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FROM SMOG TO STEWARDSHIP: THE "DUAL-LOOP" GOVERNANCE MODEL FOR PLANETARY SUSTAINABILITY DRIVEN BY WOMEN'S LEADERSHIP IN FUKUOKA, JAPAN

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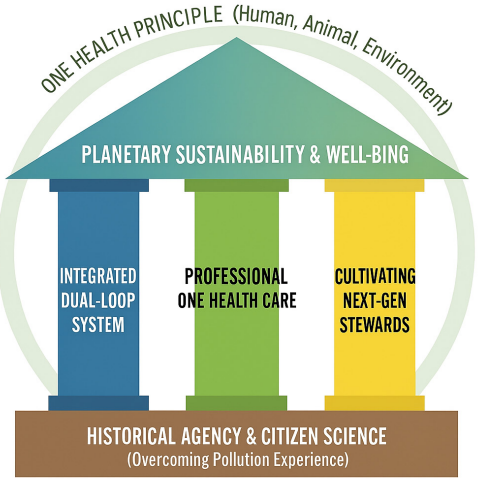
HIGHLIGHTS

- Proposes the "Dual-Loop" Governance Model as a novel framework integrating the technological Macro Loop (Fukuoka Method's ≥ 50% methane reduction) with the social Micro Loop (community-led resource circulation and nature-positive entrepreneurship)
- Establishes women's networks as the catalytic force that drives the "Dual-Loop" synergy, demonstrating how the private-sphere "Ethics of Care" is institutionalised into public-sphere scientific agency (Citizen Science) and professional competence (99.6% female JDA-DAT)
- Grounds Planetary Health in One Health Metrics, providing quantitative evidence linking the model to global goals via UNFCCC-approved climate mitigation and the use of urban beekeeping as bioindicators for influencing local environmental policy

GRAPHICAL ABSTRACT



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ABSTRACT

As cities worldwide confront the escalating challenges of the Anthropocene, Fukuoka, Japan, exemplifies a transformative approach shaped by both top-down directives and grassroots leadership. Notably, women have played a pivotal role in redefining environmental governance through care, scientific engagement, and entrepreneurship. This review analyses Fukuoka's sustainability trajectory through the frameworks of Planetary Health and One Health. The "Dual-Loop" Governance Model is introduced, consisting of a technological Macro Loop and a social Micro Loop. By integrating historical policy records, quantitative disaster resilience data (JDA-DAT), and educational curricula from Fukuoka Women's University (FWU), this article demonstrates the institutionalisation of women's agency into professional competency. While

recognising the interaction between administrative and technological factors, the analysis indicates that the Micro Loop, led by women, substantially enhances system efficacy. The Fukuoka model is presented as a potential blueprint for other Asian cities, contingent upon specific administrative capacities and community structures.

Introduction

Integrating Planetary Health and One Health

The Anthropocene epoch presents complex, cascading risks that require a fundamental transformation in urban governance (Whitmee *et al.*, 2015). The Planetary Health framework has emerged to address these challenges, emphasising the dependence of human civilisation on natural systems. In addition, the One Health approach, actively promoted by Fukuoka Prefecture, operationalises this connection by asserting that human, animal, and environmental health are inseparable (Zinsstag *et al.*, 2011).

While Japan remains characterised by a significant gender gap in formal political spheres, the Fukuoka region offers a compelling counter-narrative. Here, women's leadership has acted not merely as a participant force but as a catalytic agent, accelerating environmental governance reform. Utilising Feminist Political Ecology (FPE) (Rocheleau *et al.*, 1996), we argue that Fukuoka's women successfully transmuted the private-sphere "Ethics of Care" (Tronto, 1993) into public-sphere scientific and political agency.

This article conceptualises Fukuoka's sustainability mechanism as the "Dual-Loop" Governance Model. We aim to demonstrate how the professionalisation of care and nature-positive entrepreneurship have optimised this structure, creating a resilient urban system that addresses the holistic mandates of One Health.

Materials and Methods

To ensure transparency and scientific rigour, this study employs a qualitative case study approach integrated with conceptual framework development. The methodology is structured into the following components:

1. Case selection and scope: Fukuoka City was selected as the primary case due to its unique historical transition from industrial pollution to a global leader in waste management and One Health initiatives. The scope spans from the 1960s (grassroots movements) to 2025 (current institutionalisation at Fukuoka Women's University).
2. Data triangulation and sources: This study triangulates multiple data sources to mitigate bias and enhance reproducibility:
   (a) Historical archives: Review of municipal records and community documents from the Tobata Women's Association.
   (b) Quantitative environmental metrics: Data on GHG emission reductions (UNFCCC methodology AM0093) for the Fukuoka method and municipal waste statistics related to home composting (approximately 40% reduction per household).
   (c) Institutional records: Professional statistics from the Japan Dietetic Association (JDA-DAT, 2023) and educational curricula from Fukuoka

Women's University (e.g., EAT and Davis programmes).

3. Analytical lens: We apply Feminist Political Ecology (FPE) to analyse the transmutation of the "Ethics of Care" from the private sphere into professional public agency. This lens allows us to move beyond gender essentialism by focusing on institutionalised leadership and scientific citizenship.
4. Limitations and uncertainties: We acknowledge that while engineering metrics substantiate the Macro Loop, the Micro Loop's impact involves behavioural uncertainties. This study addresses these by focusing on professionalised agency (e.g., JDA-DAT) rather than individual volunteerism as the primary unit of analysis.

Historical Foundation: Institutionalising Care as Citizen Science

The epistemic foundation of Fukuoka's environmental governance was laid during the 1960s industrial pollution crisis in Kitakyushu. The Tobata Women's Association initiated a movement motivated by the immediate health risks to their families (Nakamura, 2002).

Critically, their methodology transcended protest. Through Citizen Science, they utilised standardised dust fall collectors to measure airborne particulate matter (Corburn, 2005). While the shift in local policy was also influenced by national regulatory pressures and industrial reputation risks, process tracing reveals that the women's data acted as a critical lever. By visualising verified data in the documentary We Want Blue Skies, they provided the undeniable evidence needed to compel the local administration to establish Japan's first specialised pollution control bureau in 1971 (Fujikura, 2001).

Urban Resilience: Professionalisation of Care

In the context of climate-induced disasters, Fukuoka has advanced the professionalisation of care, aligned with One Health.

Central to this is the Japan Dietetic Association Disaster Assistance Team (JDA-DAT), with a membership that is 99.6% female (Table 1). Unlike general volunteers, JDA-DAT provides specialised nutritional triage (Tsuboyama-Kasaoka, 2018) to assess vulnerable populations (infants, elderly) and prevent secondary health disasters. As shown in Table 1, the organisation is structurally gendered, leveraging the high participation of women in the dietetics profession to provide specialised public health interventions.

Table 1: Composition and institutional framework of JDA-DAT

Category	Statistic/Description	Source
Gender ratio	99.6% female (Approx. 50,000 members nationwide)	Japan Dietetic Association (2023)
Command chain	Prefecture request → JDA HQ → Deployment	Disaster Relief Act Protocols
Primary function	Nutritional triage, special needs meal planning	JDA-DAT Guidelines
Training	5,000 + certified specialists (as of 2023)	JDA Annual Report

Through this structure, JDA-DAT provides nutritional triage, assessing vulnerable populations (infants, the elderly) to prevent secondary health disasters. This creates a pipeline of female experts with the competence to manage public health crises, transforming care work into essential social infrastructure.

This expertise is structurally reinforced by regional higher education. Universities specialising in nutritional sciences integrate JDA-DAT protocols into their curricula, utilising Problem-Based Learning (PBL) to simulate resource-constrained scenarios. This creates a pipeline of female experts with the competence to manage public health crises, transforming care work into essential, high-value social infrastructure.

The "Dual-Loop" Circular Economy: Integrating Technology and Nature-Positive Entrepreneurship

Fukuoka's sustainability is sustained by the synergy between two resource cycles, the "Dual-Loop" Governance Model (Figure 1).

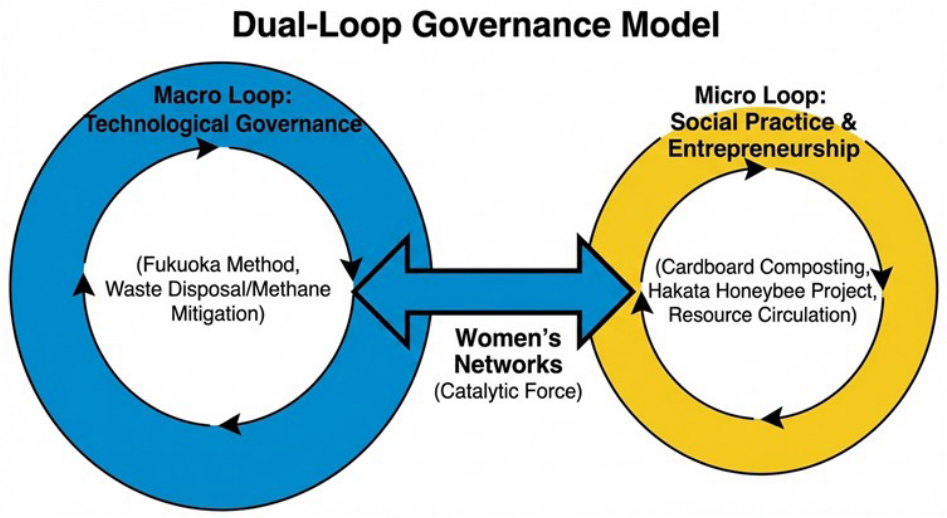

Figure 1: Operational dynamics of the Dual-Loop Governance Model: Resource and agency flows
Note: The model illustrates the interaction between the technological Macro Loop and the social Micro Loop, with women's networks acting as the catalytic force at the intersection.

The Macro Loop: The Fukuoka Method (Technology and Mitigation)

The administrative backbone is the Fukuoka method (semi-aerobic landfill). By utilising natural aeration, this mechanism significantly reduces methane (CH_4) emissions, a potent greenhouse gas. Under UNFCCC methodology (AM0093), this process is recognised for reducing methane emissions by approximately 50% or more compared to anaerobic landfills (Table 2). This technological efficiency represents the Macro Loop, providing the systemic capacity for waste management that is now being transferred to the Global South (Hulme, 2017).

Table 2: GHG emission comparison between traditional anaerobic landfill and the Fukuoka method

Feature	Traditional Anaerobic Landfill	Fukuoka Method (Semi-Aerobic)
Aeration mechanism	None (sealed)	Passive air intake via leachate pipes
Dominant bacteria	Anaerobic	Aerobic
Methane generation	100% (baseline)	~50% or less
UNFCCC status	Baseline scenario	Approved methodology (AM0093)

Source: Hirata *et al*. (2012)

The Micro Loop: One Health and Social Entrepreneurship

The Micro Loop is driven by women's agency and aims to promote behavioural change and ecological regeneration.

1. Cardboard composting: Disseminated through women's networks, this method diverts kitchen waste from the Macro Loop. Quantitative studies indicate that participating households reduce combustible waste by approximately 40%, significantly lowering the municipal incineration load (Schroeder *et al.*, 2019)
2. Hakata Honeybee Project (nature-positive entrepreneurship): This initiative exemplifies the intersection of One Health and Social Entrepreneurship.
3. Bioindicators: Led by female entrepreneurs using urban rooftops, the project utilises honeybees as sensitive bioindicators. The health of the bees reflects the environmental integrity of the city (air quality, floral diversity), thereby linking animal health to human environmental quality (Colla & MacIvor, 2017).
4. Food education and economy: The project monetises ecosystem services by branding urban honey, creating a Nature-Positive business model. This demonstrates that economic viability can coexist with ecological restoration. It provides food education (Shoku-iku) to citizens, illustrating that urban spaces can generate terroir and biodiversity (Hakata Honeybee Project, n.d.).

Cultivating Future Stewards: Institutionalising Knowledge at FWU

FWU's foundation itself is an act of historical agency, established in 1923 as the first public women's professional school in Japan, originating from the demands of Fukuoka women for advanced educational opportunities. This legacy positions FWU not merely as a modern institution, but as a historical champion of women's access to professional expertise (Fukuoka Women's University, n.d.).

FWU's educational philosophy is centred on glocalisation, deliberately bridging historical wisdom and contemporary expertise:

1. Scientific literacy and expert competency: Curricula provide rigorous scientific training in health and environmental sciences, equipping students to apply knowledge ethically and often integrating historical and contemporary best practices, such as JDA-DAT protocols, into their learning.
2. Systems thinking and practical engagement (EAT/Davis programmes): The EAT (East

Asian Tales of Food) programme is designed to foster systems thinking by analysing the entire food system from production to consumption, tackling complex issues at the juncture of the Macro and Micro Loops (e.g., food loss, sustainable technology). Furthermore, the collaboration with the University of California, Davis provides students with global perspectives on food security, climate change, agriculture, and international resource governance, enhancing their expertise.

3. Institutional guarantee of leadership: To ensure the transition from knowledge to action, the university established the Women's Leadership Centre (WLC). The WLC serves as the final institutional interface, providing dedicated training in policy-making, ethical governance, and negotiation, thereby converting specialised knowledge into adequate public-sphere leadership competency. This centre actively reproduces the legacy of grassroots female leadership within the formal governance structure.

Through this comprehensive approach, FWU assures that the ethical perspective and technical rigour necessary for the model's success are continuously cultivated in the next generation of women leaders.

Discussions and Conclusions

This review confirms that Fukuoka's transition is supported by a governance ecosystem in which women's leadership serves as a catalytic force. However, the success of this "Dual-Loop" system relies on the synergy between administrative technology and civic engagement.

Boundary conditions and scalability, while the Fukuoka model offers a blueprint for Asian cities, its transferability is not automatic. As outlined in Table 3, successful implementation requires specific boundary conditions to be met.

Table 3: Conditions for scalability of the Fukuoka model

Boundary Condition	Key Requirement	Potential Failure Modes and Risks
Administrative	Transparency and technology acceptance	Technological lock-in: Resistance from existing large-scale incineration interests is preventing the shift to semi-aerobic systems
Sociocultural	High social capital and women's agency	Patriarchal resistance: Cultural barriers that exclude women from formal decision-making, reducing the Micro Loop to unpaid domestic labour
Educational	Specialised curricula and professional paths	Brain drain: Lack of local institutional support causes trained experts (e.g., nutritionists) to leave the region, leading to loop fragmentation

It is crucial to note that the scalability of the Fukuoka model is not a normative guarantee but depends on the synchronisation of both loops. The model faces potential failure modes in contexts where administrative opacity or rigid patriarchal structures prevent the catalytic force of women's networks from being professionalised. Without institutional agency, the Micro Loop risks remaining as isolated volunteerism, failing to provide the necessary

social feedback to the Macro Loop. Future research should investigate causal mechanisms across diverse global contexts to identify specific thresholds at which these failure modes occur.

Policy Implications for the Global Community

While Figure 1 illustrates the operational dynamics, specifically how resource flows and agency circulate between the technological Macro Loop and social Micro Loop, Figure 2 provides the structural architecture. This distinction clarifies that the model is not merely a set of processes (Figure 1) but is anchored in historical foundations and institutional pillars (Figure 2) that support the overarching goal of One Health.

1. Mandate One Health in technology transfer: International development projects (e.g., transferring the Fukuoka method to Southeast Asia) must integrate One Health principles. This requires including female public health and ecological experts in the initial design phase to address local biological and social vectors.
2. Invest in care infrastructure: Governments must reclassify specialised care work, such as disaster nutrition and community composting networks, from volunteerism to essential public infrastructure and budget for it accordingly.
3. Support nature-positive entrepreneurship: Policy should actively incentivise micro-businesses (like urban beekeeping) that generate economic value while restoring urban biodiversity, recognising them as vital components of the Micro Loop.

Ultimately, the Fukuoka model demonstrates that effective planetary stewardship is achieved by integrating the rigorous engineering of the Macro Loop with the ethical, life-centred leadership of the Micro Loop.

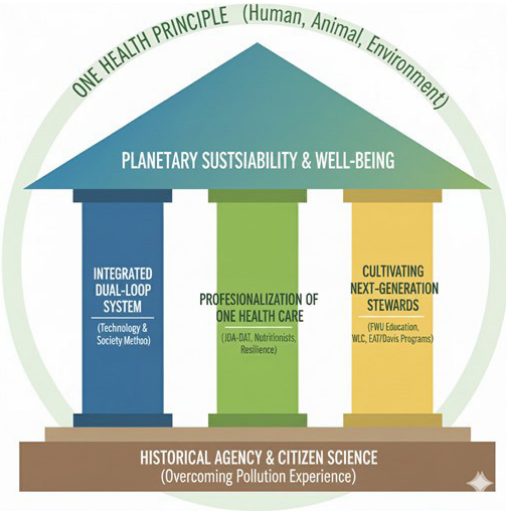

Figure 2: Structural architecture of Fukuoka's governance for planetary stewardship

Note: The framework illustrates how urban governance is built upon the Historical Foundation of Citizen Science. The three pillars: Integrated Dual-Loop, Professional Care, and Next-Generation Cultivation are unified under the One Health Principle. The core mechanism is the dynamic interaction between the Macro and Micro Loops, catalysed by women's networks, supporting the goal of planetary stewardship.

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Conflict of Interest Statement

The author declares no conflict of interest.

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