Measures the *access* to heterogeneous resources (human and material) rather than just the feeling of support.
3. Generative Interaction	Relational Energy	Relational Energy Scale [24] or High-Quality Connections [25]	Assesses the *kinetic* quality of the interaction—specifically whether communication generates vitality—distinguishing it from simple information transfer.
4. Axiological Resonance	Meaning & Transcendentals	The Work and Meaning Inventory (WAMI) [26]	Explicitly measures Positive Meaning, Contribution to Greater Good, and Meaning Making, aligning with the constructs of Truth and Goodness.
5. Systemic Stakeholder Equilibrium	Work-Life Harmony	Work–Family Enrichment Scale [15]	Measures the extent to which resources generated in one domain improve (rather than deplete) the quality of life in another, serving as a proxy for equilibrium.
6. Adaptive Capacity Building	Learning Orientation	Learning Goal Orientation Scale [27]	Differentiates between the desire to *develop* competence (Adaptive Capacity) versus the desire to merely *demonstrate* it, capturing the growth mindset.
7. Dynamic Feedback Sensitivity	Feedback Seeking & Loop	Feedback Seeking Behaviour Scale [28] or Meta-Cognitive Experience Scale [29]	Measures the active solicitation of environmental data (Vitality Elements) required to correct the planning fallacy.

6. Conclusion

As organizations increasingly seek to address the whole person, the limitations of mechanistic goal-setting models become starker. This paper has argued that human achievement is not a linear manufacturing process but a complex ecological act. By integrating the seven principles of the Holistic Ecological Framework—Cognitive-Behavioural Alignment, Social Resource Integration, Generative Interaction, Axiological Resonance, Systemic Stakeholder Equilibrium, Adaptive Capacity Building, and Dynamic Feedback Sensitivity—we offer a path that honours both the mechanics of execution and the mysteries of human agency. We invite scholars and practitioners to test this model, moving the field closer to a theory of goal setting that is as sustainable as it is effective.

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A UNIFIED VIEW OF HUMAN ORIGINS How Religion and Science Can Complement Each Other

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Abstract: While the contents of the Divine Principle—the new truth for the Completed Testament Age to come—are mainly religious and spiritual, the teaching does have some scientific implications. As Father emphasized, the DP is an expression of Truth that can be improved on over time. In this study, we see how evolution on Earth looks like when both the insights of the DP and Darwin's concepts are constructively blended together in a Unified View of Evolution. It will, naturally, challenge somewhat both current religious and scientific concepts. Examples being, for science; sophisticated biological laws; for religion, spiritually-guided hominin parents for Adam and Eve.

Keywords: Religion, Science, Unity, Human, Evolution

1. Introduction

In the Divine Principle overview of the last 500 years of Preparation-for-the-Messiah history, there is talk of Hebraism and Hellenism, of religion and science, merging into a unified view of reality.

> *"Religion and science, each in their own spheres, have been the methods of searching for truth in order to conquer ignorance and attain knowledge. Eventually, the way of religion and the way of science should be integrated and their problems resolved in one united undertaking."* ***(Exposition of the Divine Principle, 1996, p. 30)***

This study is an examination of how far this merger has occurred, especially in terms of human origins. Over the last 60 years, literature in the realms of science and religion has been scoured for hints of areas where cooperation actually enhances our understanding of the world and history. Science deals with the external world of matter, and it has not an iota of an idea about Consciousness and matters of the heart.

Over the years, I uncovered many areas in which religion or science were weak, and where science of religion could supply some missing information to generate a much more nuanced and unified view of that particular aspect of understanding. This was particularly so when dealing with the topic of human origins. Here, science details external developments while religion deals with the internal aspects of family and brotherly love. Together, they describe the triumph and despair of human origins in detail.

2. Discussion

In science, the first major change in human culture was the New Stone Age (Neolithic) that began in the Fertile Crescent—a boomerang shaped region in the Middle East—around 10,000 years ago, marking the shift from hunting-gathering to farming and settled life.

In religion, the first major change after the Adam debacle was a great flood, probably the actual flooding of the Black Sea 9,000 annual years ago. Noah (4,800 biblical years ago) survived the flood in the Middle East that had washed away the old (physically) but spiritually it was a failure.

The Neolithic hominin culture of humans, was followed by the Bronze and Iron Ages, both named for the metals used in warfare. The first major Battle of Lagash and Umma was fought around 5000 years ago. This was the stage for the Old Testament and the Rule of Law spiritually instituted by Moses.

The external peak of this period of culture was the Roman Empire and the Pax Romana preparation for Jesus' success. Unfortunately, we all know how that turned out.

Now, 2,000 years later, we see both science and religion participating in the revolution that will bring in a new age of completed restoration (Fig. 1).

Figure 1. Revolutionary times in Religion and Science.

Both have already seen division into Cain and Able views. Christianity in the West had its religious reformation and separation into Protestant and Catholic cultures. They are ripe for the New Truth brought by the Messiah, but have not yet responded.

Scientifically, there has been a great division between the Life sciences and the inanimate physics and chemistry. Biology is still attached to Darwin's Victorian viewpoint.

Physics, however, is now in revolutionary mode. It has digested the quantum revolution which insisted that the invisible, intangible mind (or wave function) had to be included with

that of the body (or particle) for a complete and accurate complex math understanding. Physics has also uncovered entanglement and its intergalactic non-local connections provide by God for use later in exploring the universe.

Figure 2. Scientific Revolution and Political maps of Europe.

So, should we look to science for hope? Look at the disguised political maps of Europe today and 1000 years ago (Fig. 2). There is no difference, and I bet you can't decide which map is which. According to modern fiction writing, we have a dystopian future to look forward to—perhaps the delights of the Handmaiden's Tale. And in the movies, it's Star Wars and intergalactic warfare just like on Earth these days.

Looking at the externals, we have the miracle of the iPhones and a worldwide internet. But we also have famine and many wars present around the globe. Even the most sophisticated of cultures, such as America's, are under assault by barbarians, just like Rome was in its day.

Hopefully, this dissolution is a preparation for something better. We know from the Providence that human responsibility is always involved in such a change. But Science cannot bring the required change. So, Religion is the discipline that can usher in a higher level of culture.

3. Conclusion

The *Divine Principle* explanation of all the metaphors in the Bible allows science and religion, to at least talk to each other now. The emerging unification is happening very slowly, but as predicted it is proceeding, if glacially. We hope this paper can help speed it up, if just a little.

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The Role of Religious Leadership in Social Transformation: Interfaith Dialogue and Peacebuilding in Kenya

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Abstract: This article delves into the intricate concept of social transformation, focusing on the pivotal role of religious leadership and the transformative potential of interfaith dialogue in fostering peace and social cohesion. Through an analysis that bridges historical and contemporary perspectives, the study highlights the enduring contributions of influential religious figures such as Pope Leo XIII and Charles Cardinal Lavigerie. Their work not only shaped the trajectory of religious thought but also laid the groundwork for integrating faith into the broader spectrum of societal change. At the center of this exploration is the Coast Interfaith Council of Clerics (CICC) in Kenya, whose initiatives in Mombasa County provide a compelling case study. The CICC employs innovative methodologies to address complex challenges in peacebuilding, such as combating religious extremism and mitigating socio-economic disparities. This study carefully examines their strategies, including grassroots engagement and interfaith collaboration, while also addressing the significant obstacles they face, such as limited resources and entrenched socio-political conflicts. Grounded in the principles of Catholic Social Teaching (CST) and the theoretical frameworks of conflict transformation, the research underscores the critical intersection of faith, social responsibility, and actionable solutions. The findings reveal the transformative potential of interfaith initiatives in addressing deep-seated structural injustices and promoting reconciliation and social harmony. Moreover, they highlight the importance of integrating local knowledge and cultural sensitivity into peacebuilding efforts to achieve lasting impact. The study's recommendations emphasize the need for strengthened partnerships between religious and secular actors, increased resource allocation to support interfaith initiatives, and the development of robust theological education programs. These measures are crucial for empowering religious leaders and communities to sustain their efforts toward social transformation and peacebuilding. By bridging the gap between spiritual values and practical action, this article presents a compelling argument for the indispensable role of religious leadership in shaping a more equitable and peaceful society.

Keywords: Social transformation, Religious leadership, Interfaith dialogue, Peacebuilding, Conflict transformation

1. Introduction

Social transformation, a multifaceted concept encompassing systemic changes in societal structures, is deeply rooted in historical, cultural, and religious contexts. Religious institutions, particularly the Catholic Church, have long been pivotal in addressing social challenges. This article explores how religious leaders and institutions contribute to social transformation, focusing on interreligious dialogue as a key strategy. Through the example of the CICC in Kenya, the study demonstrates the power of collaborative religious efforts in mitigating conflicts and fostering social cohesion. Religious leadership has historically influenced societal values and actions, shaping moral and ethical standards. As highlighted by Gifford [1],

religious leaders possess a unique capacity to mobilize communities and advocate for justice, particularly in regions grappling with systemic injustices. This article builds upon these insights to assess the practical and theoretical underpinnings of interfaith dialogue and its role in peacebuilding.

1.1. Social Transformation: Conceptual Foundations

Social transformation encompasses profound systemic shifts that reshape cultural, economic, political, and social structures, extending beyond superficial or incremental changes. It is a dynamic and multidimensional process that involves both structural modifications and ideological shifts, fundamentally altering how societies function. Pierli and Selvam [2] conceptualize social transformation as an evolving process wherein individuals and communities drive large-scale changes aimed at improving quality of life, promoting social justice, and fostering equitable societies. This notion aligns with the foundational sociological perspectives of Karl Marx and Émile Durkheim, both of whom analyzed transformative forces in different ways. Marx posited that economic structures, particularly modes of production, fundamentally determine social relations and ideologies, making economic transformation the key to societal change. In contrast, Durkheim underscored the role of social solidarity and collective conscience in maintaining cohesion amidst industrialization and urbanization. He argued that as societies transition from mechanical to organic solidarity, institutions must adapt to evolving social functions to prevent anomie and fragmentation.

1.2. Theories of Social Transformation and Globalization

Contemporary scholars have extended these classical perspectives to account for globalization, digitalization, and postcolonial realities, highlighting the role of transnational forces in shaping social transformation. Giudici argues for the decolonization of social sciences, emphasizing the need for context-sensitive methodologies that reflect localized realities and diverse epistemologies. This perspective critiques Eurocentric frameworks that historically marginalized indigenous and subaltern knowledge systems. Scholars such as Escobar advocate for alternative development paradigms that move beyond Western-centric modernization theories, recognizing that social transformation must emerge from within local communities rather than being imposed through external economic and political pressures.

Bauman introduces the concept of "liquid modernity," in which rapid technological advancements and global interconnectedness have led to the destabilization of traditional social structures, creating uncertainty and shifting power dynamics. The digital revolution and artificial intelligence further complicate this landscape, presenting both opportunities and challenges for social transformation. Castells highlights the rise of the network society, where digital technologies redefine power structures, labor dynamics, and social movements, enabling grassroots activism while also reinforcing digital divides.

1.3. Religion as a Catalyst for Social Transformation

Religious institutions and doctrines have historically played a significant role in shaping societal transformations. The abolition of human sacrifice in African traditional societies, the anti-apartheid movement in South Africa, and the U.S. civil rights movements all demonstrate how religion can be a driver of progressive change. For example, the leadership of Martin Luther King Jr., deeply rooted in Christian theology, exemplifies how religious values inspire collective action for justice and equality. Similarly, in Latin America, liberation theology emerged as a powerful movement advocating for the rights of the oppressed, intertwining religious doctrine with political activism.

Max Weber's The Protestant Ethic and the Spirit of Capitalism remains a seminal work in understanding the intersection of religion and socio-economic transformation. Weber argued that the Protestant ethic, emphasizing hard work, frugality, and individual responsibility, significantly influenced the development of capitalist economies. This thesis has been revisited in contemporary scholarship, with scholars examining how religious ethics continue to shape economic behaviors in diverse contexts.

Within the Catholic tradition, Pope Leo XIII's Rerum Novarum [3] laid the foundation for Catholic Social Teaching (CST), addressing labor rights, economic justice, and the responsibilities of the state. Zahm [4] notes that this encyclical was a direct response to the exploitative conditions of industrial capitalism and has continued to influence policies on social welfare and human dignity in modern governance structures. More recent papal documents, such as Laudato Si', have expanded the social justice discourse to include environmental ethics, emphasizing the moral responsibility of societies to address climate change and ecological degradation.

1.4. Indigenous and Interfaith Contributions to Social Transformation

Religious institutions remain central to contemporary social transformation, particularly in the Global South. African Independent Churches (AICs) have been instrumental in addressing issues such as poverty alleviation, gender equity, and environmental sustainability. Kalu [5] argues that these churches integrate indigenous knowledge systems and community-driven initiatives, fostering sustainable development from within local cultural frameworks. Unlike missionary-driven Christianity, AICs often promote a theological vision that aligns with African cosmologies, enabling a more authentic engagement with social issues.

Interfaith collaborations have also emerged as significant agents of social change. The Coast Interfaith Council of Clerics (CICC) in Kenya exemplifies how religious diversity can be leveraged to promote peace and conflict resolution in multi-religious societies. By fostering dialogue between Christian, Muslim, and indigenous faith leaders, such organizations address sectarian tensions and promote social cohesion. Similar initiatives, such as the Inter-Religious Council of Uganda, have been active in advocating for human rights, democratic governance, and public health interventions, particularly in HIV/AIDS awareness campaigns.

1.5. Gender, Social Transformation, and Religious Influence

A critical dimension of social transformation involves gender dynamics, particularly the role of religious institutions in either perpetuating or challenging gender inequalities. While religious doctrines have historically been used to justify patriarchal structures, feminist theologians argue that religious traditions also provide resources for empowerment and resistance. Scholars such as Kwok Pui-lan highlight how feminist theological interpretations within Christianity and Islam have been instrumental in advocating for gender justice, particularly in the domains of education, reproductive rights, and leadership.

African feminist theologians such as Mercy Amba Oduyoye critique androcentric readings of religious texts, arguing for a hermeneutics of liberation that centers the experiences of African women. The role of women-led religious movements, such as the Circle of Concerned African Women Theologians, demonstrates how faith-based activism contributes to broader struggles for gender equality, particularly in contexts where secular feminist movements face resistance. Social transformation is a deeply complex and multi-layered process that intersects with historical, cultural, economic, and religious dimensions. From classical sociological theories to contemporary globalization debates, scholars have sought to understand the mechanisms

that drive large-scale societal changes. Religion remains a crucial force in this landscape, serving as both a conservative institution and a radical catalyst for transformation. The challenge moving forward is to harness the positive potential of religious and cultural institutions while critically engaging with the tensions and contradictions that arise in pluralistic and globalized societies. As scholars and policymakers navigate this evolving terrain, an interdisciplinary approach—drawing from sociology, political science, theology, and indigenous knowledge systems—will be essential in fostering inclusive and sustainable social change.

1.6. Historical Contributions of Religious Figures

Religious figures have played a pivotal role in shaping socio-political structures, advocating for justice, and championing human dignity across diverse historical contexts. Their influence extends beyond spiritual guidance to include social activism, economic justice, and political mediation. The Catholic tradition, in particular, has seen its leaders engage with critical issues such as workers' rights, anti-slavery movements, democratic transitions, and peacebuilding. From Pope Leo XIII's foundational encyclicals to the courageous interventions of African clergy in the 20th and 21st centuries, religious leadership has consistently intersected with broader historical transformations.

1.6.1. Pope Leo XIII and the Foundations of Catholic Social Teaching (CST)

Pope Leo XIII's Rerum Novarum [3] is widely regarded as the foundational document of Catholic Social Teaching (CST), addressing what was known as the "social question" during the Industrial Revolution. The encyclical emerged in response to the exploitative labor conditions that characterized the 19th-century industrial economy, where workers endured harsh conditions, low wages, and a lack of basic rights. In this landmark document, Leo XIII advocated for workers' rights, fair wages, and the moral responsibilities of employers, emphasizing that economic systems must be aligned with ethical principles to uphold the dignity of labor [4].

Leo XIII's intervention was significant in that it sought to mediate between unregulated capitalism and radical socialism, rejecting both laissez-faire economic liberalism and Marxist collectivism. Instead, he proposed a third way rooted in Christian ethics, where private property was acknowledged as legitimate but balanced by the principles of social justice and communal responsibility (Pontifical Council for Justice and Peace, 2004). The encyclical laid the groundwork for subsequent Church documents that further developed CST, such as Quadragesimo Anno by Pope Pius XI, which introduced the principle of subsidiarity, emphasizing that social and economic issues should be handled at the most immediate and local level possible to ensure efficiency and justice.

In the mid-20th century, Pope Paul VI expanded the Church's social justice discourse through Populorum Progressio, which underscored the importance of global economic development and the ethical obligations of wealthier nations toward the developing world [2]. Paul VI's encyclical is particularly relevant in postcolonial contexts, where economic disparities persist due to historical injustices. By championing solidarity and equitable economic structures, CST has continued to serve as a moral compass for Catholic engagement in socio-political issues worldwide.

1.6.2. Charles Cardinal Lavigerie and the Anti-Slavery Movement in Africa

In the late 19th century, Charles Cardinal Lavigerie, the Archbishop of Algiers and Carthage, emerged as a prominent Catholic voice against slavery in Africa. A contemporary of Pope Leo XIII, Lavigerie was deeply committed to the abolitionist cause, leading campaigns

that sought to expose the atrocities of the trans-Saharan and East African slave trades. His efforts were particularly significant in Sudan and Algeria, where he mobilized both Catholic and Muslim communities to resist the exploitation of enslaved people [6].

Lavigerie's approach was characterized by interreligious and ecumenical collaboration, recognizing that addressing slavery required collective action across different faith traditions. He organized public lectures and engaged European powers in an effort to push for legislative reforms against slavery, arguing that human dignity was a universal value transcending religious and cultural boundaries. His advocacy was instrumental in shaping anti-slavery sentiments within the Catholic Church, influencing the Vatican's later stance on human rights and social justice.

Beyond abolitionism, Lavigerie's missionary work contributed to broader discussions on African self-determination and governance. His White Fathers missionary society played a complex role in colonial Africa, simultaneously engaging in evangelization and educational initiatives while navigating the ethical dilemmas of European colonial expansion. While some critique his alignment with French colonial interests, his legacy as an anti-slavery campaigner remains a critical chapter in religious social activism.

1.6.3. Archbishop Isidore De Souza and Democratic Transitions in Benin

Moving into modern African history, Archbishop Isidore De Souza of Benin played a decisive role in political transitions during the 1990s. As chairman of the National Conference of Benin in 1990, De Souza mediated between political factions, facilitating a peaceful transition from a Marxist-Leninist dictatorship to a multiparty democracy. His leadership was particularly crucial in ensuring that the conference maintained legitimacy, acting as a moral anchor amid competing interests [7]. De Souza's role in Benin's democratization illustrates how religious figures can serve as impartial mediators in highly polarized contexts. Unlike political actors, religious leaders often command broad societal respect, allowing them to facilitate dialogue where secular institutions might fail. His success in Benin serves as a model for other African nations struggling with political instability, demonstrating the potential for faith-based leadership in governance transitions.

1.6.4. Cardinal Laurent Monsengwo and Human Rights in the DRC

Another towering religious figure in contemporary African history is Cardinal Laurent Monsengwo of the Democratic Republic of Congo (DRC), who played a critical role in advocating for human rights and democratic governance during tumultuous periods in the country's history. A highly respected theologian and a biblical scholar, Monsengwo became a vocal critic of authoritarian rule, using Catholic Social Teaching as a foundation for his advocacy.

During the Inter-Congolese Dialogue, a series of negotiations aimed at resolving the DRC's prolonged conflict, Monsengwo emphasized principles of justice, peace, and reconciliation as essential for national unity [8]. His engagement was not limited to the political elite but extended to grassroots movements, where he sought to empower marginalized communities through education and social awareness campaigns. Monsengwo's leadership illustrates the transformative power of moral authority, demonstrating how religious figures can exert substantial influence in shaping national discourse.

Beyond politics, Monsengwo also addressed structural injustices within the economic sphere, criticizing corruption and advocating for economic policies that prioritize human dignity. His stance on resource mismanagement in the DRC, particularly concerning the

exploitation of minerals and environmental degradation, reflects a broader commitment to CST principles,

The historical contributions of religious figures such as Pope Leo XIII, Cardinal Lavigerie, Archbishop Isidore De Souza, and Cardinal Laurent Monsengwo highlight the enduring intersection between faith and social transformation. Whether through foundational theological contributions like Rerum Novarum, anti-slavery activism, democratic mediation, or human rights advocacy, these figures exemplify how religious leadership can shape societies in profound and lasting ways. Their work demonstrates that religious engagement is not merely a spiritual endeavor but a force capable of driving systemic change, mediating conflicts, and promoting justice across diverse historical and cultural contexts.

As contemporary societies navigate complex challenges—including economic inequality, political instability, and social fragmentation—the legacies of these religious figures serve as valuable blueprints for ethical leadership. Their contributions underscore the continued relevance of faith-based moral authority in addressing global injustices and fostering inclusive, peaceful societies.

1.7. Interreligious Dialogue and Peacebuilding: The Case of CICC

The Coast Interfaith Council of Clerics (CICC) in Kenya serves as a contemporary example of religion's role in social transformation. Operating in Mombasa County, the CICC leverages interfaith dialogue to mitigate conflicts arising from religious extremism, political marginalization, and socio-economic disparities. As a platform uniting diverse religious leaders from Christian, Muslim, and Hindu communities, the CICC demonstrates the power of collaboration in addressing complex social challenges. Guided by the conflict transformation theories of Johan Galtung and John Paul Lederach, the CICC adopts a holistic approach, addressing both interpersonal and systemic issues. Galtung's concept of "positive peace"—which goes beyond the mere absence of violence to include justice and equitable social structures—aligns with the CICC's objectives. Lederach's emphasis on relational dynamics and grassroots empowerment further informs the organization's strategies [9].

Key objectives of the CICC include:

1. Promoting interreligious dialogue to foster peace and social cohesion.
2. Developing methodologies for effective conflict resolution and community engagement.
3. Identifying and addressing challenges in peacebuilding initiatives.

Challenges encountered by the CICC include limited financial and logistical resources, diverse and sometimes conflicting religious worldviews, and entrenched socio-political conflicts. Additionally, cultural differences and mistrust among communities pose barriers to effective collaboration. Despite these obstacles, the organization employs strategies such as grassroots mobilization, capacity building, and collaborative partnerships to promote sustainable peace. For example, CICC's interfaith forums have significantly contributed to reducing incidents of electoral violence in Mombasa, particularly following the 2013 and 2017 Kenyan elections [10].

The CICC also emphasizes the importance of education and community awareness. Workshops and training sessions organized by the council focus on promoting tolerance, understanding, and conflict resolution skills among local leaders and youth groups. This proactive engagement has fostered resilience against radicalization and religious extremism, underscoring the transformative potential of interfaith initiatives [11].

2. Theoretical Frameworks and Methodologies

This study employs the See-Judge-Act methodology, rooted in CST, to analyze social realities and propose actionable solutions. This approach, developed by Cardinal Joseph Cardijn, integrates theological reflection with empirical social analysis. It aligns with the pastoral cycle's stages: contextual analysis, theological reflection, and strategic planning [2]. By systematically observing societal issues, evaluating them through the lens of faith and ethical principles, and implementing practical interventions, this methodology enables comprehensive and impactful peacebuilding efforts. Conflict transformation theory, as articulated by Lederach [9], emphasizes systemic and relational changes. Lederach's model prioritizes the empowerment of marginalized groups, the fostering of social justice, and the transformation of societal structures to achieve sustainable peace. Galtung's typology of violence—distinguishing between direct, structural, and cultural violence—further enriches the analysis by identifying underlying causes of conflict and avenues for intervention [12]. These frameworks provide a robust foundation for understanding the intersection of religion and social transformation.

The CICC's work exemplifies how these theoretical approaches can be operationalized in real-world contexts. By fostering trust, dialogue, and mutual understanding among religious communities, the council contributes to a more inclusive and harmonious society. Their efforts underscore the critical role of faith-based organizations in addressing societal challenges and building sustainable peace.

Interfaith dialogue has emerged as a crucial mechanism for conflict resolution and social cohesion, particularly in multireligious and multiethnic societies like Kenya. Religious institutions and interfaith councils, such as the Coast Interfaith Council of Clerics (CICC), have played a transformative role in mitigating religious tensions and fostering peaceful coexistence. The findings of this study reveal both the effectiveness and challenges of interfaith interventions while highlighting key strategies for enhancing their impact.

2.1. Efficacy of Interfaith Dialogue in Peacebuilding

Interfaith dialogue has proven to be an effective strategy for fostering trust, collaboration, and mutual understanding among diverse religious communities. The CICC's structured dialogue programs and peacebuilding initiatives in Mombasa provide a compelling example of how religious leaders can de-escalate tensions and prevent violence. Following the highly contested Kenyan elections in 2013 and 2017, the CICC played a critical role in addressing religious hostilities by disseminating accurate information, countering divisive rhetoric, and engaging both Christian and Muslim leaders in mediation efforts. This approach helped prevent the politicization of religious identity, a factor that has historically fueled conflict in Kenya [13].

The success of interfaith dialogue in peacebuilding aligns with John Paul Lederach's conflict transformation theory, which emphasizes long-term, relationship-centered approaches to reconciliation. Unlike short-term conflict resolution strategies that focus solely on managing crises, interfaith dialogue fosters deep-rooted cultural and religious understanding, which is essential for sustained peace. Through joint initiatives such as community peace forums, interfaith prayer meetings, and collaborative humanitarian efforts, the CICC has helped build resilient networks of trust that endure beyond moments of crisis.

2.2. The Role of Grassroots Engagement in Peacebuilding

One of the most significant findings of this study is the importance of grassroots

engagement in interfaith peacebuilding efforts. Successful conflict resolution requires the active participation of local communities, ensuring that peace initiatives reflect their lived realities. The CICC has prioritized bottom-up approaches, involving youth, women, and traditional leaders in peace dialogues, training programs, and advocacy efforts.

Youth engagement has been particularly critical, as young people are often both victims and perpetrators of violence in conflict-prone regions. The CICC has established youth peace networks that provide platforms for young leaders to participate in constructive dialogue and community service projects. These initiatives have been instrumental in countering youth radicalization and recruitment into extremist groups, which is a growing challenge in coastal Kenya [2]. Similarly, women-led dialogues have played a pivotal role in strengthening social cohesion. Despite their historical exclusion from formal peace processes, women remain key actors in conflict prevention and reconciliation. The CICC's support for female religious leaders and community activists has created spaces for women to address gendered dimensions of conflict, rebuild trust, and facilitate intercommunal healing.

By incorporating local knowledge systems, cultural practices, and community-driven initiatives, the CICC has ensured that its peacebuilding efforts remain relevant and sustainable. This approach resonates with Lederach's [9] conflict transformation framework, which emphasizes that peacebuilding efforts must be tailored to the specific social, economic, and political contexts of affected communities.

2.3. Challenges of Limited Resources

Despite its successes, the CICC faces significant resource constraints that limit the scalability and sustainability of its interfaith programs. Inadequate funding has been a major obstacle, restricting the expansion of peace initiatives to other conflict-prone regions in Kenya. Many interfaith organizations rely on short-term donor funding, which often lacks consistency and flexibility to adapt to evolving conflict dynamics [14].

In addition to financial challenges, the shortage of trained personnel in interfaith dialogue and conflict mediation has hindered the effectiveness of peace programs. There is a growing need for capacity-building programs that equip religious leaders with theological, political, and mediation skills. Furthermore, infrastructure limitations, particularly in remote and marginalized areas, have made it difficult to sustain interfaith engagement programs that require physical meeting spaces and logistical support. As Wani [8] argues, interfaith peacebuilding requires long-term investments rather than fragmented short-term interventions that fail to address systemic and structural causes of conflict.

2.4. The Need for Context-Specific Approaches

Another key finding of this study is that one-size-fits-all peacebuilding strategies are ineffective. Successful interfaith interventions must be context-sensitive, addressing the unique socio-political and cultural dynamics of specific regions. The CICC's methodology has been effective because it integrates traditional leaders, engages marginalized communities, and responds to local grievances that often fuel religious tensions.

For instance, the CICC has engaged traditional elders and local community leaders in resolving disputes, recognizing that informal justice mechanisms hold significant authority in many communities. Additionally, by addressing socioeconomic grievances, such as youth unemployment and resource inequalities, the CICC has tackled some of the root causes of religious extremism. These approaches align with Lederach's [9] argument that peacebuilding efforts must be localized and community-driven, rather than externally imposed.

3. Discussion

3.1. Strengthening Partnerships for Greater Impact

To enhance the impact of interfaith initiatives, there is a need to strengthen partnerships between religious organizations, government institutions, non-governmental organizations (NGOs), and international bodies. Collaborative efforts can facilitate resource mobilization, technical expertise exchange, and advocacy for policy reforms. Strategic partnerships with global entities such as the United Nations Development Program (UNDP) and the African Union (AU) can help bolster the financial and technical capacity of organizations like the CICC.

3.2. Enhancing Theological Education for Peacebuilding

Religious leaders play a critical role in shaping social attitudes and fostering peace. Therefore, theological education should be reformed to include interfaith dialogue, conflict resolution, and mediation training. By integrating these elements into seminary and religious studies curricula, future religious leaders can be better equipped to mediate conflicts, promote coexistence, and challenge extremist narratives [15].

3.3. Increasing Funding for Sustainable Peacebuilding

Long-term peace initiatives require consistent and sustainable financial investment. Governments, international donors, and philanthropic organizations should prioritize funding for grassroots interfaith initiatives, capacity-building workshops, and women-led peace programs. Sustainable funding is essential for ensuring that peace efforts do not collapse due to financial constraints [8].

3.4. Promoting Policy Advocacy for Systemic Change

Religious leaders, leveraging their moral authority, should actively engage in policy advocacy to address structural inequalities that contribute to conflict. Advocacy efforts should focus on equitable resource distribution, inclusion of marginalized communities, and human rights protections. Collaborative advocacy campaigns with civil society organizations can amplify interfaith voices in governance and development [2].

3.5. Leveraging Technology for Wider Outreach

Digital platforms offer new opportunities for interfaith engagement and peacebuilding. Online forums, social media campaigns, and virtual workshops can connect religious leaders and communities across regions. Additionally, mobile applications can provide interfaith learning resources, counter extremist narratives, and strengthen community engagement [13]. Technology can bridge infrastructural gaps, making peacebuilding efforts more accessible, scalable, and inclusive. Interfaith dialogue remains a powerful mechanism for peacebuilding, as demonstrated by the successes and challenges of the CICC in Kenya. While resource limitations and structural barriers pose significant challenges, strengthening partnerships, integrating peacebuilding into theological education, and leveraging technology can enhance the sustainability and impact of interfaith initiatives. By addressing systemic inequalities and fostering inclusive dialogue, interfaith organizations can build resilient societies that are capable of resolving conflicts peacefully and promoting long-term coexistence.

4. Conclusion

Religious leadership continues to be a critical driver of social transformation, as evidenced by historical figures such as Pope Leo XIII and Charles Cardinal Lavigerie and contemporary initiatives like the Coast Interfaith Council of Clerics (CICC). The findings from this study emphasize the transformative potential of interfaith dialogue in addressing systemic injustices and fostering peaceful coexistence. The CICC's work highlights the importance of grassroots engagement, context-specific approaches, and sustained dialogue in mitigating conflicts and promoting unity. However, the challenges posed by resource limitations and entrenched socio-political dynamics necessitate innovative strategies and robust partnerships to enhance the efficacy of peacebuilding efforts.

The recommendations provided—ranging from strengthening partnerships and increasing funding to leveraging technology and advocating for systemic change—offer a roadmap for amplifying the impact of interfaith initiatives. A collaborative approach that integrates the efforts of religious and secular actors is essential for navigating the complexities of social transformation in a rapidly globalizing world. By harmonizing faith, social responsibility, and practical action, religious leaders and institutions can address structural injustices and foster sustainable peace, underscoring the critical role of interfaith dialogue as both a reconciliatory tool and a catalyst for systemic change.

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Section 2

Sciences and Innovation

The Unseen Logic of Life: AI-Assisted Metabolomic Exploration of Microbial Environmental Responsiveness
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The Unseen Logic of Life: AI-Assisted Metabolomic Exploration of Microbial Environmental Responsiveness

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Abstract: Bacterial survival depends upon a sophisticated sensory repertoire capable of detecting chemical gradients, thermal fluctuations, and osmotic pressure. However, the extent to which prokaryotes can distinguish and respond to complex acoustic architectures remains a subject of skepticism and limited mechanistic understanding. Here, we report that Escherichia coli exhibits a distinct, stimulus-specific physiological response to low-frequency, rhythmically layered acoustic patterns ("Chanyang" stimulation). Macroscopic analysis revealed that while high-frequency, transient-heavy stimulation ("Rhythmic Complex") elicited a negligible phenotype, the Afro-Anthemic (Chanyang) condition triggered a transition to a hyper-proliferative, biofilm-like state. Unbiased, AI-assisted metabolomic profiling identified a global metabolic phase shift driving this phenomenon, characterized by the unique accumulation of eukaryotic-like signaling lipids, specifically N-acylglycines and N-acylethanolamines—and membrane-structuring ceramides. These findings suggest that specific acoustic structures act as abiotic stressors that are transduced into chemical signals, effectively hijacking quorum-sensing pathways to coordinate collective stress responses. We propose that the microbial "unseen logic" extends beyond chemical chemoreception to include a refined capacity for mechanotransduction of complex environmental oscillations.

Keywords: Antarctic organisms, Non-targeted metabolomics, Pharmacological properties, Synthetic biology

1. Introduction

The evolutionary success of *Escherichia coli* is predicated on its capacity to rapidly decode and adapt to stochastic environmental variability [1,2]. Decades of microbiological research have meticulously mapped the sensory transduction networks governing chemotaxis [3,4], thermotaxis [5], and osmoregulation [6], revealing a cellular computational logic that is deterministic and highly sensitive to chemical composition [7]. The two-component signal transduction systems, such as EnvZ/OmpR and CheA/CheY, provide a robust framework for understanding how prokaryotes integrate multiple sensory inputs to modulate flagellar motility and gene expression [8,9]. Yet, despite this detailed understanding of chemical and thermal sensing, the bacterium's capacity to detect and interpret complex physical forces, specifically distinct acoustic architectures or mechanical oscillations, remains a poorly defined frontier in microbial physiology [10].

While the structural and functional properties of mechanosensitive channels (e.g., MscL and MscS) are well-documented responders to membrane tension and hypoosmotic shock

[11–13], the hypothesis that bacteria can distinguish between specific acoustic frequencies or rhythmic structures has largely been viewed with skepticism [14]. Prior investigations into the "bio-acoustic" effect have frequently suffered from methodological limitations, often failing to decouple the specific effects of sound waves from generalized fluid agitation, thermal confounds, or cavitation [15,16]. Consequently, whether acoustic stimulation represents merely background physical noise or a decipherable abiotic cue for niche adaptation remains an unresolved question in biophysics [17].

In this study, we address this gap by subjecting *E. coli* to distinct acoustic environments under nutrient-limited conditions, a context known to prime the stationary-phase stress response (RpoS) regulon [18]. We postulate that complex acoustic patterns may mimic natural mechanical stressors, such as fluid shear frequencies in the intestinal tract or host visceral motility, thereby triggering conserved survival programs [19,20]. By integrating phenotypic observation with high-resolution, AI-assisted metabolomics, we aim to delineate the chemical logic governing the bacterial response to the "unseen" physical environment. We demonstrate that specific acoustic architectures do not merely physically agitate the cell but induce coordinated metabolic reprogramming involving signaling lipids previously thought to be rare in prokaryotic systems [21], effectively hijacking quorum-sensing pathways to coordinate biofilm morphogenesis [22].

2. Materials and Methods

2.1. Bacterial Strains and Culture Conditions

Escherichia coli was selected as the model organism to assess cellular responses to acoustic stimulation under nutrient-limited conditions. Cultures were maintained on R2A agar, a low-nutrient medium chosen to reduce rapid proliferation and enhance the sensitivity of the bacterial stress response. Inoculation was performed using a standard quadrant streak method to ensure the isolation of single colonies and the generation of a density gradient across the plate surface. Experimental plates were randomly assigned to three cohorts (n = 3 biological replicates per condition): a non-stimulated control ("Silence"), a "Rhythmic Complex" group, and an " Afro-Anthemic " group. All plates were incubated at 37℃ in a unified thermal environment for a total duration of 60 hours.

2.2. Acoustic Stimulation Protocols

Acoustic stimuli were delivered to the experimental incubators via standardized audio drivers positioned to ensure uniform sound pressure levels across the plate surface. The "Rhythmic Complex" stimulus (K-pop) was defined by a soundscape of minimalist, metallic synthesizer textures overlaid with high-tempo, broad-frequency percussive elements. The "Afro-Anthemic" stimulus (Chanyang) consisted of a layered structural composition featuring aggressive, repetitive synthesizer loops and vocal chanting anchored by driving, polyrhythmic percussion. To prevent thermal accumulation from continuous speaker operation and to simulate periodic environmental stress, stimulation was applied in discrete 10-minute windows every 12 hours. Control plates were maintained in an identical incubator environment but kept in acoustic isolation (silence).

2.3. Metabolite Extraction and Sample Preparation

Following the 60-hour incubation period, metabolic activity was quenched to preserve the chemical profile of the stationary-phase colonies. A defined colony area (5×5 mm) was

excised from the agar surface of each plate, targeting the transition zone between single colonies and the confluent lawn. Metabolites were extracted using 80% (v/v) cold methanol to precipitate macromolecules while solubilizing a broad range of polar and non-polar small molecules. The supernatant was concentrated to dryness using a vacuum evaporator and subsequently reconstituted in MS-grade 50% acetonitrile to ensure compatibility with reverse-phase chromatography.

2.4. LC-MS/MS Profiling and Data Analysis

Non-targeted global metabolomics was performed using an X500R QTOF high-resolution mass spectrometer. Data were acquired in a data-dependent acquisition mode to capture both precursor and fragment ion spectra. Raw data files were converted to mzML format using MSConvert and processed via the Global Natural Products Social Molecular Networking (GNPS) platform. Molecular features were aligned and normalized using MetaboAnalyst to correct for inter-sample variability. Feature annotation relied on AI-assisted spectral matching against public libraries. Given the complex nature of the matrix, annotations described herein are considered putative (Level 2/3 identification) and are based on precursor mass accuracy and spectral similarity scores. The resulted files were downloaded as a graphML network file and visualized in Cytoscape [23].

3. Results

3.1. Acoustic stimulation induces distinct morphological phenotypes

To assess the macroscopic impact of acoustic stress on bacterial physiology, we evaluated colony morphology following 60 hours of intermittent stimulation. The non-stimulated control group (Silence) displayed a canonical phenotype characteristic of *E. coli* on oligotrophic media: colonies were discrete, translucent, and punctiform, with smooth margins and limited radial

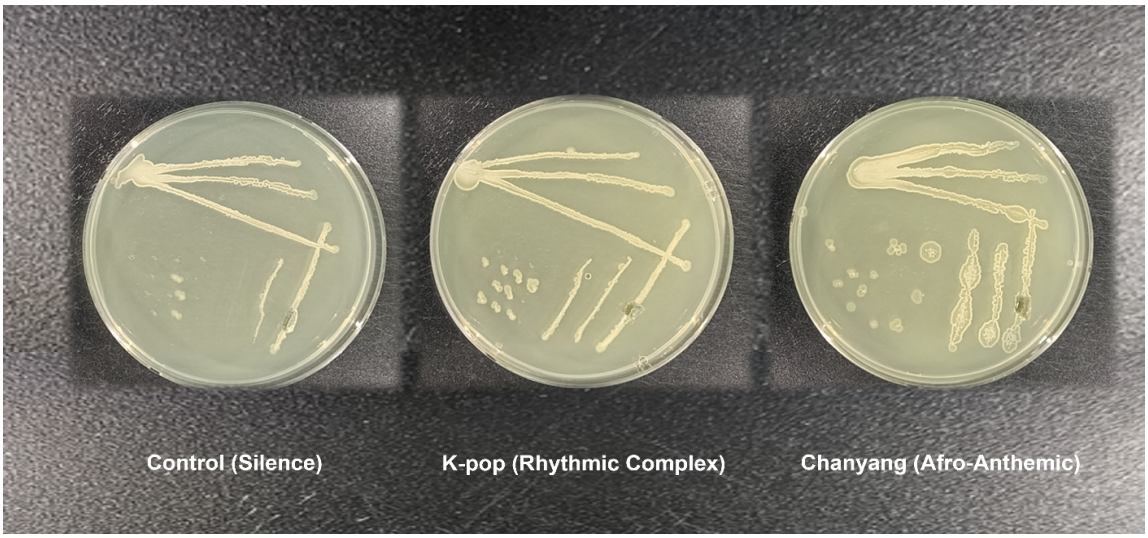

Figure 1. Acoustic stimulation alters macroscopic colony morphology.

Representative images of E. coli colonies cultivated on R2A agar following 60 h of intermittent acoustic stimulation at 37 °C. Left: Control (Silence) colonies exhibit a canonical phenotype with discrete, smooth margins and limited radial expansion. Center: Colonies exposed to "Rhythmic Complex" (K-pop) stimuli display an intermediate phenotype with modest increases in optical density. Right: "Afro-Anthemic" (Chanyang) stimulation induces a robust hyper-proliferative response, characterized by confluent biomass accumulation and the emergence of rugose, spreading margins indicative of biofilm matrix production.

expansion (Figure 1, Left). In contrast, the "Rhythmic Complex" cohort exhibited a transitional phenotype; while retaining the general spacing of the control, these colonies displayed a modest increase in optical density and a slight coarsening of the colony surface (Figure 1, Center), suggesting a mild perturbation of cellular replication or aggregation kinetics. The most significant deviation from baseline, however, was observed in the "Afro-Anthemic" condition. Colonies exposed to this specific acoustic structure exhibited a robust hyper-proliferative phenotype, characterized by a marked increase in total biomass and mean colony diameter (Figure 1, Right). Unlike the discrete colonies of the control, the bacterial lawn in the primary streak zones appeared confluent and opaque. Furthermore, single colonies in the tertiary streaks displayed irregular, spreading margins and a rugose texture indicative of enhanced extracellular matrix production. This morphological shift strongly suggests that the specific frequencies or rhythmic patterns of the Afro-Anthemic stimulus trigger a stress-response program analogous to biofilm formation.

3.2. Heatmap analysis reveals global metabolic reprogramming

To determine if these morphological changes reflected a systemic physiological shift, we

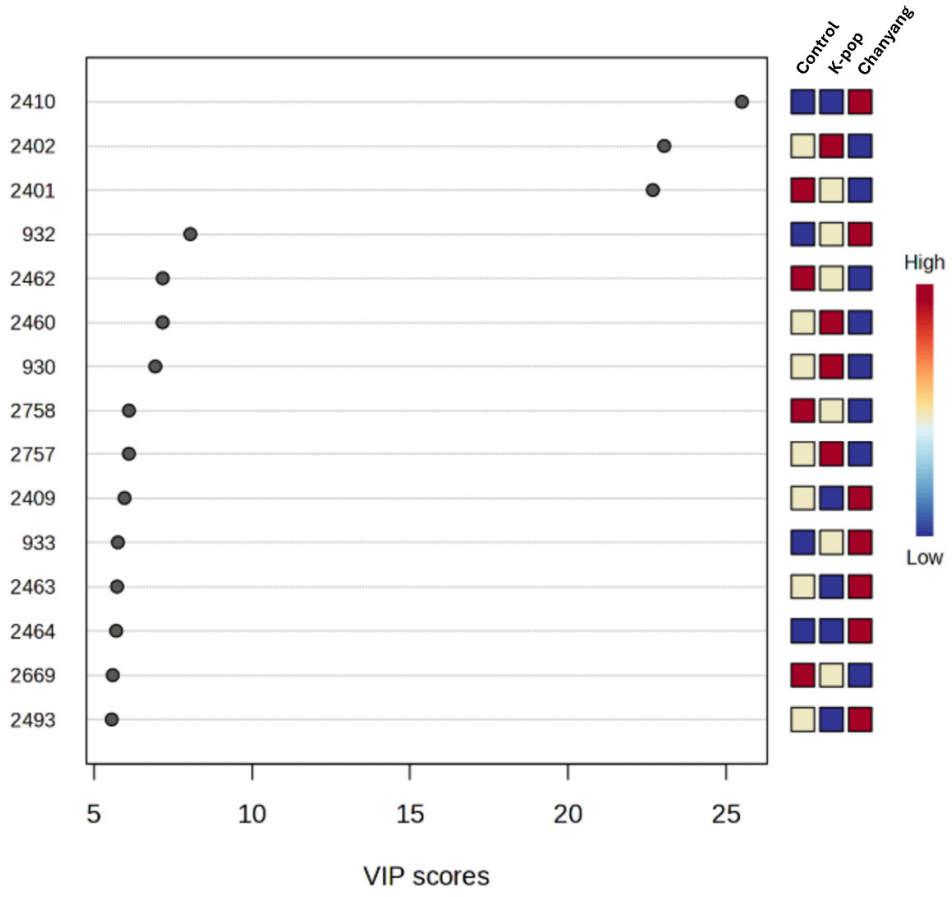

Figure 2. Hierarchical clustering reveals global metabolic phase separation.

Heatmap visualization of global metabolomic profiles generated via MetaboAnalyst. Rows represent individual molecular features (Alignment IDs); columns represent biological replicates (n = 3 per condition). Color scale indicates normalized relative abundance (Blue: low/absent; Red: high). The dendrogram (top) denotes Euclidean distance clustering, highlighting the statistical distinctness of the "Afro-Anthemic" clade (Right) compared to the overlapping profiles of the "Control" and "Rhythmic Complex" groups. The "hot" block (lower right) corresponds to the stress-responsive lipid signature unique to the biofilm phenotype.

performed multivariate statistical analysis using MetaboAnalyst. Unsupervised hierarchical clustering of the global metabolomic profiles generated a heatmap (Figure 2) where the vertical axis represents discrete molecular feature Alignment IDs. This visualization reveals a stark bifurcation in the metabolic landscape: the "Afro-Anthemic" replicates cluster into a cohesive, statistically distant clade, separated from the Control and K-pop groups by a distinct "hot" block of high-intensity molecular features (dark red regions). This global segregation confirms that the biofilm phenotype is supported by a fundamental phase shift in the metabolome, rather than minor fluctuations in baseline metabolism.

3.3. Molecular networking unveils unique lipid families

To map the chemical diversity driving this statistical separation, we subjected the MS/MS fragmentation data to classical molecular networking via the GNPS platform (Figure 3). Unlike the heatmap, which organizes features by abundance, this analysis clusters metabolites based on spectral similarity, grouping structurally related molecules into "molecular families." The network topology reveals that the metabolic shift in the Chanyang condition is driven by the enrichment of specific, interconnected clusters (highlighted nodes). These molecular families, absent in the control networks, displayed fragmentation patterns characteristic of complex lipid conjugates, guiding our targeted inquiry into specific signaling and membrane-modulating compounds.

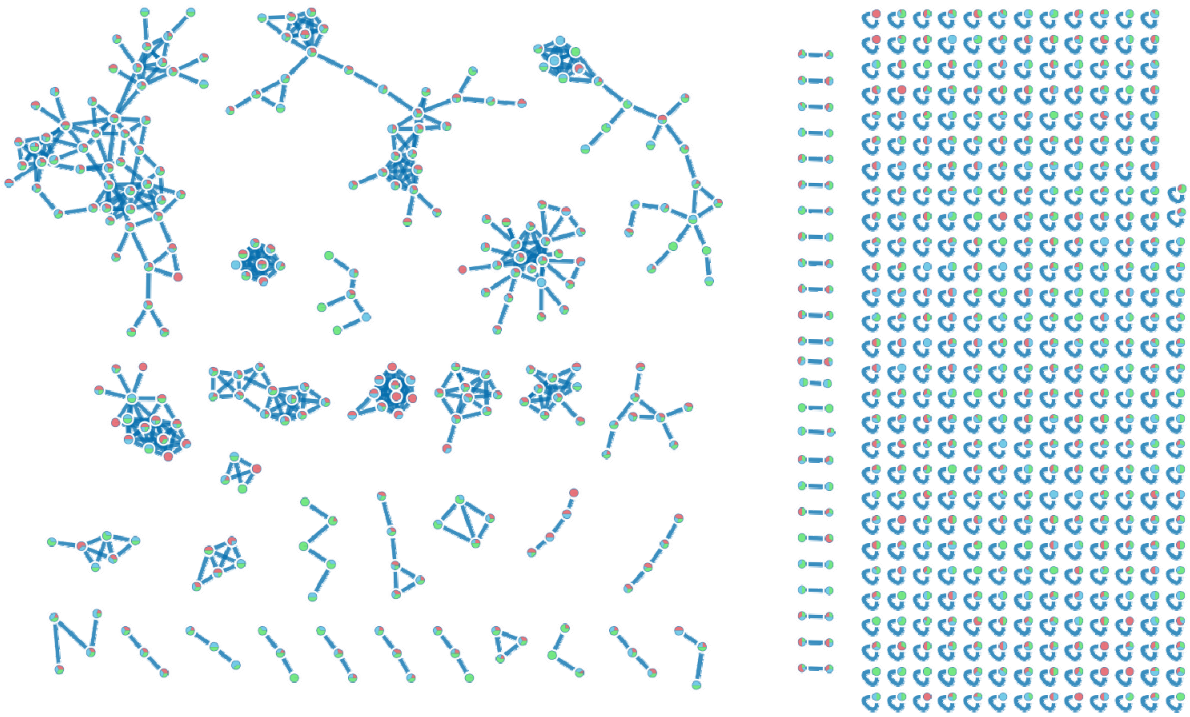

Figure 3. Molecular networking of crude extracts.

Classical molecular network (GNPS) displaying structural relationships between detected metabolites. Nodes represent consensus MS/MS spectra; edges connect nodes exceeding a cosine similarity threshold of 0.7, indicating shared chemical substructures.

3.4. Enrichment of putative "Endocannabinoid-like" signaling lipids

Targeted analysis of the unique molecular clusters revealed a suite of signaling lipids typically associated with eukaryotic systems. We identified high-intensity features annotated as N-acylglycine (NAGly) analogs (e.g., NAGly 14:1/24:2, intensity 5.8×10^6) exclusively in the Chanyang condition. Furthermore, trace levels of N-acylethanolamines (NAE), such as NAE 19:1 and NAE 22:4, were detected. Although unexpected in E. coli, these lipid species bear a striking structural resemblance to N-acyl homoserine lactones (AHLs). Their specific upregulation suggests they may function as "mimic" signals, hijacking quorum-sensing pathways to coordinate the high-density behavior observed macroscopically.

3.5. Upregulation of respiratory quinones and structural lipids

Downstream of these signaling events, the metabolic profile indicated a coordinated upregulation of energetic and structural machinery to support the biofilm phenotype. We identified a unique accumulation of Coenzyme Q3 (CoQ3, intensity $\sim 2.0\times10^4$), an essential component of the electron transport chain, reflecting the increased respiratory demand of the hyper-proliferative colonies. Concurrently, the lipidome was remodeled with membrane-stabilizing species, including bis(monoacylglycero)phosphates (BMP) and diverse ceramide-like features (e.g., Cer 9:0;2O/36:7). The exclusive presence of these structural lipids correlates directly with the rugose colony morphology (Section 3.2), providing the necessary chemical building blocks for the robust membrane architecture required for survival in the acoustically stressed environment.

Table 1. Putative metabolites uniquely associated with the Afro-Anthemic condition. Annotation confidence limited to MS1 mass accuracy and AI-assisted spectral matching (w/o MS2 confirmation)

Metabolite Class	Putative Annotation	Intensity (Chanyang)	Intensity (Control/K-pop)	Proposed Biological Role
Signaling Lipid	NAGly 14:1/24:2	5.8×10^6	n.d.	Biofilm modulation / Signaling
Membrane Lipid	Cer 9:0;2O/36:7	1.3×10^6	n.d.	Membrane stress response
Membrane Lipid	Cer 9:0;2O/40:7	3.1×10^5	n.d.	Structural reorganization
Signaling Lipid	NAE 19:1	1.5×10^4	n.d.	Quorum sensing analog
Respiratory	CoQ3	2.0×10^4	6.5×10^2	Electron transport (Upregulated)
Storage Lipid	DG O-18:1_28:7	1.3×10^5	n.d.	Lipid storage
Membrane Lipid	BMP 2:0_16:4	2.1×10^5	5.1×10^2	Phospholipid metabolism

4. Discussion

This study demonstrates that the acoustic environment can function as a powerful abiotic regulator of *Escherichia coli* physiology, revealing an unexpected dimension of bacterial phenotypic plasticity. Exposure to acoustically structured, low-frequency, repetitive stimuli induced a marked transition from a planktonic-like state to a hyper-proliferative, biofilm-associated phenotype. The absence of a comparable response under acoustically energetic yet high-frequency, rhythmically complex conditions indicates that this effect is not driven by sound intensity alone, but rather by specific spectral and temporal features of the stimulus.

Lipidomic analyses provide mechanistic insight into this phenomenon, indicating extensive membrane remodeling in acoustically stimulated colonies. The enrichment of membrane-stabilizing lipid species, together with evidence of increased respiratory activity, suggests that mechanical oscillations are transduced into physiological stress signals that promote membrane rigidification and biofilm formation. Notably, the detection of N-acylethanolamine- and N-acylglycine-like molecules exclusively in the hyper-proliferative phenotype points to a potential convergence between mechanotransduction and quorum-sensing pathways. These endocannabinoid-like lipids may act as quorum-sensing mimetics, artificially lowering the population density threshold required to trigger collective behaviors and thereby accelerating biofilm development.

The specificity of the response further implies that bacterial mechanosensory systems preferentially respond to sustained, low-frequency oscillations, while higher-frequency transients are likely dampened by the viscoelastic properties of both the growth medium and the cell envelope. Although the metabolite annotations remain putative and the precise molecular sensors have yet to be identified, these findings suggest that *E. coli*, a prominent member of the human gut microbiota, is capable of integrating non-chemical environmental cues into coordinated survival strategies. This raises the intriguing possibility that acoustic or mechanical signals may contribute to microbial behavior within complex host-associated ecosystems, warranting further investigation into their physiological and biomedical relevance.

5. Conclusions

In conclusion, this study reveals that *Escherichia coli* can sense and respond to structured acoustic stimuli, undergoing pronounced physiological and metabolic shifts. The findings suggest that specific low-frequency acoustic patterns, rather than sound intensity alone, can trigger membrane remodeling and quorum-like signaling, leading to enhanced collective behavior. As a key member of the human gut microbiota, *E. coli*'s ability to integrate mechanical cues highlights a previously unrecognized pathway by which non-chemical environmental signals may influence bacterial function and host-associated microbial ecosystems.

Author Contributions: Conceptualization, R.Y., H.Y. and T.-J.O.; methodology, R.Y.; formal analysis, R.Y. and H.Y.; investigation, R.Y. and H.Y.; resources, T.-J.O.; writing-original draft preparation, R.Y., H.Y. and T.-J.O.; writing-review and editing, R.Y., H.Y. and T.-J.O.; supervision, T.-J.O.; project administration, T.-J.O.; funding acquisition, T.-J.O. All authors have read and agreed to the published version of the manuscript.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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Isolated Optical Indirect Voltage Sensing

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Abstract: A battery management system requires accurate cell voltage monitoring and stable balancing in high-voltage environments. As electric vehicles and energy storage systems increase in voltage and capacity, safe and reliable voltage sensing becomes more challenging. Conventional battery management system architectures directly connect battery cells to low-voltage circuits, which may cause circuit damage and safety risks. This paper presents an isolated indirect voltage measurement architecture based on a light-emitting diode and cadmium sulfide sensor structure with a multi-cell single-path configuration. The influence of output load resistance on measurement resolution is quantitatively analyzed. Experimental results show that voltage resolution in the range of 3.0 V to 4.2 V improves with increasing load resistance, while output saturation occurs beyond 20kΩ. Based on these results, an optimal load resistance of 20kΩ is derived, providing a practical design guideline for maximizing measurement resolution without performance degradation.

Keywords: Battery Management System, Cell Voltage Monitoring, Isolated Voltage Measurement, LED–CDS Sensor, Load Resistance, Measurement Resolution, High-Voltage Battery Pack

1. Introduction

With the rapid expansion of electric vehicles (EVs), battery management systems (BMS) have become key technologies for ensuring safety and efficient energy management. BMS monitors the voltage of each battery cell in real time to prevent risks such as overcharging, deep discharge, and thermal runaway, thereby ensuring battery lifetime and safety. EV batteries are composed of thousands of cells, and voltage imbalance among cells can lead to overloading and thermal runaway in some cells, which has been identified as a major cause of vehicle fires [1–7]. Conventional BMSs operate by directly connecting battery cells to control circuits for voltage measurement. However, applying battery voltages directly to control circuits operating below 5 V in high-voltage environments exceeding 1,000 V poses risks of circuit damage and malfunction [4,5]. Therefore, indirect voltage measurement technologies that physically isolate high-voltage battery cells from low-voltage control boards have been required. To address this issue, optically isolated voltage sensing structures based on LED-based signal conversion have been proposed, and studies have been conducted to improve measurement accuracy by applying temperature compensation and stabilization techniques. However, structures employing multiple LEDs suffer from millivolt-level measurement errors due to process variations and temperature-dependent characteristics [1]. Subsequently, a single-path architecture utilizing a single optical channel to sequentially measure multiple cell voltages was developed, reducing device mismatch and wiring complexity while enabling high-resolution measurements [2,3]. In addition, voltage monitoring techniques employing multiplexer-based differential measurement structures and high-performance analog front-end circuits have been proposed [8]. These structures integrate LDO- and PTAT-based temperature compensation circuits to stabilize reference voltages and improve measurement accuracy. Furthermore, voltage sensing structures combined with balancing circuits, active energy

transfer schemes, and closed-loop control techniques have been applied to enhance system reliability [4–7]. However, most existing studies mainly focus on voltage sensing architectures and temperature compensation techniques, while the influence of output circuit parameters on measurement resolution in isolated indirect measurement systems has not been sufficiently analyzed. Although the output load resistance directly affects conversion gain and saturation behavior, quantitative investigations remain limited. In this paper, the effect of output load resistance on voltage monitoring resolution in an LED–CDS-based isolated indirect voltage sensing architecture is systematically analyzed. Experiments are conducted over the practical operating voltage range of lithium-ion battery cells to evaluate resolution enhancement and saturation characteristics. Based on these results, optimal load resistance is derived to maximize measurement performance without degradation. The proposed results provide practical design guidelines for reliable isolated voltage monitoring in high-voltage battery management systems.

2. Proposed Multi-Cell Single-Path Voltage Monitoring Architecture

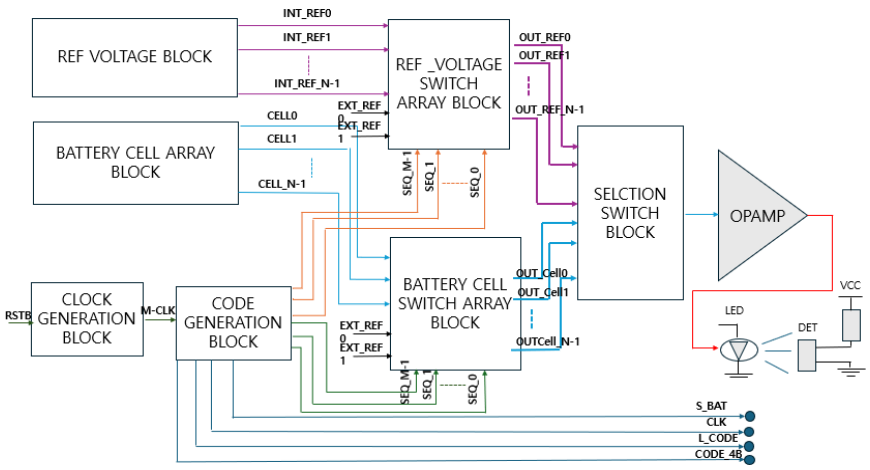


Figure 1. Overall architecture of the proposed multi-cell single-path voltage monitoring system.

Figure 1 illustrates the overall architecture of the proposed single-path multi-cell voltage monitoring system. The proposed system consists of a reference voltage block, reference voltage switch array block, battery cell array block, battery cell switch array block, and selection switch block. The reference voltage block generates multiple internal reference voltages (INT_REF0–INT_REFN−1), which are delivered to the reference voltage switch array block. Simultaneously, individual cell voltages (CELL0–CELLN−1) from the battery cell array block are input to the battery cell switch array block. Both switch array blocks are controlled by the Seq_M−1 signal generated from the code generation block. According to the control signals, the selected reference voltage or battery cell voltage is delivered through the selection switch block to drive the LED via a single output path. The optical signal generated by the LED is converted into an electrical signal by the photodetector and transmitted to the low-voltage domain. Through this structure, the high-voltage battery domain and low-voltage control domain are completely isolated, enabling voltage information transfer without direct electrical connection. Moreover, the proposed single-path architecture sequentially measures all cell voltages through a shared signal path, effectively reducing circuit complexity and device mismatch.

2.1. Control Clock and Battery Code Generation Circuit

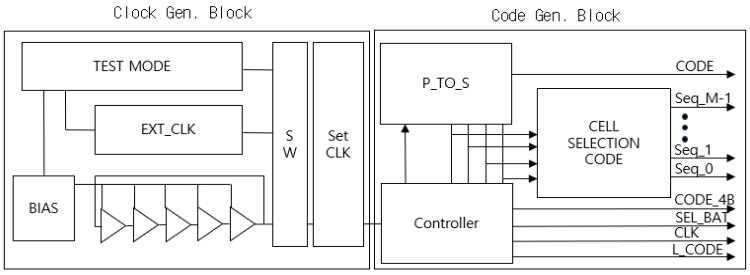


Figure 2. Control clock generation and battery code generation circuit.

Figure 2 shows the configuration of the clock generation block and code generation block. The clock generation block produces an internal reference clock using an external clock source, bias circuits, and buffer chains. This clock synchronizes overall system operation. The code generation block consists of a controller, a parallel-to-serial converter, and a cell selection code generator. Synchronized with the internal clock, it generates digital control signals to sequentially select battery cells and reference voltages. The main control signals include SEL_BAT, CLK, L_CODE, and CODE_4B. L_CODE specifies the cell selection sequence, while CODE_4B represents the reference voltage level. These signals are delivered to the reference voltage switch array block and battery cell switch array block to ensure synchronized voltage selection. This centralized control structure prevents mismatch timing and malfunction, enabling stable voltage scanning.

2.2. Sequential Voltage Monitoring Operation

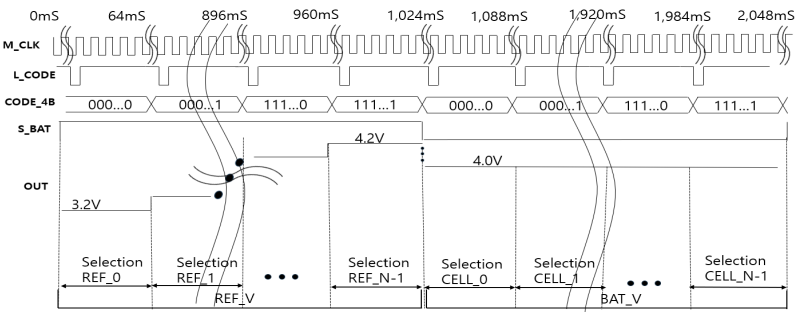


Figure 3. Timing diagram of the sequential voltage monitoring operation.

Figure 3 presents the timing diagram of the proposed voltage monitoring system. The overall measurement sequence is controlled by the internal clock (M_CLK), according to which selection signals are sequentially generated. During operation, the L_CODE signal indicates the currently selected battery cell, and the CODE_4B signal specifies the selected reference voltage level. The S_BAT signal determines the output signal type. When S_BAT is low, the output terminal (OUT) delivers the battery cell voltage. When S_BAT is high, the reference voltage (REF_V) is output. These outputs alternate according to the predefined sequence. Using the simultaneously transmitted L_CODE and CODE_4B signals, the external control unit (ECU) identifies each cell voltage and reference voltage. As a result, individual cell voltage information is reconstructed in the digital domain. This sequential measurement scheme enables

high-reliability voltage monitoring through a single signal path while maintaining complete electrical isolation under high-voltage conditions.

3. Results

3.1. Experimental Setup and Measurement Conditions

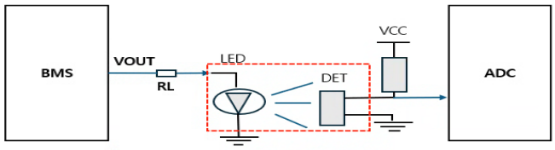
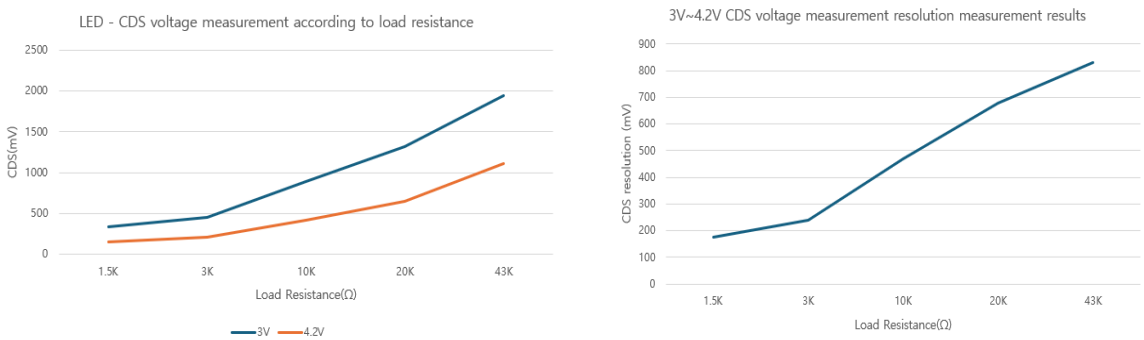


Figure 4. Experimental configuration of the LED–CDS isolated voltage measurement system using an ADC.

Figure 4 shows the experimental configuration used to evaluate the proposed LED–CDS based isolated voltage measurement system. The BMS output drives the LED through the load resistance RL, and the resulting optical signal is converted into an electrical voltage by the CDS detector. To analyze the effect of load resistance, RL varied from 1.5kΩ to 43kΩ, and output characteristics were measured under input voltage conditions of 3.0 V and 4.2 V.

3.2. Output Voltage Characteristics and Measurement Resolution



(a) (b)

Figure 5. Measured characteristics of the LED–CDS output according to load resistance:
(a) output voltage at 3.0 V and 4.2 V input conditions, and (b) measurement resolution in the 3.0–4.2 V range.

Figure 5(a) shows the measured CDS output voltage as a function of load resistance. As RL increases, the output voltages at both 3.0 V and 4.2 V input conditions increase monotonically. In addition, the voltage difference between the two input conditions also increases with increasing RL. Figure 5(b) presents the measurement resolution in the 3.0–4.2 V operating range. The resolution increases significantly as RL increases from 1.5kΩ to 20kΩ. This improvement is attributed to the increased voltage conversion gain caused by higher load resistance. However, when RL exceeds 20kΩ, further resolution improvement becomes limited, and output saturation is observed. Moreover, high-resistance conditions increase sensitivity to output fluctuation and noise.

4. Discussion

The experimental results demonstrate that load resistance strongly affects the voltage conversion characteristics of the LED–CDS interface. Increasing load resistance improves measurement resolution by enhancing conversion gain, while excessive resistance leads to output saturation and increased noise sensitivity. Compared with conventional direct-connection sensing structures, the proposed isolated single-path architecture eliminates electrical coupling and reduces the effects of device mismatch and temperature variation. The derived optimal load resistance of 20kΩ provides a practical guideline for high-voltage battery monitoring systems. Future work will focus on improving dynamic response and integrating digital calibration techniques.

5. Conclusions

This paper presented an LED–CDS based isolated single-path voltage monitoring architecture for high-voltage battery management systems. The proposed structure enables safe voltage sensing without direct electrical connection between high-voltage battery cells and low-voltage control circuits. The effect of load resistance on measurement characteristics was systematically analyzed. Experimental results confirmed that increasing load resistance improves voltage resolution in the 3.0–4.2 V operating range, while excessive resistance causes output saturation and increased noise sensitivity. Based on these observations, an optimal load resistance of 20kΩ was derived. The proposed design guideline provides a practical solution for achieving high-resolution and reliable voltage monitoring in optically isolated battery management systems. The developed system is suitable for safety-critical applications such as electric vehicles and energy storage systems.

Acknowledgments

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Soil Erosion Dynamics across Agro-Ecologies in Werie Watershed, Northern Ethiopia: A RUSLE Model, GIS and Remote Sensing Approach

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Abstract: Soil erosion by water is arguably the most significant environmental threat to the sustainability of agricultural systems in the Ethiopian Highlands. In the Werie Watershed, located within the rugged terrains of Northern Ethiopia, the combination of steep topography, erratic yet high-intensity rainfall, and historical land-use pressure has created a landscape highly susceptible to topsoil loss. This study provides a comprehensive, spatially explicit analysis of soil erosion dynamics across three distinct agro-ecological zones (AEZs): the Lowland (Kolla), Midland (Weina Dega), and Highland (Dega) zones. By integrating the Revised Universal Soil Loss Equation (RUSLE) with Geographic Information Systems (GIS) and Remote Sensing (RS), this research captures the complex biophysical interactions that drive land degradation. The significance of this study lies in its ability to move beyond a simplistic watershed-wide average, providing a high-resolution diagnostic tool that identifies specific "hotspots" of erosion, thereby allowing for the precision application of soil and water conservation (SWC) measures.

Keywords: Soil erosion dynamics, RUSLE model, Geographic Information Systems, Remote Sensing, water conservation measures

1. Introduction

The methodology of this research was built upon a multi-scalar data synthesis approach designed to calibrate the five primary factors of the RUSLE model to the local conditions of the Werie Watershed. The Rainfall Erosivity (R) factor was calculated using 31 years of historical rainfall data, modeling the cumulative kinetic energy of precipitation events. In this semi-arid region, the "Kiremt" rainy season delivers concentrated energy that is the primary agent of soil particle detachment. The Soil Erodibility (K) factor was derived through a detailed analysis of soil physical and chemical properties across the watershed. Parameters such as texture, organic matter content, and soil structure were processed within a GIS environment to quantify the inherent resistance of the ground to the abrasive forces of runoff.

The topographical influence on erosion was captured through the Slope Length and Steepness (LS) factor, generated from a 30m Digital Elevation Model (DEM). This factor is particularly critical in the Werie Watershed, where dramatic altitudinal shifts and vertical gradients significantly accelerate the velocity and transport capacity of surface runoff. To represent the temporal and spatial variations in land cover, the Cover Management (C) factor was extracted from multi-temporal Landsat 8 and 9 OLI imagery. By utilizing the Normalized Difference Vegetation Index (NDVI) and correlating it with specific land-use classes, the model was able to distinguish between the protective capabilities of natural vegetation and the

extreme vulnerability of bare agricultural fields. Finally, the Support Practices (P) factor was assigned based on a systematic assessment of existing conservation interventions, such as stone bunds and terracing, which are vital in mitigating the erosive power of water on steep slopes.

A critical conceptual refinement in this research addresses the mathematical behavior of the multiplicative RUSLE model (A=R×K×LS×C×P). To avoid the "black box" effect often criticized by reviewers, this study reports a minimum soil loss value of 0.09 t ha−1 yr−1. This value is explicitly defined as the mean soil loss per pixel aggregated across specific spatial units. This methodological choice ensures that the reported range is theoretically consistent with the input factors, where extremely low values (but not absolute zeros) in the P or LS factors are appropriately reflected in the final product. By utilizing zonal statistics and spatial averaging, the results provide a more representative estimation of soil loss that is better suited for watershed-scale management than raw, unadjusted pixel outputs.

2. Results

The results of the geospatial analysis reveal a mean annual soil loss of 9.73 t ha−1 yr−1, with a total spatial range extending from 0.09 to 436.37 t ha−1 yr−1. While the majority of the watershed (78.23%) is characterized by "slight" erosion (0.09–5 t ha−1 yr−1), which is generally within the range of natural soil formation, a critical 10.65% of the area is in a state of crisis, experiencing "high to very extreme" erosion exceeding 30 t ha−1 yr−1. The spatial distribution of these rates is intrinsically linked to the watershed's agro-ecology. The Lowland (Kolla) zone emerged as the most vulnerable, exhibiting the highest mean erosion rate of 22.83 t ha−1 yr−1. This high rate is a consequence of sparse vegetation cover combined with high-intensity convective rainfall that results in severe surface scouring.

In contrast, the Midland (Weina Dega) zone, while maintaining a moderate mean loss of 8.77 t ha−1 yr−1, is the largest contributor to the total annual sediment tonnage of the watershed. Because this zone encompasses the largest geographical area and the highest density of agricultural activity, it represents the primary source of the total soil volume entering the Tekeze Basin downstream. The Highland (Dega) zone showed the lowest mean erosion rate at 7.64 t ha−1 yr−1, a finding that highlights the effectiveness of higher biomass density and established traditional conservation practices, even in a landscape characterized by steep slopes.

3. Discussion

The discussion of these findings, supported by an extensive review of 35 peer-reviewed sources from global scholarly databases such as Scopus, Web of Science, and DOAJ, places the Werie Watershed within the broader context of East African land degradation research. The dominance of the R and C factors as widespread drivers of erosion suggests that climate variability and land management are the primary levers of environmental change in the region. The LS factor, although showing the strongest positive correlation with soil loss, is restricted to localized "hotspots," suggesting that while topography creates the potential for extreme erosion, it is the mismanagement of the vegetative cover (C-factor) that ultimately triggers it. These dynamics necessitate a shift away from "one-size-fits-all" conservation strategies. Instead, a targeted approach is required: biological measures and reforestation should be prioritized in the Lowland zones to mitigate the R-factor impact, while structural engineering and physical barriers are essential in the Midland zones to handle the volume of runoff generated across its vast agricultural extent.

3. Conclusion

In conclusion, this research demonstrates that the integration of the RUSLE model with GIS and Remote Sensing provides a high-fidelity diagnostic tool for sustainable watershed management. By identifying the specific mechanisms of erosion within each agro-ecological zone, the study offers a scientifically grounded roadmap for regional policymakers and conservationists. The findings underscore that without immediate, precision-targeted interventions in the high-risk zones—which constitute over 10% of the watershed—the long-term agricultural productivity and hydrological integrity of Northern Ethiopia's land resources remain under severe threat. This spatial estimation serves as both a scientific benchmark and a practical blueprint for protecting the Werie Watershed for future generations.

Impact of Vachellia etbaica on Soil Properties and Socioeco-nomic Benefits in Tigray Ethiopia

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Abstract: Abstracts should give a pertinent overview of the work including the essential contents of the work, key ideas and results. Smallholder farmers in Northern Ethiopia face persistent challenges of soil infertility, land degradation, food insecurity, and climate vulnerability. To cope with these constraints, many farmers integrate Vachellia etbaica, a drought-resistant native tree, into their land-use systems, yet its ecological and socioeconomic benefits remain insufficiently quantified. This study assessed the effects of V. etbaica on soil properties and local livelihoods in Tsrae-Wonberta district, Tigray, Ethiopia. Soil samples were collected from 120 composite sites stratified by land use (grazing and cultivated lands), distance from trees, and soil depth (0–20 cm and 20–40 cm). Socioeconomic data were obtained through semi-structured interviews with 92 randomly selected households. Most soil properties, including moisture content, organic carbon, and total nitrogen, differed significantly ($p < 0.05$), decreasing with increasing distance from trees but generally increasing with soil depth. About 85% of respondents reported multiple benefits from V. etbaica, including firewood, charcoal, income generation, fencing materials, fodder, and traditional medicine. The results demonstrate that appropriate management of V. etbaica can enhance soil fertility, strengthen ecosystem resilience, and support rural livelihoods. The study highlights the species' potential role in sustainable land management and agroforestry systems aimed at improving soil health and livelihood resilience in similar dryland environments.

Keywords: Agroforestry, canopy distance, land use types, parkland, soil depth

1. Introduction

Smallholder farmers face multiple, interrelated challenges, including limited resources, food insecurity, land degradation, population pressure, and increasing vulnerability to climate change [1]. In many regions, the continued expansion of cereal cultivation under conventional practices has become unsustainable due to declining availability of productive land [2]. As agriculture extends into marginal areas, soil degradation intensifies, resulting in reduced fertility, declining productivity, and long-term threats to agricultural viability [3]. Climate change further compounds these challenges through erratic rainfall, frequent droughts, and shifting growing seasons, disproportionately affecting smallholder farmers with limited adaptive capacity [4].

In Ethiopia, rapid population growth and persistent food insecurity underscore the urgent

need for sustainable agricultural practices that enhance productivity, soil fertility, and resilience to climate variability [5]. The agricultural sector is constrained by widespread land degradation, poor land management, and heavy reliance on rain-fed farming, leading to low yields and high vulnerability to climatic shocks [6]. Although mineral fertilizers can improve soil fertility, their high cost and limited availability make them largely inaccessible to smallholder farmers [7]. In this context, agroforestry offers a viable and sustainable alternative by integrating trees into farming systems to restore soil health, conserve water, and enhance resilience [8,9].

Agroforestry systems mitigate land degradation, improve soil fertility, and promote biodiversity while providing economic benefits through fuelwood, fodder, and other tree products. In Ethiopia, trees are widely integrated into croplands to improve soil quality, control erosion, and buffer climate variability [10,11]. By increasing soil organic matter, enhancing nutrient cycling, and moderating microclimates, agroforestry systems improve moisture retention, reduce evapotranspiration, and strengthen resilience to drought [8].

In the Tigray region of northern Ethiopia, Vachellia etbaica (Seraw) has traditionally supported soil fertility and crop production, yet its specific effects across land-use types and soil depths remain insufficiently studied. This study evaluates the influence of V. etbaica on key soil physico-chemical properties—moisture content, bulk density, soil organic carbon, and total nitrogen—across varying soil depths and distances from the tree. It also assesses the species' socioeconomic benefits. The findings provide evidence to support the integration of nitrogen-fixing trees into smallholder farming systems as a cost-effective strategy to enhance soil fertility, climate resilience, and sustainable agricultural productivity in semi-arid regions such as Tigray.

2. Materials and Methods

2.1. Description of the study area

The study was conducted in Kihen Tabia, Tsrae-Womberta district, eastern Tigray, northern Ethiopia, located between 13°38′30″–13°40′30″ N and 39°34′00″–39°36′00″ E (Fig. 1). The area covers 5,673 ha with elevations ranging from 2,025 to 2,315 m a.s.l. [12]. The population is 6,257, with livelihoods primarily dependent on rain-fed agriculture. Major crops include tef (Eragrostis tef), sorghum (Sorghum bicolor), and wheat (Triticum spp.) [13]. Livestock grazing (cattle, goats, sheep, and donkeys) is common on natural grasslands and sloping terrain (0–30°) [14]. The area receives a uni-modal rainfall with a mean annual precipitation of 598 mm and an average temperature of 19.8°C. Dominant soils include Cambisols, Luvisols, and Leptosols, with frequent rock outcrops limiting cultivation [15]. *Vachellia etbaica* is the dominant tree species, accounting for over 90% of woody vegetation, and occurs across cultivated land, grazing land, forest patches, and settlements [12].

2.2. Sampling design and soil collection

Following a reconnaissance survey, Kihen Tabia was purposively selected due to its dominance of *V. etbaica*. Soil samples were collected from cultivated land and grazing land containing mature *V. etbaica* trees. Sampling was conducted at three radial distances: mid-canopy, canopy edge, and outside canopy influence (≥15 m from the canopy edge), following established agroforestry protocols [9,16]. Soil was sampled at two depths: 0–20 cm (topsoil) and 20–40 cm (subsoil).

Samples were collected along four transects (north–south and east–west) radiating from each tree base (Fig. 2). In total, 120 composite soil samples were collected: 48 from grazing land (8 trees × 3 distances × 2 depths) and 72 from cultivated land (12 trees × 3 distances

× 2 depths). A higher number of samples were taken from cultivated land to account for greater management variability associated with plowing and fertilizer inputs. Bulk density samples were collected using a core sampler. All samples were labeled and transported to the Mekelle University Soil Laboratory for analysis.

2.3. Soil physicochemical analysis

Soil samples were air-dried, ground, and sieved (< 2 mm). Particle size distribution was determined using the Bouyoucos hydrometer method [17]. Soil organic carbon (SOC) was analyzed using the Walkley–Black method [18], and total nitrogen (TN) was determined by the Kjeldahl method [19]. Bulk density (BD) was measured using the oven-dry method at 105°C for 24 h [20], while moisture content (MC) was determined gravimetrically [21]. SOC stock (t ha^{-1}) was calculated following Pearson et al. [22].

2.4. Household survey

Socioeconomic data were collected using a semi-structured questionnaire administered in Tigrigna. A stratified random sampling approach was used to identify households owning *V. etbaica* trees, with assistance from local leaders and development agents. Sample size (n = 92) was determined using Yamane's [23] formula at a 5% precision level. The survey captured information on tree uses (fuelwood, fodder, income, medicinal value) and ecosystem services such as shade and erosion control.

2.5. Statistical analysis

Data normality was tested using the Shapiro–Wilk test. A factorial ANOVA was applied to assess differences in soil properties across land use, soil depth, and radial distance at $\alpha = 0.05$. Socioeconomic data were analyzed descriptively using percentages and means. All analyses were performed using SPSS version 26.

3. Results

3.1. Selected soil physicochemical properties

The study assessed the effects of *V. etbaica* on soil properties across land use types, soil depths, and radial distances. Soil particle distribution did not vary with distance or depth but differed significantly by land use ($p < 0.05$), with cultivated land showing higher silt and grazing land higher clay content. Soil moisture content varied significantly with radial distance, land use, and depth, with the highest values under tree canopies and at 20–40 cm depth. Bulk density was significantly influenced by soil depth ($p < 0.05$), being higher at 20–40 cm, while radial distance and land use showed no significant effects (Table 1).

Table 1. Effect of *V. etbaica* trees on soil physical properties affected by radial distance from the canopy and soil depth at different land use types

Soil parameters	Depth		Radial distance			Land use	
	0 - 20 cm	20-40 cm	Half canopy	Edge of canopy	Out of canopy	Grazing land	Cultivated land
Sand (%)	25.70a±1.73	24.30a±1.26	24.13a±2.54	25.21a±1.14	23.15a±2.14	27.13a±2.11	23.31a±0.94
Silt (%)	30.10a±1.36	30.05a±1.64	36.38a±1.65	34.18a±1.85	34.28a±1.15	24.63a±1.04	32.38b±1.35
Clay (%)	44.20a±1.82	45.65a±1.83	39.50a±1.41	41.31a±1.02	38.60a±1.23	48.25a±2.41	44.31b±1.62
MC (%)	10.26a±0.44	13.43b±0.77	13.10a±1.12	12.13b±0.89	11.20a±1.02	9.98a±0.48	13.23b±0.87
BD(g/cm^3)	1.22a±0.02	1.26b±0.03	1.30a±0.06	1.25a±0.03	1.201a±0.04	1.21a±0.02	1.23a±0.02

Note: Values with the same letter within a row are not significantly different at P > 0.05. Values are Mean ± SEM.

SOC and TN varied significantly with soil depth, radial distance, and land use, with higher values at 20–40 cm, at the canopy edge, and in grazing land ($p < 0.05$) (Table 2). Grazing land recorded greater SOC and TN than cultivated land, reflecting reduced disturbance and higher organic matter inputs. These results highlight the role of V. etbaica–based agroforestry in enhancing soil fertility, moisture retention, and carbon sequestration, particularly in degraded agricultural landscapes.

Table 2. Effect of *V. etbaica* trees on soil chemical properties affected by radial distance from the canopy and soil depth at different land use types

Soil parameters	Depth		Radial distance			Land use	
	0 - 20 cm	20-40 cm	Half canopy	Edge of canopy	Out of canopy	Grazing land	Cultivated land
SOC (t ha^{-1})	63.26^{a}±3.44	72.46^{b}±3.75	52.63^{a}±4.34	61.15^{a}±2.68	50.43^{b}±4.89	77.19^{a}±3.70	67.15^{b}±3.28
TN (%)	0.22^{a}±0.01	0.25^{b}±0.02	0.17^{a}±0.01	0.20^{a}±0.01	0.15^{b}±0.01	0.27^{a}±0.02	0.23^{b}±0.02

Values with the same letter within a row are not significantly different at $P > 0.05$. Values are Mean ± SEM.

3.2. Economic and environmental benefits of V. etbaica on the community

V. etbaica provides major economic benefits, with 85% of households using it for firewood (average 3,412 ETB/year) and 56% producing charcoal (2,185 ETB/year), alongside use for farm tools (60%), construction (63%), fodder (55%), and medicine (11%). Environmentally, 63% of respondents reported reduced land degradation and 70% reduced soil erosion, while 36% observed improved soil moisture. The tree is widely valued for shade (91%), benefiting both people and livestock in drylands (Table 3).

Table 3. Economic and environmental benefits of *V. etbaica* to the community

Economic Benefits	Farmer's Response				Income from sales per year (mean value in ETB)
	Yes	%	No	%	
Firewood	78	84.80	14	15.20	3412 (per household)
Charcoal	51	55.40	41	44.60	2185 (per household)
Farm implements	55	59.81	37	40.20	
Building materials	58	63.00	34	37.10	
Fodder for livestock	51	55.40	41	44.60	
For traditional medicines	10	10.86	82	89.23	
Environmental Benefits					
Reduces land degradation	58	63.00	34	37.00	
Reduces soil erosion	64	69.60	28	30.40	
Enhancing soil moisture	33	35.90	59	64.10	
Uses as fence on border fields	54	58.70	38	41.30	
Uses as food for bee colony	43	46.70	49	53.30	
Shade (for livestock and people)	84	91.30	8	8.70	
Increase stream flow and springs	30	32.60	62	67.40	
Increase in crop production	33	35.90	59	64.10	

(ETB = Ethiopian Birr)

4. Discussion

4.1. Effects of Vachellia etbaica on soil physicochemical properties

The study shows that soil physicochemical properties are mainly influenced by land use type, tree presence, soil depth, and distance from the tree trunk. Soil texture varied significantly among land use types ($p < 0.05$), with clay-dominated soils prevailing throughout the study area. Grazing lands with *V. etbaica* exhibited higher clay content than cultivated lands, indicating that reduced disturbance and tree cover help conserve fine particles, consistent with Haile et al. [24] and Bazie et al. [25]. Soil depth had no significant effect on particle size distribution ($p > 0.05$), and sand fractions were largely unaffected by land use, in agreement with Abdella et al. [26].

Soil moisture content (MC) varied significantly with land use, soil depth, and radial distance. Higher MC was observed under tree canopies, particularly in cultivated lands, reflecting canopy shading, litter accumulation, and reduced evaporation. Moisture levels increased with soil depth, likely due to reduced evaporative losses and higher clay content. The overall mean MC (11.84%) was lower than values reported in other Ethiopian studies, which may be attributed to agroecological and seasonal differences.

Bulk density (BD) was significantly affected by soil depth but not by land use or distance from the tree. Lower BD values occurred in areas with tree cover, especially grazing lands, due to organic matter inputs that enhance soil structure, while higher BD in cultivated lands without trees reflected continuous tillage and soil compaction. The observed increase in BD with depth aligns with earlier studies in Ethiopia [27,28].

Soil organic carbon (SOC) and total nitrogen (TN) were significantly influenced by land use, soil depth, and proximity to trees. Both SOC and TN decreased with increasing distance from the trunk but increased with soil depth. Grazing lands with trees recorded the highest SOC and TN, while cultivated lands without trees showed the lowest values, reflecting differences in organic matter inputs, erosion, and management intensity. These results corroborate findings by Bazie et al. [25], Selassie et al. [29], and Danjuma et al. [30], emphasizing the role of trees in maintaining soil fertility. Overall, the findings demonstrate that *V. etbaica* enhances soil quality by improving moisture retention, reducing compaction, and increasing SOC and TN, highlighting its importance in sustainable land management.

4.2. Socioeconomic and environmental benefits of Vachellia etbaica

Survey results indicate that *V. etbaica* provides substantial socioeconomic benefits to local communities. Over 85% of respondents use the tree for firewood, generating an average annual income of 3,412 ETB per household, while about 55% earn approximately 2,185 ETB annually from charcoal production. Additional benefits include construction materials (63%), farm tools (60%), livestock fodder (55%), and traditional medicine, underscoring its multifunctional role in rural livelihoods [31, 32]. Environmentally, *V. etbaica* contributes significantly to land restoration, with 70% of respondents reporting reduced soil erosion and 63% noting mitigation of land degradation, while 36% observed improved soil moisture and fertility. These benefits are consistent with previous studies highlighting the role of acacia species in soil conservation and ecosystem resilience [25, 33]. Despite these advantages, the expansion of *V. etbaica*–based agroforestry systems is constrained by free grazing, weak enforcement, limited awareness, overharvesting, and insufficient seedling supply. Addressing these challenges through targeted policy support and community engagement is essential to sustain the socioeconomic and environmental benefits of *V. etbaica*.

5. Conclusions

The study highlights the importance of integrating *V. etbaica* into grazing and farming systems to enhance soil fertility. Soils under tree canopies showed significantly higher MC, SOC, and TN, while BD was highest in open fields; most soil properties varied significantly with land use, except sand and BD. Soil depth influenced only MC and BD. *V. etbaica*–based systems, particularly in grazing lands, recorded the highest SOC and TN, confirming the tree's role in improving soil fertility. Beyond environmental benefits, *V. etbaica* supports livelihoods through firewood, charcoal, fodder, shade, and construction materials. The study recommends promoting *V. etbaica* agroforestry through community awareness, improved seedling access, and supportive policies to ensure sustainable land management and livelihoods.

Author Contributions: Conceptualization, N.S. and H.G.; methodology, N.S. and H.G.; software, N.S. and H.G.; validation, N.S., H.G., T.A., Y.G. and E.B.; formal analysis, N.S. and H.G.; investigation, N.S. and H.G.; resources, H.G.; data curation, N.S. and H.G.; writing—original draft preparation, N.S., H.G., T.A., Y.G. and E.B.; writing—review and editing, N.S., H.G., T.A., Y.G. and E.B.; visualization, N.S., H.G., T.A., Y.G. and E.B.; supervision, N.S. and T.A.; project administration, H.G.; funding ac-quisition, H.G. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: All data generated or analyzed during this study can be obtained from the corresponding author.

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Conflicts of Interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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Carbon Sequestration Potential of the Gamadu Indigenous Forest: An Afromontane Forest Partially Sacred for Cultural Rituals in Borana Woodland, Southern Ethiopia

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Abstract: Forests are key components of the global carbon cycle, yet their sequestration potential is increasingly threatened by anthropogenic disturbance, particularly in dryland ecosystems. This study assessed ecosystem carbon stocks of the Gamadu Indigenous Afromontane Forest in the Borana dryland of southern Ethiopia across low-, moderate-, and high-disturbance gradients. Aboveground and belowground biomass, soil organic carbon (0–30 cm), litter, and deadwood carbon pools were quantified using systematic plot-based sampling and standard allometric and laboratory methods. Results showed a pronounced decline in total ecosystem carbon stock with increasing disturbance, from 363.04 t ha^{-1} in low-disturbance sites to 267.06 t ha^{-1} in highly disturbed sites. Live biomass constituted the dominant carbon pool (≈72.5%), followed by soil organic carbon (≈24.3%), while litter and deadwood contributed marginally. Biomass carbon was strongly correlated with tree structural attributes, particularly diameter at breast height and basal area. Deadwood carbon increased with disturbance, reflecting elevated tree mortality. Despite disturbance, large culturally protected trees persisted across sites, highlighting the conservation role of the Borana Gada system. The study demonstrates that minimizing disturbance is critical for maintaining carbon stocks and underscores the importance of integrating indigenous forest governance into climate change mitigation strategies.

Keywords: Afromontane forest, Biomass carbon, Disturbance gradient, Soil organic carbon, Dryland Ethiopia

1. Introduction

Terrestrial ecosystems function as major carbon sources and sinks, with carbon stored in biomass, litter, deadwood, and soils [1–5]. Land use and management changes strongly influence carbon dynamics, particularly in dryland systems, by altering vegetation structure, soil disturbance, and decomposition processes [1,6–10]. Forest carbon stocks vary with canopy cover, basal area, elevation, and land use type, with higher stocks often found in less disturbed and higher-elevation forests [11–13]. In Ethiopian and African drylands, minimizing human and livestock disturbance enhances carbon sequestration [2,14–18]. However, carbon storage in Borana dryland forests remains poorly quantified [2,19–22]. This study addresses this gap by assessing carbon stocks across disturbance gradients.

2. Materials and Methods

2.1. Study Area Description

The study was conducted in the Gamadu Indigenous Afromontane Forest, located in the Borana Zone of southern Ethiopia. The area is characterized by dryland climatic conditions and long-standing cultural protection under the Gada system.

2.2. Sampling Design and Disturbance Classification

A total of 24 plots (10 m × 10 m) were established along low-, moderate-, and high-disturbance gradients based on canopy cover, stump density, and livestock pressure.

2.3. Biomass and Carbon Estimation

All woody individuals with dbh > 2.5 cm were measured. Aboveground biomass was estimated using allometric equations, while belowground biomass was derived using a root-to-shoot ratio. Carbon content was assumed as 46% of dry biomass.

2.4. Soil, Litter, and Deadwood Carbon

Soil samples were collected at 0–15 cm and 15–30 cm depths and analyzed using the Walkley–Black method. Litter and deadwood were sampled using subplot techniques.

3. Results

3.1. Association between Biomass Carbon and Dendrometric Variables

Biomass carbon stock of individual trees showed strong positive correlations with dbh (r = 0.95), crown diameter (r = 0.88), basal area (r = 0.87), and tree height (r = 0.79), while wood basic density showed only a weak association.

These relationships indicate that tree size and stand structure are the primary determinants of biomass carbon storage in the studied forest.

3.2. Biomass Carbon Stocks across Disturbance Levels

Biomass carbon stocks (tree + herbaceous) declined significantly with increasing disturbance intensity. Low-disturbance sites stored the highest aboveground, belowground, and total biomass carbon, while highly distured sites stored the lowest values.

Table 1. Biomass Carbon Stocks across Disturbance Levels

Carbon Pool	Carbon Variables (t/ha)	Highly Disturbed (Mean ± SD)	Moderately Disturbed (Mean ± SD)	Low Disturbance (Mean ± SD)	Prob > F
Standing Tree Carbon	AGBC	115.74 ± 12.46	149.96 ± 23.92	256.39 ± 53.96	0.000
	BGBC	30.09 ± 3.24	38.99 ± 6.22	66.66 ± 14.03	0.000
	TBC	145.83 ± 15.70	188.95 ± 30.14	323.05 ± 67.99	0.000
	$EqCO_2$	535.19 ± 57.63	693.46 ± 110.63	1185.61 ± 249.51	0.000
Herbaceous Carbon	AGBC	1.93 ± 1.36	3.48 ± 1.99	7.25 ± 4.87	0.008
	BGBC	0.50 ± 0.35	0.90 ± 0.52	1.88 ± 1.27	0.008
	TBC	2.44 ± 1.72	4.38 ± 2.51	9.13 ± 6.14	0.008
	$EqCO_2$	8.94 ± 6.30	16.07 ± 9.21	33.52 ± 22.53	0.008
Total Biomass Carbon Stock (Tree + Herbs)	AGBC	117.67 ± 11.91	153.44 ± 25.19	263.64 ± 54.46	0.000
	BGBC	30.59 ± 3.10	39.89 ± 6.55	68.55 ± 14.16	0.000
	TBC	148.26 ± 15.00	193.33 ± 31.74	332.19 ± 68.62	0.000
	$EqCO_2$	544.13 ± 55.06	709.53 ± 116.48	1219.13 ± 251.85	0.000

AGBC –aboveground biomass carbon, BGBC –belowground biomass carbon, TBC –total biomass carbon, $EqCO_2$- Equivalent carbon dioxide.

The reduction in biomass carbon from low- to high-disturbance sites reflects losses in stem density, canopy cover, and regeneration caused by anthropogenic pressures.

3.3. Litter and Deadwood Carbon Stocks

Litter carbon stocks showed minor variation among disturbance levels and were not statistically significant. In contrast, deadwood carbon increased significantly in highly disturbed sites, indicating elevated tree mortality.

Table 2. Litter and dead wood carbon stock across disturbance level

Carbon Pool	Highly Disturbed (Mean ± SD)	Moderately Disturbed (Mean ± SD)	Low Disturbed (Mean ± SD)	Prob > F
Litter C (t/ha)	8.12 ± 5.32	9.43 ± 3.13	10.40 ± 2.86	0.517
Deadwood C (t/ha)	1.42 ± 1.89	0.20 ± 0.14	0.08 ± 0.04	0.043
Total (deadwood and litter) C (t/ha)	9.54 ± 6.17	9.63 ± 3.08	10.48 ± 2.86	0.891
$EqCO_2$ (t/ha)	35.02 ± 22.64	35.35 ± 11.29	38.47 ± 10.51	0.891

3.4. Soil Organic Carbon Stocks

Soil organic carbon (SOC) stocks were highest in low-disturbance sites and declined with both increasing disturbance and soil depth. SOC in the 0–15 cm layer consistently exceeded that in the 15–30 cm layer.

Table 3. Soil carbon stock

	Soil depth	Study sites			Significance
		Highly disturbed	Moderately disturbed	Low disturbance	P values
Total soil carbon stock in t ha^{-1}	0-15cm	34.07	35.33	50.55	0.017
	15-30cm	29.45	31.51	44.72	0.012
	0-30cm	63.52	66.84	95.27	0.007

3.5. Total Ecosystem Carbon Stocks

Total ecosystem carbon stocks ranged from 363.04 t ha^{-1} in low-disturbance sites to 267.06 t ha^{-1} in highly disturbed sites, representing a decline of over 26%. Live biomass accounted for approximately 72.5% of total carbon, followed by soil carbon (24.3%), while litter and deadwood together contributed less than 4%.

Table 4. Total carbon stock of different carbon pools in t ha^{-1}

Carbon stock and CO_2 in t ha^{-1}	Study sites' disturbance levels			Average
	Highly disturbed	Moderately disturbed	Low disturbed	
Biomass carbon stock	194.00	222.50	257.29	224.60
Litter and dead wood carbon stock	9.54	9.63	10.48	9.88
Soil carbon stock (0-30cm)	63.52	66.84	95.27	75.21
Total carbon stock	267.06	298.97	363.04	309.69
Eq. CO_2	980.11	1097.22	1332.36	1136.56

4. Discussion

4.1. Relationship between biomass carbon stock and dendrometric variables

Biomass carbon stock showed a strong positive relationship with dbh, confirming dbh as the most influential predictor of tree biomass [23,25–28]. This is consistent with Chave et al. [26], who demonstrated that dbh alone explains much of the variation in tree biomass due to its reflection of cumulative growth. The positive association with basal area is therefore expected [24]. Crown diameter and tree height also correlated positively with biomass carbon, reflecting their roles in photosynthetic capacity and growth [23,25,29]. In contrast, wood basic density showed weak association with biomass carbon, as it is mainly a species-level trait with limited explanatory power when used alone [23,27,30].

4.2. Biomass carbon stock

Biomass carbon stock declined significantly with increasing disturbance, with the highest values in low-disturbance sites and the lowest in highly disturbed areas. Anthropogenic activities such as logging, fuelwood extraction, and grazing reduce stem density, basal area, and canopy cover, leading to lower biomass accumulation. Similar patterns have been reported in Ethiopian dry Afromontane forests and other dryland ecosystems [11,31–37]. Land-use change also strongly influences carbon stocks, with dense indigenous forests storing more carbon than open forests and cultivated lands [7–9,13].

4.3. Litter and deadwood carbon stock

Litter carbon stock was slightly higher in low-disturbance sites but did not vary significantly across disturbance levels, consistent with previous observations [38–40]. In contrast, deadwood carbon stock increased significantly with disturbance, reflecting higher tree mortality and physical damage associated with anthropogenic pressure [41,42]. The combined litter and deadwood carbon pool showed no significant variation, suggesting compensatory dynamics between reduced litter and increased deadwood in disturbed sites.

4.4. Soil carbon stock

Mean soil carbon stock was comparable to values reported for Ethiopian forests [43–45] but higher than those reported for Borana rangelands [15,16]. Soil carbon declined with increasing disturbance, consistent with studies showing that land-use change and grazing accelerate SOC loss by reducing organic inputs and disrupting soil structure [7,10,43,45,46]. Higher SOC in surface soils agrees with previous findings [11,28,43,44].

4.5. Total carbon stock

Total carbon stock differed significantly across disturbance gradients, with higher values in less disturbed and higher-altitude sites. Reduced accessibility, cooler temperatures, and higher moisture availability at higher elevations favor biomass accumulation and slow decomposition [32,37,49,52–54]. These findings align with studies showing higher carbon stocks under reduced disturbance [2,14,16,47].

4.6. Distribution of carbon stocks across pools

Live biomass dominated total carbon storage, followed by soil carbon, while litter and deadwood contributed marginally. This pattern is consistent with studies in Ethiopian dry forests [7,32,48,49,50,51,55] but contrasts with Borana rangelands where soil carbon dominates [2,18], reflecting ecosystem structural differences and carbon allocation strategies [7,49,56].

5. Conclusions

Forest disturbance significantly reduces carbon sequestration potential in the Gamadu Indigenous Forest. Strengthening traditional governance systems and implementing sustainable management practices are essential for conserving carbon stocks and supporting climate mitigation efforts.

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Data Availability Statement: The research data for this study is available and can be submitted upon request. The raw data (i.e., species composition, biomass measurements, carbon stock data for biomass and soil) can be made available by Mr. Dida Jilo at the following address: College of Agriculture and Environmental Sciences, Arsi University, Asella P.O. Box 193, Ethiopia; didole2000@gmail.com

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A Kim Jong-un's Successive Regime Building Process and CNC (Computerized Numerical Control) Propaganda-Agitation

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Abstract: The purpose of this paper is to identify the relation between North Korea's CNC propaganda-agitation and Kim Jong-un's successive regime. Moreover, although there are differences in time, this paper made a comparison with Kim Jong-il's period where it was the only socialist state that has completed a successive regime by bloodline. Also, based on North Korean data, this paper analyzed why the CNC technology already developed during Kim Jong-il's era is being emphasized after 2009, when Kim Jong-un's successive regime started. While most of South Korean media interpreted that CNC is only a temporary phenomenon of 'image-making of Kim Jong-un' that will not last long, North Korea already has continuously emphasized CNC by Kim Il-sung and Kim Jong-il since 1970's, according to North Korean data. In other words, CNC propaganda-agitation is used for two of the most important factors in building Kim Jong-un's own successive regime, which are 'completion of succession of power' and 'economic development'. When communicating with the Western world while picking up and utilizing the newest technology, it would be a greater burden for North Korea to expose its reality of being out of date to lots of North Korean people. Even if political purpose of succession of power may be reached through CNC propaganda-agitation, without opening up its economy with reforms, North Korea will be close to impossible to actually be successful in reaching its goal of reaching economic growth as there will be too many problems to go through.

Keywords: North Korea, Kim Jong-Un, Propaganda-Agitation, Successive Regime, CNC, Science Technique

1. Introduction

The term CNC, which stands for Computerized Numerical Control, has been frequently mentioned since 2009, coinciding with the emergence of Kim Jong-un as the successor to Kim Jong-il in North Korea. CNC machines do not rely on hand-drawn designs to create machines or factories; instead, they utilize computer-aided design (CAD) for design. Furthermore, rather than having a lathe operator manually operate the lathe to produce machines or having numerous skilled workers engaged in production processes, CNC represents advanced machinery manufacturing technology that creates machines and controls production processes through computer-aided manufacturing (CAM).In 2010, North Korea featured CNC in the backdrop of its "Arirang" performance, with the phrase "The power of CNC Juche Industry" appearing in the card section behind the stage. Additionally, a poster installed in front of the Pyongyang Department Store in 2010 displayed the phrase "CNC and Towards the World" in large letters, accompanied by scenes from the large-scale fireworks event "Chukpo Night,"

held in April 2009, and long-range rockets. The Chukpo Night event, which celebrated the birthday of Kim Il-sung, was reportedly planned and led by Kim Jong-un as part of his rise to become a successor, and there have been reports from South Korean media linking the recent CNC initiatives in various industrial facilities to Kim Jong-un's accomplishments starting from August 2009 when rumors of his succession emerged. In particular, in early October 2009, Japan's Mainichi Shimbun obtained and reported on a document glorifying Kim Jong-un, titled "Educational Materials on the Greatness of Respected General Kim Jong-un." The Mainichi Shimbun speculated that this document was used by the Ministry of People's Armed Forces or the Ministry of State Security and that, since it included information about the May Day fireworks event, it was likely drafted after that date.

The document mentioned that "Respected General Kim Jong-un has produced many inventions with new ideas and high practical value based on rich imagination and advanced science and technology. The recent launch of the 'Kwangmyongsong-2' and the 'Flames of Prosperous State' fireworks event, which celebrated the Sun Day with the respected General's personal organization and supervision, are among his achievements," citing both the satellite launch and fireworks event as linked to CNC and Kim Jong-un's accomplishments. Analysis of North Korea's concentrated propaganda surrounding CNC since 2009 can be divided into two main viewpoints. One view, held by mainstream media in South Korea, asserts that North Korea's CNC is merely a tool for image-making to formalize Kim Jong-un's status as successor, lacking any technical achievements worthy of external bragging. They regard it as a temporary 'image manipulation' related to building Kim Jong-un's successor status internally. Since 2009, North Korea's propaganda has emphasized the unity of its citizens toward entering a strong and prosperous state, particularly focusing on the idolization of Kim Jong-un, portraying his clothing, hairstyle, and mannerisms as similar to those of Kim Il-sung, suggesting a strategic intent to highlight a legacy of revolutionary tradition rather than mere hereditary succession. In practice, Kim Jong-il exhibited leadership above and beyond his position initially focused on propaganda in the early 1970s when he established his succession system. The other viewpoint sees North Korea's CNC not just as a simple propaganda tool but as a result of the science and technology-oriented policies pursued since the Kim Jong-il era, regarded as an important technological achievement to overcome economic difficulties. This paper will first analyze why the English acronym CNC, which contrasts with North Korea's traditional propaganda slogans, has been continuously emphasized in the process of building Kim Jong-un's successor system. Traditionally used North Korean slogans are primarily in Korean, such as "Chollima Movement," "Red Flag Struggle," and "Strong and Prosperous State." The direct usage of English words by a self-reliant North Korea is remarkable, considering the absolute influence that each propaganda word has on society. Additionally, it is significant that CNC is a word that encapsulates science and technology. It is common for socialist countries to emphasize science and technology when a new supreme leader assumes power. For instance, when Kim Jong-il's hereditary succession was confirmed in the 1980s, the launch of "Kwangmyongsong-1" showcased the completion of his leadership succession system both domestically and internationally.

2. Materials and Methods

Propaganda has been a significant aspect in socialist states such as North Korea, but throughout various eras and countries, rulers have used it to effectively manage the relationship between the ruling and the ruled by compelling the masses to submit to a specific belief system. The term "propaganda" combines "propagation" and "agitation." First, "propagation" in its dictionary definition means "the act of explaining and widely disseminating

a belief, claim, or the existence and efficacy of something so that many people understand it." Thus, propaganda encompasses all means of spreading or conveying images, concepts, or information that influence people's actions, either actively or passively. According to this definition, nearly all aspects of art or communication fall under the concept of propaganda, as both art and communication generally possess a message (the content or meaning being delivered) that is intended to persuade others, either intentionally or inadvertently. North Korea can be classified as a socialist state alongside the Soviet Union and China; however, it shows significant differences concerning its succession system.

These differences can be summarized in three main points. First, in North Korea, the long-term rule by a wealthy individual has persisted for over half a century without a power transition, resulting in the blockage of the emergence of elites who are not favored by the ruler. Second, because power has been inherited by the son, there cannot be any demotion campaigns against the predecessor or a revolutionary choice of alternative lines, as seen in China or the former Soviet Union. Additionally, the current structure of power elites has already been established alongside the consolidation of Kim Jong-il's successor system, making the formation of factions within the elite group difficult. Third, unlike the Soviet Union, which saw the emergence of pluralism and competitive ideologies after Khrushchev's campaign against Stalin, or Mao Zedong's principle of united struggle in China, North Korea lacks the soil for such competitive thoughts to coexist. In North Korea, only the guiding ideology and the singular line of thought are allowed; alternative lines are not permitted. The succession system and its construction process in North Korea are unique, based on Juche, the ruling ideology, which presupposes the leader's extraordinary abilities and personality, as well as the establishment of a successor to ensure the transfer of power. Furthermore, studies on the establishment of Kim Jong-un's successor system are closely related to the construction of Kim Jong-il's successor system. The logic mobilized during the establishment of Kim Jong-il's succession system in the 1980s is rooted in the inviolable nature of Juche and the concept of the leader, making research into these ideologies quite significant.

Before Kim Jong-il formally emerged as the successor, the term "Party Center" (Dang-jung-ang) was known to symbolize him. Although more indirect, "CNC" (Computer Numerical Control) symbolizes the establishment of the Kim Jong-un succession. It is no coincidence that CNC became widely known and actively propagandized in 2009, when the Kim Jong-un succession system emerged. Furthermore, the fact that an English word—usually viewed with aversion in North Korean society—was adopted as is allows us to infer that this reflects the strong will of the highest power circle. References to CNC in North Korean periodicals and various events thoroughly manufacture an image corresponding to the requirements of a North Korean successor, which can be broadly classified into three categories. First, loyalty to the Suryong (Supreme Leader) is a core element of character and quality. The successor must revere the Suryong from the bottom of their heart and possess endlessly pure and passionate ideological sentiments, devoting their all to the Suryong. Loyalty of the successor to the Suryong is defined, above all, as loyalty to the ideology put forth by the Suryong and the revolutionary cause he achieved; it is claimed that carrying out the Suryong's lines and policies is a lifelong task. The struggle to inherit and complete the Suryong's revolutionary cause is a fierce process of class struggle. Because obstructionist maneuvers by opportunists, traitors, and imperialists are constantly unfolding during this process, the revolution could be corrupted midway if the successor is not faithful to the Suryong's revolutionary ideology.

This is why loyalty is prioritized above all else. For this reason, while CNC symbolized Kim Jong-un until Kim Jong-il's death, there was never a single instance where it was directly

described as Kim Jong-un's own achievement. Everything related to CNC is praised as being pushed forward thoroughly to implement the lines and policies laid out by Kim Jong-il. The logic is that since the process of inheriting the Suryong's revolutionary cause is essentially a process of adhering to the revolutionary ideology founded by the Suryong and implementing it in revolutionary practice, the successor must be well-versed in the Suryong's revolutionary ideology and embody it perfectly. If North Korea's Juche ideology was created by Kim Il-sung, then Kim Jong-il, who systematically completed it, was the exemplar in adhering to that revolutionary ideology. Second, only an outstanding leader with extraordinary wisdom can accurately capture the aspirations of the people and the demands of the era better than anyone else, thereby leading the masses with excellent ideological theory and firm conviction. In this regard, outstanding wisdom is an essential quality for performing the successor's historical mission. One must possess leadership as an excellent leader to "make one's way through the grim, thorny path of history creation, skillfully rally the people in complex situations, and organize and mobilize their infinite creative power toward the Suryong's revolutionary cause." Third, the Suryong's successor must possess achievements that allow them to be highly evaluated as a recognized leader among the people. This is because such achievements are the externalization and realization of the leader's qualities through practice.

Therefore, the Suryong's successor, equipped with excellent qualities, is said to "build up great achievements that become the ideological-spiritual and material-cultural wealth guaranteeing the nation's prosperity and the people's happiness through energetic activities, and by doing so, is acclaimed as a recognized leader among the people." This means the successor must possess absolute authority and prestige among the people due to achievements and contributions made in revolution and construction. To obtain "achievements and contributions" as a successor, one must drive substantial development in science and technology to trigger economic growth. CNC is receiving attention in the sense that overcoming North Korea's economic hardships—which were not solved even in the Kim Jong-il era—will be an absolute element in establishing the Kim Jong-un succession system.

3. Results

Before Kim Jong-il formally emerged as the successor, the term "Party Center" (Dang-jung-ang) was known to symbolize him. Although more indirect, "CNC" (Computer Numerical Control) symbolizes the establishment of the Kim Jong-un succession. It is no coincidence that CNC became widely known and actively propagandized in 2009, when the Kim Jong-un succession system emerged. Furthermore, the fact that an English word—usually viewed with aversion in North Korean society—was adopted as is allows us to infer that this reflects the strong will of the highest power circle. References to CNC in North Korean periodicals and various events thoroughly manufacture an image corresponding to the requirements of a North Korean successor, which can be broadly classified into three categories. First, loyalty to the Suryong (Supreme Leader) is a core element of character and quality. The successor must revere the Suryong from the bottom of their heart and possess endlessly pure and passionate ideological sentiments, devoting their all to the Suryong. Loyalty of the successor to the Suryong is defined, above all, as loyalty to the ideology put forth by the Suryong and the revolutionary cause he achieved; it is claimed that carrying out the Suryong's lines and policies is a lifelong task.

The struggle to inherit and complete the Suryong's revolutionary cause is a fierce process of class struggle. Because obstructionist maneuvers by opportunists, traitors, and imperialists are constantly unfolding during this process, the revolution could be corrupted midway if the successor is not faithful to the Suryong's revolutionary ideology. This is why loyalty is prioritized above all else. For this reason, while CNC symbolized Kim Jong-un until Kim

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4. Conclusion

North Korea's claims of "newest technology" are likely political moves rather than facts. Economic growth is difficult without opening up and reform; exposing reality of outdated technology poses a burden.

While the political purpose of succession might be reached through CNC propagation, the goal of economic development is uncertain. The campaign serves to satisfy the requirements for the successor but faces challenges in actual implementation.

Section 3

Human Well-being and Sustainability

Social Ecosystem: Toxicity in the Family
Frederick Wakhisi and Charles Kimamo

Landscape Analysis of the Effects of Environmental Policies and Practices on Public Health Trajectories in Kenya from 2000 to 2025
Ali Adan Ali

The Mediating Effect of Emotional Alienation on the Relationship Between Daily Stress and Marital Stability for Married Men and Women: Focusing on Dyadic Coping
Dayoung Kwan

Community-Based Approaches as Local Institutional Mechanisms for Climate Change Adaptation: Evidence from the Eastern Tigray, Ethiopia
Tesfaalem Hagos, Tewodros Tadesse, Melaku Berhe and Bihon Kassa

SOCIAL ECOSYSTEM: TOXICITY IN THE FAMILY

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Abstract: Human development has its core in the family, the basic unit and motherboard of all institutions in the social ecosystems-existence, a critical component. The parents may not be aware of how their behavior affects their children, as it is perceived as a transmission from their ancestors on how they were raised and thus culture and not abuse. The study observes, identifies, outlines, explains and describes this family toxicity and the impact on the larger society. Toxicity is about consistency of behaviors and attitudes that directs and shapes family and subsequent social institutions' deficits\excesses. It could make or break. Every family has darkness keenly guarded. Effects of toxicity include; black sheep, golden child, scapegoat, mascot, martyr, family angel, the hero child, etc. Understanding toxicity is key in realizing homeostasis-self maintenance of a system in balance or equilibrium.

Keywords: Ecosystems, Co-existence, Toxicity, Behavior, Attitude.

1. Introduction

Toxic relationships are characterized by chronic, emotionally damaging behaviors such as manipulation, control and disrespect that leave the individuals feeling drained, unsupported and devalued. Common signs include constant criticism, gaslighting, isolation from support systems, lack of accountability, etc. These, often cause significant long-term harm to the persons mental and physical health.

Key Indicators of toxic relationship:

- Gaslighting and manipulation, making a partner question their own reality, memories or perceptions.
- Constant criticism and belittling via persistent negative comments that damage self-esteem.
- Control and jealousy, for example dictating who a partner sees, what they do, or how they dress, thereby undermining individuation.
- Lack of support and disrespect leading to ignoring boundaries and needs leading to feelings of being unvalued.
- Emotional volatility; "A rollercoaster" dynamic with extreme highs and lows.
- Persistent unhappiness, feeling tense, drained, or unsafe rather than supported.

1.1 Toxicity in Action

Family/community is a system like a car engine and related components. When one of the components goes off, the car stalls, an indication of inner finer connection not so obvious but imperative. Toxicity is about consistency of these behaviors and attitudes labeled

troublesome child but in reality, the representative of the pain in the home.

Family anxiety/dysfunction occurs when one family member goes against what is the "norm," the family goes into chaos. This means that whatever is perceived as the norm is a matter of conjecture. At such juncture the black sheep of the family/community probably is the one who cause the shift in the system. In turn the black sheep experience negative attention. They are the troublesome child, yet in reality they are the representation of the pain in the home/institution that has to be understood. The black sheep is child who carries the disease of the family. Black sheep because they speak as is where is, and therefore get punished, unlike a choleric child (extravert), the family hero – the one who wants things to happen right – the paragon of perfection. There is also the mascot (sanguine) – symbolizing optimism. While lost child symbolizes non- involvement, come what may. However, beyond the family, this is keenly and fiercely guarded. At the bottom line, every family has darkness.

Every time there is this experience, stop projecting out and do an introspection; The emotions, feeling so deeply and strongly, what have the children triggered in me so the I can heal me! Meaning there is an innate connection between ancestor and posterity stored within the subconscious. Whatever comes out the children triggers in the parent prompting some form of defense mechanism of unspoken type. Something known and felt but explained in circuitous manner. These children have not lived life before. They are living, and yours is to train them the way they should go. Do not break their spirit. Horn into and attune into what they show you they are. Here it is nuanced that toxicity is bequeathed from forefathers and inherited by posterity, hence such intense feeling from the "echo." The real self only manifests when the subconscious overrides the conscious mind to allow us a glimpse into a real person. This is not an epiphany, but those moments that you need to pay attention.

1.2 DYSFUNCTIONAL FAMILIES

Every family aspires for happiness. However, the environment that we live in is not very normal as one would expect. It is for this reason that we talk dysfunctional families that have a tendency for members to enact set roles like care giver, scapegoat, family angel/ saint, bad girl or boy that serve to restrict feelings, experience etc.

Children are often selected for and inducted into family roles inadvertently. Commonly, some chance characteristics that distinguishes the child from other family members (it need not be an obnoxious trait -it only differentiates the person) is singled out and focused on by others, emphasizing the difference between the child and the rest of them. Such roles are externally imposed because the family has discovered that this structuring is the best way to handle complex relationships within the group. Once the roles become fixed – and especially typecast as pathological, the basis for chronic behavioral disturbance is established

2. Discussions

2.1. INDUCTED ROLES

What happens when you grow up in a dysfunctional family?

You experience trauma and pain from your parent's actions, words and attitudes.

Due to this trauma, you grow up changed, different from other children, missing important parts of necessary parenting that prepare you for adulthood.

Miss parts of your childhood when you are forced into unnatural roles within your family, for example (child Parent)

It forces some people to flee the pain of the past through alcohol and drug use.

Some people feel inexplicably compelled to repeat abuses that were done to them on their children or spouse.

Feelings of anxiety or rage which one cannot explain

2.1.1. SCAPEGOAT

The person with symptoms (identified patient carries the burden of the illness in the family). The "bad egg" in the family, or the most difficult child in the family.

2.1.2. PARENT CHILD

The child who is given too much parental functions and starts to develop symptoms of mental illness, for example, in an alcoholic family, this child looks for food. This child is also the mediator when parents fight, but do not have experience or emotional capability of carrying it out. Some resort to prostitution to support the family while others develop psychological problems.

2.1.3. BLACK SHEEP

The child who carries the disease of the family. Black sheep because they speak "as is where is." And often get punished even where/when innocent.

2.1.4. MARTYR

This is a family member who is always being crucified for anything wrong. The martyr is the scapegoat.

2.1.5. FAMILY ANGEL/SAINT

A family member who cannot do wrong things. The family hero (The one who wants things to happen right).

2.1.6. THE CARETAKER

The one who takes responsibility of the emotional well-being of the family

2.1.7. THE MASCOT

The one who uses comedy to divert attention away from the increasingly dysfunctional family system.

2.1.8. THE MASTERMIND

This is the opportunist who capitalizes on the family members' faults in order to get whatever s/he wants.

2.1.9. THE LOST CHILD

This is the inconspicuous, quiet one, whose needs are often ignored or hidden.

2.2. CONTRIBUTORY FACTORS

From modern world to the contemporary, the world has changed and transformed tremendously especially with the advent of information technology, infecting and affecting the day- to - day life, inducing behavioral change and conduct leading to culture modification

at a price. These changes include:

2.2.1. COLLAPSE OF TRADITIONAL FAMILY SET UP.

Family is sacred and root from which all strength and purpose grow. Traditional Family consisted of nuclear family, extended family and community, all sort of responsible for one another. The children belonged to the community, hence the dictum, it takes a village to raise a child, highlighting an entire community - extended family, neighbors, teachers, and friends – Must support, teach, and care for children, not just the parents. All parents were parents to all the children – social fatherhood. It emphasizes collective responsibility for the child's safe, healthy upbringing. The entire community of people must provide for and interact positively with children for those children to experience and grow in a safe and healthy environment. That forgiveness, dignity, and unconditional love are foundations of families and societies. However, modernity in a record shortest period, wiped this out, leaving families/communities feeling like fish out of water. From hunting in packs hyena style to lone rangers. The social cohesion and accompanying discipline and order vanished leaving huge laguna in moral ethical infrastructure.

2.2.2. MODERNITY

Modernity "represents the quality or condition of being modern," emphasizing forward - looking attitudes, technical progress, and individualization. This is very contrary to traditional that is rooted in family and community.

The change that we see here is more of an encounter than change in structures and spirit which are brutally and ruthlessly ripped apart leaving societies/ communities in shock, stuck in the past while stranded forward. This is what escalated toxicity, as a result of disintegration of the traditional societal fabric. The two could not merge due to irreconcilable differences, despite both professing religion and God.

Many found themselves at cross roads – religious pluralism, induced via syncretism with traditional supernatural powers at heart and the modern god in mind. This resulted in a chaotic spiritual/ religious space. Truth be told, modernity offered improved upgraded life without bridging change in structures and spirit.

2.2.3. GLOBALIZATION

Globalization describes the growing interdependence of the world's economies, cultures, and populations, brought about by cross-border trade in goods and services, technology, and flows of investment, people, and information. This becomes a melting pot of the whole world. The inferior cultures aspire to embrace the perceived superior culture without requisite foundations leading to toxicity.

2.3. IMPACT

Toxicity is as old as mankind, always the driver behind human vices and subsequent impediments:

Cultural dysfunction – Distortion of beliefs and attitude changing intended world view e.g traditional Christianity vs cultural Christianity. This resulted into hundreds of sects leave alone denominations. There is no doubt we live in an era of religious pluralism

Social dysfunction – Integration and cohesion is essential for any given society despite pluralism. However, in many aspects the binding social fiber is absent. However, this is

undermined by mistrust, distrust creating factions and misunderstanding due to toxic relations. It appears like the toxicity growth is proportional to that of society itself.

Family dysfunction – The deviation from original family order is very much attributed to toxic relations enforcing disintegration of the original. The family forms the basic unit of society and foundation for all other institutions managed by people from families. This means that strong families will translate to strong institutions and vis versa. The less the toxicity in the family the better for related allied institutions.

The highest form of development is the development of person- human development. This entails the development of the inner person alongside the outer person leading to character competency and intellectual competence. This holistic individual is the quintessential global citizen.

On matters well- being, toxic relationships often culminate to decreased self- esteem, chronic stress, anxiety, depression, and physical health issues like sleep disorders. Some toxic behaviors can be addressed through therapy, others, particularly those involving abuse and lack of desire to change, may require ending relationship to ensure safety and mental health. Remember a slave detests slavery but reluctant to freedom that he has never experienced.

Toxicity hinders good will/faith in the day- to -day transactions and relations making people to be very circumspect in every endeavor. The greater good/ common good that is vital for society's hope and confidence is eroded.

2.4. MERITS

Despite what has been stated and discussed above, toxicity has its own unique merits in life that include:

In matters sports, managers often implore toxicity to psyche and rally up teams' morale to the desired results. This is well exemplified by soccer managers in dressing room talks in the break of a tough match. The same is experienced during boxing bouts. The managers charge up the players.

In power dominance situations, upcoming hegemonic candidates spur their troops toxically to gather courage of facing superior powers. Studies of child soldiers allude to that. That is why rehabilitation of child soldiers is developmentally challenged.

3. Findings

Toxicity falls under what is considered primordial in human history. However, due to societal structuralism toxicity was suppressed existing in form of underlying issues often referred to as taboo. The rigid structural social fabric kept toxicity suppressed thus unspoken due to exigencies then.

Modernity ushers in forward- looking attitudes as opposed to preservative pre-existing status. However, modernity superimposes itself without due consideration of the lay on the ground, resulting into dysfunctionalities like syncretism. Syncretism corrupts and impairs existing world view.

Good will is an essential component of a healthy vibrant society. Toxicity undermines and erodes it leaving the community/society dysfunctional.

Change is the law of nature as well as the law of history. Our ability to embrace and manage change will greatly minimize toxicity and stabilize society/community.

It is not easy to understand how toxic one is since toxicity is within and part and parcel us, our lives and activities. It is an area that requires attention and understanding in order to improve life.

4. Conclusion

Toxicity is as old as the history of mankind spanning through all human civilization and still surviving. Just like change, it is the law of nature and law history, mutating and adapting with civilizations. Thus, it may differ in form but always the same in essence. Toxicity has taught minds, touched hearts and transformed lives for worse or better.

Toxicity is something we carry unaware, but very conspicuous to the observer, who in turn is also a carrier. It is an issue that requires concerted efforts to be tackled low.

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Landscape Analysis of the Effects of Environmental Policies and Practices on Public Health Trajectories in Kenya from 2000-2025

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Abstract: Africa has undergone tremendous environmental policy reforms since Rio Earth Summit. Every country made efforts to adapt and implement the agenda 21. Kenya was not an exception as it has faced serious environmental degradation attributed to deforestation, soil erosion, water pollution, waste management and depletion of wildlife species. The aim of this article is to evaluate the landscape analysis of environmental policy evolution and management practices on public health outcomes in Kenya between 2000 and 2025. It analyzes how legislative frameworks have shaped epidemiological trends and health equity. To collect data for this article, a mixed-methods approach was employed, integrating a desk review of national policy documents and legislative frameworks with longitudinal secondary data analysis of public health indicators from the Kenya Demographic and Health Surveys (KDHS) and the National Bureau of Statistics. Some of the selected national legislations included EMCA 1999, Constitution 2010, Water Act 2026, Climate Change Act 2016/2023, Forest Act 2005/ 22, and Energy 2019, government reports and published sources. The data from the above sources was used to determine correlations between environmental policy interventions and health outcomes.

Keywords: Environmental Policies, Public Health, Climate Change, Water Management, Air Quality, Governance, Enforcement Gaps

1. Introduction

Between 2000 and 2022, Kenya's nationwide access to improved and safe drinking water sources increased markedly—contributing to an expansion from roughly 57 % to approximately 68–74 % of the population with potable water—reducing reliance on contaminated surface sources that are a key driver of waterborne infections, and this improvement in water supply and associated sanitation and hygiene policies has been linked with a measurable reduction in the incidence and prevalence of diarrhoeal diseases, particularly among children under five, through improved microbial water quality and decreased exposure to faecal-oral contamination pathways (MOW, 2025; UN 2025, KIPPRA 2024)

Kenya's strengthened climate change policy framework, including the integration of advanced early warning systems such as the Early Warnings for All (EW4All) initiative and increased budgetary allocation for disaster risk preparedness, has enhanced social and infrastructural resilience by enabling timely hazard forecasting and anticipatory action that reduce flood-related mortality and morbidity, mitigate economic losses, protect water resources and ecosystems, and support public health and sustainable development outcomes across vulnerable communities (GOK 2025, and Mbenywe, M. (2025).

Between 2000 and 2025, Kenya's progressive environmental policy reforms—including strengthened water resource management frameworks, the enactment of the Sustainable Waste Management Act (2022) to reduce pollution and promote circular economy practices, and county-level air quality action plans—have produced measurable improvements in ecosystem health and public health outcomes by reducing water contamination, controlling waste flows, and targeting air pollutant emissions; these reforms have enhanced clean water access and sanitation, lowered risks of waterborne and air pollution-related illnesses, and supported ecological function and sustainable resource use, demonstrating how integrated environmental, water, and waste management policies deliver co-benefits for environmental quality, human health, and socio-economic resilience (NEMA 2025, GOK 2022 and NCC 2025).

2. Discussions

2.1. Landscape Analysis of the Effects of Environmental Policies and Practice on Public Health Trajectories in Kenya

The historical trajectory of Kenya's environmental governance from the dawn of the twenty-first century to the mid-2020s represents an ambitious evolution from fragmented sectoral management toward a sophisticated, rights-based, and climate-responsive framework. At the heart of this transition lies a profound understanding that the ecological integrity of the nation is the primary determinant of its public health outcomes. Over the twenty-five-year period between 2000 and 2025, the Kenyan state has navigated significant legal reforms, institutional restructuring, and social shifts aimed at mitigating the burden of environmentally mediated diseases, ranging from traditional waterborne pathogens to emerging climate-sensitive zoonoses [1].

The driver of this environmental vision is rooted in an empirical recognition of the country's vulnerability. Throughout the early 2000s, it became increasingly evident that the high prevalence of respiratory conditions, diarrheal diseases, and malaria was not merely a failure of the healthcare system, but a consequence of degrading ecosystems, poor waste management, and inefficient energy use [1]. Consequently, the period between 2000 and 2025 witnessed a strategic alignment of environmental conservation and public health policy, characterized by landmark legislation such as the Environmental Management and Coordination Act (EMCA) of 1999, the Constitution of 2010, and the comprehensive Climate Change Acts of 2016 and 2023 [1].

2.2. Foundational Legislative Frameworks and the Constitutionalization of Health

The structural transformation of Kenya's environmental landscape began with the operationalization of the Environmental Management and Coordination Act (EMCA) in 1999, which provided the first integrated legal framework for environmental management. Prior to this epoch, environmental regulations were scattered across over seventy different statutes, creating a "silo effect" that rendered enforcement nearly impossible and allowed industrial pollution to directly compromise community health [2]. The establishment of the National Environment Management Authority (NEMA) served as the institutional anchor for this new era, centralizing the authority to regulate pollution, manage waste, and oversee Environmental Impact Assessments (EIA) [2].

2.3. The 2010 Constitutional Revolution

The most significant shift in the relationship between the environment and public health occurred with the promulgation of the Constitution of Kenya in 2010. Article 42 explicitly

mandates that "every person has the right to a clean and healthy environment," which includes the right to have the environment protected for the benefit of present and future generations through legislative and other measures [1]. This constitutional entrenchment elevated environmental health from a secondary policy goal to a fundamental human right, providing a legal basis for citizens to challenge state and private actions that compromise ecological safety [3].

Table 1. Legislation/Policy for Environmental Focus and Health Outcomes during 2000-2025

Legislation/Policy	Primary Period of Impact	Key Environmental Focus	Health Outcome Target
EMCA (1999)	2000–2010	Pollution & Waste Control	General morbidity reduction
Forest Act (2005)	2005–2015	Watershed protection	Waterborne disease prevention
Constitution (2010)	2010–Present	Rights-based framework	Legal accountability for health
Water Act (2016/24)	2016–2025	Resource management	Diarrheal disease suppression
Climate Change Act (2016/23)	2016–2025	Resilience & Adaptation	Disaster mortality reduction
Energy Act (2019)	2019–2025	Renewable energy shift	Respiratory health improvement

Furthermore, the 2010 Constitution introduced a devolved system of government, transferring significant environmental and health functions to forty-seven newly created county governments [3]. This devolution aimed to localize environmental management, making authorities more responsive to the specific ecological health risks faced by their constituents. However, as the synthesis of policies from 2013 to 2025 indicates, this transition also introduced complexities in jurisdictional overlap and resource allocation that continue to influence health outcomes [4].

2.4. Forestry Conservation, Hydrological Stability, and Waterborne Disease Dynamics

The relationship between forest ecosystems and public health in Kenya is mediated primarily through the hydrological cycle. Between 2000 and 2025, Kenya's forest policy shifted from a focus on timber production toward a focus on "ecosystem services," specifically the regulation of water supplies and the prevention of erosion-linked water contamination [1].

2.5. Forest Cover Trends and Restoration Efforts

At the turn of the millennium, Kenya's forest cover was in a state of crisis, having declined to approximately 6.0% by 2000 [5]. This degradation of critical "water towers"—such as the Mau Forest Complex, Mt. Kenya, and the Aberdares—resulted in erratic river flows, increased sedimentation, and a higher vulnerability to cholera and other waterborne outbreaks during flood events [6].

The implementation of the Forest Act of 2005 and its subsequent 2016 iteration initiated a period of recovery. By 2010, despite ongoing pressures, forest cover was stabilized at 5.9%, and through aggressive afforestation and the "15 Billion Trees" initiative, it rose to 8.8% by 2020/2021 [1]. Official assessments by the Kenya Forest Service (KFS) in 2022 confirmed a forest cover of 8.83% and a total tree cover of 12.13%, marking a significant milestone in the

quest to meet the 10% constitutional threshold [5].

2.6. Epidemiological Correlates of Forest Protection

The recovery of forest ecosystems has had a measurable impact on the prevalence of diarrheal diseases. Forests act as natural filtration systems, reducing the pathogen load in surface water. Synthesis of household survey data and WHO reports indicates that national access to portable drinking water increased from 57% in 2000 to 74% in 2022 [1]. This infrastructure expansion, supported by healthier watersheds, led to a direct decline in waterborne disease incidence across rural and urban peripheries [1].

Furthermore, the stabilization of the Mau Forest has been linked to more consistent water volumes in the Great Rift Valley lakes, which support the livelihoods and nutrition of millions [6]. However, the 2000–2021 period also saw significant losses in specific regions; for example, from 2002 to 2021, the nation experienced a 14% reduction in some forest types due to unregulated grazing and agricultural expansion, highlighting the uneven success of conservation policies [7].

2.7. Energy Transition and the Mitigation of Respiratory Morbidity

One of the most profound effects of environmental policy on public health in Kenya has been achieved through the energy sector. The period from 2000 to 2025 is characterized by a strategic shift away from fossil fuels and traditional biomass toward a renewable-dominated electricity grid, with significant implications for air quality and respiratory health [1].

Table 2. Forest Cover Metrics from 2000 to 2025

Forest Cover Metric	2000 (%)	2010 (%)	2021/22 (%)	2025 (Projected %)
National Forest Cover	6.0	5.9	8.83	10.0
National Tree Cover	-	-	12.13	15.0
Portable Water Access	57.0	61.0	74.0	79.0

2.8. Geothermal Advancement and Air Quality Improvements

Kenya has emerged as a global leader in geothermal energy, which now serves as the single largest generation source for grid-connected electricity [8]. Geothermal capacity expanded from roughly 200 MW in 2008 to 860 MW in 2022, and reached 954 MW by 2024 [1]. This transition is critical for health because geothermal power plants emit less than 1% of the air pollutants (SO_x, NO_x, and particulate matter) compared to coal-fired plants of equal capacity [9].

The policy vision outlined in the Energy Act of 2019 and various National Climate Change Action Plans (NCCAP) has contributed to a reduction in fine particulate matter ($PM_{2.5}$) exposure, particularly in urban areas that were previously reliant on diesel-powered emergency generators [1]. Recent air quality monitoring from 2019 to 2023 indicates that while Nairobi still faces challenges with average $PM_{2.5}$ levels around 21.7μg/m^3 (exceeding WHO annual guidelines of 5μg/m^3), the avoidance of coal and heavy fuel oil has prevented a much more severe public health crisis [10].

2.9. The Persistence of Household Air Pollution (HAP)

Despite the greening of the national grid, the "energy poverty" gap remains a primary

driver of respiratory morbidity. Approximately 68% of Kenya's primary energy consumption still comes from wood fuel and other biomass [11]. Peer-reviewed studies highlight that household air pollution (HAP) causes over 3.8 million deaths globally per year, and in Kenya, it remains a leading cause of pneumonia, stroke, and ischemic heart disease, disproportionately affecting women and children in rural settings and urban slums [12].

Environmental policies between 2015 and 2025 have increasingly focused on "clean cooking" interventions. The Kenya Climate-Smart Agriculture Strategy (2016–2027) and the NCCAP 2023–2027 prioritize the reduction of sectoral GHG emissions through efficient cookstoves and a transition to LPG or electric cooking [13]. The health benefits of these policies are substantial; reductions in biomass combustion directly correlate with decreased instances of acute respiratory infections (ARI) in children under five [14].

2.10. Geothermal Trade-offs and Localized Health Risks

A nuanced analysis of geothermal expansion reveals that "green" energy is not without localized health controversies. In the Olkaria and Menengai areas, communities have reported negative impacts including noise pollution and the release of toxic gases like hydrogen sulfide (H_2S) [12]. Some research indicates that the exposure to geothermal fluids during drilling can lead to the fouling of heavy metals, posing risks of eye irritation and neurological effects if safety thresholds are exceeded [12]. These findings emphasize that while macro-level energy policies improve national health by reducing $PM_{2.5}$, micro-level environmental safeguards are essential to protect the "just transition" for local communities [12].

2.11. Waste Management and the 2017 Plastic Bag Ban

Perhaps the most visible environmental policy success in the 2000–2025 period was the 2017 ban on single-use plastic carrier bags. This intervention provides a clear case study in how environmental regulation can produce rapid and measurable public health gains [1].

2.12. Urban Drainage and Cholera Suppression

Prior to 2017, plastic bags were the primary cause of drainage blockages in Kenya's rapidly growing cities [15]. In informal settlements, these blockages created stagnant pools of water that served as breeding micro-environments for *Anopheles* mosquitoes and reservoirs for *Vibrio cholera* [15]. The elimination of approximately 6.2 billion bags from the national waste stream relieved the pressure on municipal drainage systems and improved the functionality of sewerage infrastructure [15].

Scientific data from the 2017–2019 period indicates a sharp decline in cholera cases. In Nairobi and Homa Bay, cholera cases decreased by 85% compared to the 2014–2015 period [16]. While other multisectoral interventions were active, the removal of the environmental "clogging" factor is cited as a significant contributor to this epidemiological shift [1].

2.13. Toxins and the Food Chain

The plastic ban also addressed long-term risks associated with toxin exposure and the food chain. Before 2017, up to 50% of sampled livestock had plastic bags in their stomachs, which impacted animal health and, subsequently, the safety of the human meat supply [15]. Furthermore, the reduction in open-air burning of plastic waste—a common practice in areas with inadequate waste collection—lowered the release of greenhouse gases and carcinogenic fumes, directly benefiting localized respiratory health in urban slums [15].

2.14. Climate Change Adaptation and Emerging Health Vulnerabilities

As Kenya moves toward 2025, climate change has emerged as the most significant threat to the public health gains achieved in the early part of the century. The policy response has evolved from general environmental protection to specific climate-health adaptation strategies [17].

Table 3. The plastic bags Ban before and after

Variable	Pre-Ban (2014-2016)	Post-Ban (2017-2019)	Change (%)
Est. Bags in Waste Stream	~100M/month	Near Zero (Market-based)	-99.0
Cholera Cases (Kenya)	16,500	14,074	-16.0
Cholera Cases (Sampled Counties)	-	-	-85.0
Reusable Bag Ownership	Low	12 bags/household	+300.0

2.15. The Expansion of Climate-Sensitive Diseases

Recent research (2000–2024) indicates that rising temperatures and precipitation variability are altering the map of disease in Kenya. Higher temperatures have facilitated the expansion of malaria suitability into the Kenyan highlands, placing previously unexposed populations at risk [18]. Simultaneously, prolonged droughts in the Arid and Semi-Arid Lands (ASALs) have worsened food insecurity and malnutrition, which remains a principal risk factor for child mortality [17].

The Climate Change Act of 2016 (amended in 2023) and the National Climate Change Action Plan (NCCAP) 2023–2027 provide the legal framework for addressing these risks [19]. These policies prioritize:

- **Disaster Risk Management:** Reducing the impact of floods and droughts through early warning systems [1].
- **Water and Food Security:** Enhancing the resilience of the agricultural sector and ensuring equitable water apportionment [2].
- **Health System Integration:** Mainstreaming climate adaptation into the health sector to manage the geographic expansion of vector-borne diseases and the surge in heat-related conditions [20].

3. The Research and Policy Gap in Northern Kenya

A critical synthesis of over 350 peer-reviewed articles reveals a significant geographic bias in environmental health research. Approximately 90% of research is concentrated in the Lake Victoria Basin, the Rift Valley, and the Coast [17]. There is a profound lack of data and health surveillance in the northern ASAL regions, which are the most climatically fragile and vulnerable to drought [17]. This lack of baseline evidence hampers the development of evidence-informed health policies for pastoralist communities, who face unique challenges such as tribal conflicts over water and gendered violence triggered by weather shocks [17].

Table 4. Health Topics Research (2000-2023)

Health Topic Focus (Research)	% of Articles (2000-2023)	Key Disease/Exposure
Vector-Borne Diseases	41.0	Malaria, Aedes vectors
General Environment	59.0	Water, Air Pollution, Social Determinants
Injury & Death	2.8	Flood/Drought mortality
Heat Exposure	1.9	Fetal strain, Heat stress
Mental Health	1.9	Psychosocial stress of drought

3.1. Socio-Environmental Awareness and Behavioral Change

The effectiveness of environmental policies in Kenya is increasingly tied to levels of public awareness and compliance. Between 2000 and 2025, Kenya achieved a 55-percentage point increase in environmental awareness, rising from 30% to a projected 85% [1].

3.1.1. Drivers of Consciousness

This 183% relative improvement in awareness is attributed to several factors. First, the 2017 plastic ban acted as a powerful behavioral trigger, forcing citizens to find alternatives and making the link between waste management and environmental health a daily conversation [1]. Second, the constitutional right to a clean environment has empowered civil society and the media to report on environmental degradation and its health impacts more aggressively [21].

However, public concern remains volatile. While 47% of Kenyans cite deforestation as their top global concern (the highest globally), a 2025 survey showed a decline in abstract climate concern as war and conflict dominated public worries [22]. This suggests that policy messaging must continue to link environmental protection directly to tangible local benefits, such as water security and disease prevention, rather than abstract global goals [23].

3.1.2. Governance Challenges and Implementation Gaps

Despite the robust legislative framework developed between 2000 and 2025, Kenya continues to face significant hurdles in policy enforcement. The National Environment Management Authority (NEMA) and other lead agencies often possess the legislative tools they need but lack the political will or financial resources to enforce them effectively [4].

3.1.3. Jurisdictional Friction and "Silo" Planning

The transition to a devolved system has sometimes resulted in jurisdictional overlaps and conflicts. For example, solid waste management is a county function, but national pollution standards are set by NEMA [24]. This can lead to a "blame game" where national agencies and county governments split resources and create unnecessary bureaucracy [3].

Furthermore, health and environmental sectors still largely operate independently regarding policy formulation and budgeting [25]. For instance, while the Climate Change Act 2016/2023 mandates mainstreaming climate change into all sectors, many county-integrated development plans (CIDP) still lack clear links between climate adaptation and public health outcomes [25].

3.1.4. Sustainable Financing and the FLoCCA Opportunity

One of the most promising developments in the 2020–2025 period is the Financing of Locally-Led Climate Action (FLoCCA) program. By performing health assessments on grassroots climate projects, Kenya has a "real opportunity" to achieve synergy between climate and health funding [25]. This approach addresses the persistent challenge of limited funding specifically allocated to the climate-health nexus, where donor funding traditionally targets only one sector [25].

4. Future Outlook and Strategic Recommendations

As Kenya approaches the end of this twenty-five-year synthesis, the path forward requires a more integrated "One Health" approach that bridges the gap between scientific innovation and real-world implementation. The next phase of environmental health policy (2025–2030)

must shift toward the integration of "human metrics" into environmental monitoring. Instead of measuring forest cover or MW of energy in isolation, the government should adopt transmission metrics—such as the molecular force of infection (mFOI) for malaria or water quality indices—that directly relate ecological changes to desired epidemiological outcomes.

To accelerate the gains made in the early 21st century, the following strategies are essential:

- **Closing the ASAL Evidence Gap:** Prioritizing research and health infrastructure in northern Kenya to prepare for the intensifying impacts of drought on maternal and child health [17].
- **Addressing the HAP Crisis:** Transitioning the focus from national grid greening to aggressive household-level clean energy access to tackle the leading cause of respiratory disease [12].
- **Formalizing "One Health":** Establishing a permanent institutional link between the Ministry of Health and the Ministry of Environment to coordinate zoonotic disease surveillance and climate adaptation [17].
- **Strengthening Legal Accountability:** Empowering NEMA and county environmental committees to move beyond "lenient" supervision and enforce solid waste and water quality regulations through stricter sanctions and rewards [24].

5. Conclusion

In conclusion, the synthesis of Kenya's environmental policies and practices between 2000 and 2025 demonstrates that legislative reform can produce measurable improvements in ecosystem health and public health outcomes. However, the emerging risks of the climate crisis, combined with persistent governance gaps and regional research disparities, require a new era of proactive, integrated, and well-financed environmental health stewardship [1].

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The Mediating Effect of Emotional Alienation on the Relationship Between Daily Stress and Marital Stability for Married Men and Women: Focusing on Dyadic Coping

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Abstract: This study (N=450) examined how daily stress impacts marital stability. Results showed that stress negatively affects stability, partially mediated by emotional alienation. Notably, dyadic coping moderated this mediation, suggesting that enhancing mutual coping strategies and emotional support can effectively mitigate stress-induced alienation and improve marital stability

Keywords: Daily stress, Marital stability, Emotional alienation, Dyadic coping

1. Introduction

Rapid changes in modern society, characterized by nuclearization and economic instability, have shifted the focus of marriage toward emotional support, where unmet expectations increase the risk of dissolution [1]. Given that marital stability directly impacts the quality of life for the entire family [2-3], identifying its predictors is crucial. Notably, accumulated daily stress serves as a latent risk factor that undermines marital relationships [4] and weakens interactions, leading to emotional alienation [5].

Based on the stress-divorce model, this study analyzes the impact of daily stress on marital stability. Specifically, it examines the mediating role of emotional alienation and the moderated mediating effect of dyadic coping—a strategy that strengthens bonds and protects relationships under stress [6]. The ultimate goal is to provide foundational data for practical interventions to enhance marital stability.

2. Materials and Methods

Participants and Data Collection Data were collected from October 17 to October 20, 2024, through an online panel survey involving 450 married men and women (aged 20–69) residing nationwide in South Korea. The sample was balanced by gender (49.6% male, 50.4% female). Key demographics included a high percentage of individuals in their 30s (37.1%), university graduates (90.9%), and dual-income households (68.7%). Only legally married individuals were included, and all procedures were conducted following institutional approval.

2.1. Measures

2.1.1. Daily Stress

Measured using a Korean version of the Daily Hassles Scale (DHS). It consists of 36 items on a 5-point Likert scale (Cronbach's α = .94).

2.1.2. Marital Stability

Assessed using the Marital Instability Index (MII) modified for the Korean context. All 18 items were reverse-coded so that higher scores indicate higher stability (Cronbach's α = .96).

2.1.3. Emotional Alienation

A 3-item scale focusing on feelings of loneliness and lack of understanding within the relationship with one's spouse (Cronbach's α = .89)

2.1.4. Dyadic Coping

Measured using 20 items from the Dyadic Coping Inventory (DCI). It assesses how couples support each other through empathy and practical help (Cronbach's α= .91).

2.2. Data Analysis

Statistical analysis was performed using SPSS 28.0, AMOS 28.0, and PROCESS MACRO v7.0.

3. Results

This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation, as well as the experimental conclusions that can be drawn.

3.1. Descriptive Statistics and Correlation AnalysisSubsection

Descriptive statistics for the primary variables—daily stress, marital stability, emotional alienation, and dyadic coping—confirmed that all data met the assumptions for normality. Correlation analysis revealed that marital stability had a significant negative (-) correlation with daily stress (r = -.40, p < .01) and emotional alienation (r = -.73, p < .01). Conversely, a significant positive (+) correlation was found with dyadic coping (r = .51, p < .01), indicating that marital stability is higher when stress and alienation are low and the couple's collective coping level is high.

3.2. Relationship Between Daily Stress and Marital Stability

Analysis of the direct impact of daily stress on marital stability showed that daily stress has a significant negative (-) effect on marital stability (β = -.36, p < .01). This implies that as the level of perceived minor hassles or daily stress increases, the psychological and behavioral stability of the marital relationship directly decreases.

3.3. Mediating Effect of Emotional Alienation

The study examined the mediating role of emotional alienation in the relationship between daily stress and marital stability. The results indicated that daily stress significantly increases emotional alienation (β = .36, p < .001), which in turn acts as a major factor undermining marital stability. Bootstrapping analysis confirmed the statistical significance of this indirect path, empirically validating the mediating mechanism where stress harms the relationship by creating emotional distance.

3.4. Moderated Mediating Effect of Dyadic Coping

An analysis of whether dyadic coping buffers the relationship between stress and alienation revealed a significant interaction effect between daily stress and dyadic coping on emotional alienation ($B = -.28, p < .01$). This suggests that the higher the couple's ability to cope with stress together, the weaker the negative impact of stress on emotional alienation. Ultimately, the moderated mediation index was significant, proving that high levels of dyadic coping serve as a critical resource for protecting marital stability by blocking the harmful indirect effects of stress.

Table 1. The Effect of Daily Stress on Marital Stability Mediated by Emotional Alienation (N = 450)

Model 1		Model 1 Dependent Variable: Marital Stability		Model 2 Dependent Variable: Emotional Alienation		Model 3 Dependent Variable: Marital Stability	
		β(S.E)	*t*	*β(S.E)*	*t*	*β(S.E)*	*t*
Constant		(.35)	18.02***	(.41)	-2.56*	(.27)	21.36***
Control Variables	Age	-.14(.01)	-1.11	.36(.01)	2.87**	.10(.01)	.99
	Satisfaction with Economic Life	-.10(.06)	-2.25	.14(.07)	3.24**	-.07(.04)	-.19
	Length of Marriage	-.01(.01)	-.09	-.21(.01)	-1.51	-.15(.01)	-1.40
	Number of Children	-.09(.06)	-1.32	.08(.06)	1.18	-.04(.04)	-.73
Independent Variable	Daily Stress	-.36(.07)	-7.98***	.36(.08)	8.08***	-.12(.06)	-3.35**
Mediating Variable	Emotional Alienation					-.66(.03)	-18.03***
R^2		.22		.24		.55	
F		24.53***		28.43***		89.55***	

**$p < .01$, ***$p < .001$

Table 2. Significance Test of the Indirect Effect of Emotional Alienation (N = 450)

Path	*B*	*S.E*	**95% CI**	
			LLCI	**ULCI**
Daily Stress → Emotional Alienation → Marital Stability	-.36	.05	-.47	-.26

Bootstrap samples = 5,000

Table 3. Significance Test of the Indirect Effect of Emotional Alienation (N = 450)

Variable	*B*	*SE*	*t*	95% CI	
				LLCI	ULCI
Constant	1.87	.34	5.48***	1.20	2.54
Age	.01	.01	1.13	-.01	.03
Satisfaction with Economic Life	.07	.06	1.18	-.04	.18
Length of Marriage	-.01	.01	-.63	-.02	.01
Number of Children	.01	.05	.12	-.10	.11
Daily Stress	.57	.07	8.56***	.44	.70
Dyadic Coping	-.93	.07	-14.06***	-1.06	-.80
R^2 = .49, F = 59.90***					
Significance Test of the Interaction Term	*B*	*SE*	*t*	95% CI	
				LLCI	UCLI
Daily Stress × Dyadic Coping	-.28	.09	-3.10**	-.46	-.10
R^2 = .01, F = 9.59**					
Conditional Effects of Dyadic Coping	*B*	*SE*	*t*	95% CI	
				LLCI	ULCI
M-1SD	.73	.09	8.42***	.56	.89
M	.57	.07	8.56***	.44	.70
M+1SD	.42	.08	5.12***	.26	.57

**p < .01, ***p < .001

4. Discussion

Daily Stress was found to have a significant negative effect on marital stability. This result confirms that the stress-divorce model, originally proposed in Western contexts, is applicable to Korean couples regardless of cultural differences. In particular, this study empirically demonstrated that factors threatening marital stability are not limited to major life events such as infidelity or violence; rather, the accumulation of daily stress alone can shake the very foundation of a relationship [7-8]. This suggests that managing an individual's daily stress, in addition to marital interaction, is key to enhancing marital stability.

Furthermore, Daily Stress undermines marital stability through the mediation of emotional alienation. This supports prior research [9] indicating that as stress accumulates, mutual consideration and commitment between spouses diminish, leading to emotional alienation and a subsequent decline in marital quality. These findings illustrate that emotional alienation is a decisive predictor of marital stability [10] and highlight the necessity of professional intervention to prevent emotional isolation, ensuring that couples do not perceive minor issues as major conflicts during stressful periods.

Lastly, dyadic coping serves as a critical protective factor that blocks the pathway through which stress escalates into emotional alienation. The finding that higher levels of dyadic coping mitigate the negative impact of stress aligns with Family Stress Theory [9]. This empirically proves that a strategy of perceiving a spouse's distress not as an individual problem but as a collective challenge—and responding to it together—acts as a powerful buffer that strengthens emotional bonds and maintains marital stability [10].

5. Conclusions

First, the finding that daily stress significantly influences marital stability highlights that factors threatening a relationship are not limited to major life events such as infidelity or domestic violence. This study newly confirms that the accumulation of seemingly minor daily hassles, which are often overlooked, can be a decisive factor in destabilizing a marriage [11]. This suggests that high levels of daily stress can cause couples to perceive small issues as significant conflicts, potentially shaking the foundation of the relationship. Thus, managing daily stress is a paramount task for maintaining a stable marriage.

Second, the mediating role of emotional alienation in the relationship between daily stress and marital stability suggests that while managing stress itself is a primary solution, psychological intervention to prevent emotional alienation is crucial when stress is unavoidable or experienced by both spouses. In other words, the key to maintaining a relationship lies in preventing external environmental stress from escalating into emotional disconnection between partners. Third, the result that dyadic coping acts as a protective factor—effectively moderating the indirect path through which daily stress undermines marital stability via emotional alienation—demonstrates the critical importance of perceiving a spouse's stress as a "joint task" rather than an individual problem. When couples collaborate effectively during times of distress, their emotional bond is strengthened and alienation is reduced, providing the strength to sustain the marriage stably even in crisis situations.

The academic and practical implications of this study are as follows. First, by incorporating emotional alienation and dyadic coping into the stress-divorce model, this study expanded the model's scope to include marital stability and established a theoretical foundation applicable to Korean couples [12]. Second, it broadened the perspective of marital research by empirically demonstrating the influence of daily stress, which had previously been overlooked. Third, the discovery of the mediating role of emotional alienation provided a specific identification of the psychological mechanism through which stress destroys a relationship. Finally, by confirming the moderating effect of dyadic coping, this study provided useful foundational data for developing tailored intervention and education programs aimed at strengthening emotional bonds and enhancing marital stability in counseling settings.

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Community-Based Approaches as Local Institutional Mechanisms for Climate Change Adaptation: Evidence from the Eastern Tigray, Ethiopia

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Abstract: Climate change poses a major threat to the livelihood security of smallholder farmers in developing countries such as Ethiopia. Although national adaptation initiatives have expanded in recent years, a persistent gap remains between policy frameworks and the lived realities of local communities where adaptation must take place. This study explores the role of community-based groups as local institutional mechanisms facilitating climate change adaptation and mitigating climate-driven impacts. A qualitative research design was employed, drawing on semi-structured interviews, focus group discussions, and key informant interviews. Findings reveal that community institutions, including soil and water conservation committees, reforested area user groups, water user groups, hillside land administration committees, and natural resource development groups, play vital roles in organizing collective action, mobilizing resources, and promoting adaptive practices. The community level institutions perform various activities such as conservation committees coordinate land rehabilitation, reforested user groups support afforestation, and water user groups manage irrigation and domestic water use. Despite limited human and financial resources, agricultural extension workers and local NGOs enhance these groups' adaptive functions through technical and institutional support. The study concludes that strengthening community groups within national adaptation frameworks is vital to bridge the gap between policy ambitions and grassroots realities.

Keywords: Community groups, Local institutions, Climate change adaptation, Ethiopia

1. Background and Rationale

Climate change poses a profound threat to the livelihood security of smallholder farm households in developing countries, particularly in Sub-Saharan Africa where agriculture remains predominantly rain-fed and highly sensitive to climatic variability [1,2]. Ethiopia exemplifies this vulnerability, as fluctuations in rainfall patterns and rising temperatures directly affect agricultural productivity, natural resource availability, and rural welfare [3]. While national and international adaptation initiatives have expanded over the past two decades, empirical evidence consistently highlights a persistent gap between top-down policy frameworks and the realities of adaptation at the local level [4].

Recent climate change scholarship increasingly recognizes that adaptation is inherently local, shaped not only by biophysical exposure but also by social, political, and institutional contexts [5,6]. Institutions structure incentives, regulate access to resources, and mediate collective action, thereby influencing both vulnerability and adaptive capacity [7,8]. However, much of the existing literature continues to prioritize national policies and formal public institutions, often overlooking community-based groups that operate closest to vulnerable

households. This oversight limits understanding of how adaptation actually unfolds on the ground.

Against this backdrop, this study investigates the role of community-based groups as local institutional mechanisms for climate change adaptation in Eastern Tigray, Ethiopia. The region is characterized by recurrent droughts, land degradation, and limited livelihood diversification, making it a critical context for examining locally embedded adaptation processes [9]. By foregrounding community institutions, this study contributes to bridging the gap between national adaptation strategies and grassroots realities.

2. Objectives of the Study

The study pursued three interrelated objectives: (i) to identify and document local community-level groups engaged in climate change adaptation; (ii) to examine the specific roles these groups play in facilitating adaptation practices and reducing livelihood vulnerability; and (iii) to analyze interactions among community groups and between community institutions and formal public and non-governmental actors in shaping collective adaptive capacity [4].

3. Conceptual Framework

The study conceptualizes institutions as human-constructed formal and informal structures that shape social interaction and collective behavior [7]. Drawing on institutional theory, community-based groups are understood as civic institutions that operate alongside public and private actors, governed by locally embedded rules, norms, and decision-making processes [10]. In the context of climate change, such institutions influence adaptation by mobilizing labor and resources, coordinating collective action, disseminating knowledge, and linking households to external support systems [8].

A conceptual framework was developed to illustrate the interaction between climate stressors, community-based institutions, and adaptation outcomes. The framework emphasizes the mediating role of local institutions in translating external interventions, such as extension services, NGO support, and national adaptation plans, into locally appropriate and actionable responses [6].

4. Methodology

A qualitative research design was employed to capture the institutional dynamics of adaptation at the community level [11]. The study was conducted in two districts of the Eastern Zone of Tigray Regional State, selected for their exposure to climatic variability and the presence of multiple community-based institutions.

Primary data were collected through semi-structured interviews, focus group discussions (FGDs), and key informant interviews. Four FGDs were conducted with members of community groups, local administrators, and extension agents. In addition, twelve key informants, including community group leaders, development agents, and sector experts, were interviewed. Data collection focused on perceptions of climate change, adaptation practices, institutional roles, and patterns of interaction among actors.

Qualitative data were analyzed using thematic analysis, allowing for the identification of recurrent patterns and themes related to institutional functions, coordination, and constraints.

5. Key Findings

The findings reveal that a diverse set of community-based groups play a central role in facilitating climate change adaptation in the study areas. These include soil and water conservation committees, reforested area user groups, water user groups, hillside land administration committees, and natural resource development groups (NRDGs). Each group performs distinct but complementary functions that enhance local adaptive capacity.

Soil and water conservation committees mobilize community labor for land rehabilitation activities such as terracing, bund construction, and check dams, which reduce soil erosion and improve moisture retention consistent with the findings of Abiye [3]. Reforested area user groups manage communal enclosures, promoting afforestation and sustainable resource use which is similar to the findings discussed by Berhe & Hoag [12]. Water user groups regulate access to irrigation and domestic water sources, helping communities cope with increasing water scarcity that corroborated with results identified by Grum et al. [13]. Natural Resource Development Groups (NRDGs), often supported by local governments, serve as focal institutions for coordinating adaptation planning and linking community initiatives with district-level development plans

Despite limited financial and human resources, these institutions demonstrate strong local legitimacy and organizational capacity. Agricultural extension services and non-governmental organizations, particularly regional NGOs, provide technical support, training, and material inputs that strengthen institutional effectiveness [14,15]. However, the study also identifies significant constraints, including shortages of extension personnel, uneven external support, and weak coordination between local and higher-level institutions [8].

6. Discussion

The results underscore that community-based institutions function as critical platforms for translating climate risks into collective adaptive action. Their effectiveness stems from their embedment in local socio-cultural contexts, which facilitates trust, participation, and compliance with communal rules [16]. These findings align with broader institutional literature emphasizing that adaptation outcomes depend not only on resource availability but also on the quality of institutional arrangements [17].

Nevertheless, the study highlights that local institutions cannot operate in isolation. Their adaptive potential is significantly enhanced when supported by coherent national adaptation frameworks, responsive extension services, and sustained NGO engagement [1]. Weak vertical coordination and limited resource flows from higher governance levels constrain the scalability and sustainability of community-led adaptation efforts.

7. Conclusions and Policy Implications

This study provides empirical evidence that community-based groups constitute a vital institutional foundation for climate change adaptation in Eastern Tigray. Strengthening these locally embedded institutions is essential for reducing livelihood vulnerability and enhancing resilience among smallholder farmers. Policy efforts should prioritize institutional capacity building at the community level, improve coordination across governance scales, and formally integrate community groups into national and regional adaptation planning [4,15].

By highlighting the central role of grassroots institutions, this study contributes to advancing institutional perspectives on climate change adaptation and offers practical insights

for designing context-sensitive and inclusive adaptation strategies in developing-country settings.

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