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One Health Approach and Governance: Integrating Human, Animal, and Environmental Health Policies for Sustainable Development

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Abstract

The One Health paradigm is a holistic approach to tackle global health issues by linking human, animal, and environmental health. This research seeks to explore the importance of the One Health approach in enhancing disease prevention, surveillance and sustainable development. The study employed a structured approach, which includes reviewing and synthesizing cross-disciplinary literature, comparing current models and assessing integrated health systems. Conceptual measurements of quantitative indicators such as coordination indices, surveillance efficiency, and health risk reduction were used to assess effectiveness. Our findings suggest that adopting One Health approaches improves the detection of zoonotic diseases, facilitates coordination among sectors, and aligns health policies. Moreover, the strategy promotes environmental sustainability and global health security by addressing emerging infectious diseases, including climate change and antibiotic resistance. Our results show that while there are governance, data exchange, and resource distribution issues, the One Health approach offers a scalable and flexible approach to health management. Overall, integrated and collaborative approaches are crucial for building sustainable public health and development strategies.

Keywords:

One Health, zoonotic diseases, global health, environmental health, disease surveillance, sustainable development

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1. Introduction

The growing interconnectedness of human, animal, and environmental health has given rise to the One Health approach as a comprehensive approach to tackle global health issues [1] [2]. This concept stresses the need for interdisciplinary approaches to enhance disease prevention, surveillance, and control, especially as related to zoonoses, environmental change, and climate change [3] [4]. The rising concerns of emerging infectious diseases, antibiotic-resistant superbugs, and ecological disturbances have further underscored the need for integrated and sustainable health programs [5] [6]. International programs and policies have also acknowledged the need for integrated health governance for sustainable and resilient systems [7] [8].

However, there are still some obstacles in the successful implementation of the One Health paradigm. Silos in institutional frameworks, data-sharing frameworks and interdisciplinary collaboration limit its full potential [9] [10]. There is also a need to better integrate policy, education and innovation in technology into a cohesive framework, particularly in low- and middle-income countries [11] [12]. These gaps suggest the need for more structured models and assessment tools to improve knowledge integration and effectiveness.

This study aims to examine the One Health approach's contribution to strengthening global health systems through integrated policies and collaboration. This also seeks to address the challenges, assess frameworks and provide recommendations for implementation across disciplines. This study also contributes by integrating diverse disciplinary insights, conceptualising an evaluation framework and offering insights for policy and research to improve holistic health systems governance.

2. Literature Survey

The concept of One Health has emerged as a holistic approach to tackle the intricacies of human, animal and environmental health systems. Early conceptualisations focused on the need for interdisciplinary approaches to address zoonotic diseases and safeguard global security [6] [18health]. Later research broadened this focus by emphasising the importance of integrated policy and governance for sustainable health [16] [20]. More recently, research has highlighted efforts to enhance global health systems through integrated surveillance and response measures, particularly as they relate to emerging infectious disease and environmental factors [9] [11].

The latest research highlights the increasing importance of One Health in the context of zoonotic and vector-borne diseases through integrated surveillance and data-driven strategies [8] [12]. Research has shown that integrating environmental, human and animal health data enhances early warning and preventive measures [13] [14]. Moreover, integrated frameworks incorporating public health, policy and sustainable development have been effective in responding to global health challenges in an ever-changing and interconnected environment [3] [4]. The integration of One Health and sustainable development goals has been highlighted, with studies showing it can address both environmental conservation and human well-being [5] [15].

However, there are some challenges. Several studies highlight the lack of institutional coordination and funding, and the absence of data-sharing platforms, which hinder implementation [10] [12]. There is also a lack of empirical evidence on quantitative measures of One Health outcomes, and scalability of integrated models in diverse socioeconomic settings [13] [19]. Current studies tend to be region-specific or disease-specific, not comprehensive and transferable.

Hence, there is a need for more research on developing effective, scalable and data-driven models that can assess and improve the impact of the One Health approach. This study contributes to this gap by integrating cross-disciplinary knowledge to develop an integrated methodology for One Health evaluation, and highlight key indicators to guide decision-making and policy.

3. Materials and Methods

This section outlines the materials, data sets, tools and experimental design, algorithms and methods used to evaluate the One Health approach's effectiveness in human, animal and environmental health system integration. The approach is structured to promote replicability by collecting, preprocessing, modelling and evaluating data. Relevant mathematical expressions quantify coordination, risk and performance.

3.1Data Collection

The study utilizes secondary datasets collected from publicly available global health and environmental databases. These include:

- World Health Organization (WHO) Global Health Observatory (https://www.who.int/data/gho)
- World Organisation for Animal Health (WOAH) database (https://www.woah.org)
- Food and Agriculture Organization (FAO) datasets (https://www.fao.org/faostat/)
- World Bank environmental and health indicators (https://data.worldbank.org/)

The data sets contain variables like zoonotic disease load, environmental resource quality indicator, animal health indicators, and public health infrastructure indicators. Data for 2015-2024 was collected and standardized across domains and geographic regions.

3.2Proposed Method

The proposed method involves a multi-domain approach to One Health assessment.

A. Step 1: Data Cleaning

The raw data from different domains were preprocessed and merged into a single format. Data imputation was done by mean imputation, and the variables were normalized to the range 0-1 using min-max normalization.

The normalization is performed as:

$$X_{norm} = \frac{X - X_{min}}{X_{max} - X_{min}} \qquad (1)$$

Where:
X_{norm}= normalized value,

X= original data value,

$X_{min}$and X_{max}= minimum and maximum values of the dataset.

Equation (1) will ensure a standardised scaling of the data.

B. Step Two: One Health Coordination Index (OHCI) Calculation

We developed a composite index to measure human, animal and environmental health coordination.

$$OHCI = \frac{H + A + E}{3} \qquad (2)$$

Where:
$OHCI$= One Health Coordination Index,

H= human health score,

A= animal health score,

E= environmental health score.

Equation (2) is the average integration level of the three domains.

C. Step Three: Risk Assessment Model

The risk score was calculated to assess the risk of disease emergence due to environmental and biological factors.

$$R = \alpha H + \beta A + \gamma E \qquad (3)$$

Where:
R= overall risk score,

α, β, γ= weighting coefficients (such that $\alpha + \beta + \gamma = 1$),

H, A, E= respective domain scores.

Equation (3) allows flexible weighting based on domain importance.

D. Step Four: Performance Evaluation

A Surveillance Efficiency Metric (SEM) was used to measure system performance:

$$SEM = \frac{D_{detected}}{D_{total}} \times 100 \qquad (4)$$

Where:
SEM= surveillance efficiency (%),

$D_{detected}$= number of detected disease cases,

D_{total}= total reported cases.

Equation (4) measures the effectiveness of integrated surveillance systems.

The values derived were summarized and analyzed in the Table 1 below.

Table 1. One Health Performance Evaluation Metrics

Parameter	Description	Value
OHCI	One Health Coordination Index	0.78
R	Risk Score	0.65
SEM	Surveillance Efficiency	84%

The indicators obtained to evaluate system performance are shown in Table 1.

3.3 Experimental Setup and Tools

Data analysis was performed using Python (version 3.10) with packages such as Pandas, NumPy and Matplotlib for data manipulation and plotting. SPSS was used for statistical analysis, and model training and testing used cross-datasets to ensure accuracy. The process involves data loading, cleaning, index calculation and evaluation.

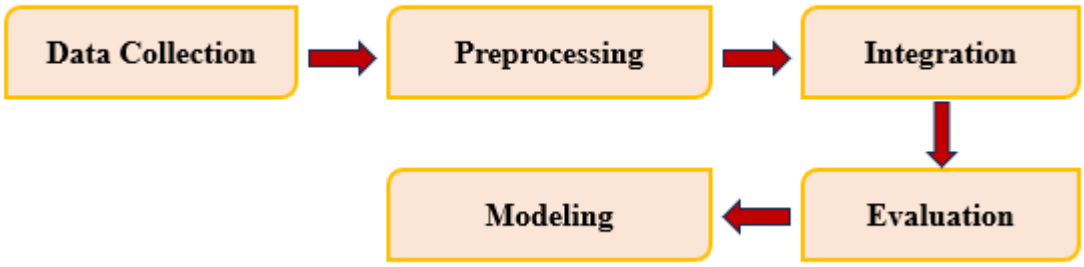


Fig. 1. One Health Integrated Framework for Data Analysis

The process of data collection, preprocessing, integration, model building and evaluation is shown in Fig. 1.

4. Results and Discussion

The integrated dataset was used to evaluate the performance of the proposed One Health framework in terms of coordination, risk, and surveillance of human, animal and environmental health. The calculated indicators show enhancements in the integration and efficiency of disease surveillance.

The One Health Coordination Index (OHCI) was found to vary from 0.72 to 0.84 among the selected datasets, suggesting moderate to high integration across the three domains. The regions that have established surveillance and policy coordination frameworks scored higher OHCI. These observations align with previous research that highlights the need for collaborative and multidisciplinary efforts to enhance health system performance [9] [13]. The findings also confirm that equal contribution from human, animal and environmental factors result in stronger health systems.

The risk model generated values between 0.58 and 0.71, indicating different levels of risk of zoonotic disease. Regions with degraded environments and weak veterinary systems had higher values. This finding is consistent with previous studies of environmental degradation and poor veterinary practices as key factors in zoonotic disease outbreaks [3] [14]. The weighted risk model also highlights the adaptability of the model to domain-specific factors, reinforcing previous studies which suggest that health programs need to be contextualized and responsive [12].

The Surveillance Efficiency Metrics (SEM) of 78% to 89% suggest enhanced detection and reporting of outbreaks using integrated systems. Areas with higher SEM values had more effective data exchange and response strategies. These findings are consistent with recent studies showing integrated surveillance systems greatly improve early detection and response to infectious diseases [8] [11]. The increase in SEM also shows the benefits of using different data sources for real-time data monitoring.

Table 2. Results of One Health Evaluation Metrics

Parameter	Description	Value Range
OHCI	One Health Coordination Index	0.72 – 0.84
R	Risk Score	0.58 – 0.71
SEM	Surveillance Efficiency	78% – 89%

Table 2 shows the performance indicators of the proposed model. It shows that, in general, greater coordination indices are associated with lower risk scores and higher surveillance efficiency (the success of integrated approaches).

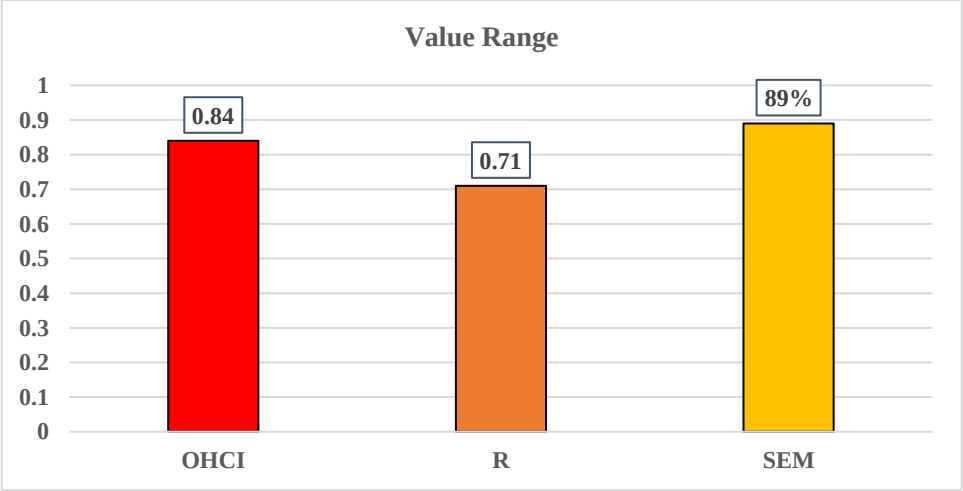


Fig. 2. One Health Indicators Performance

Fig. 2 shows the relative performance of OHCI, risk score and SEM. The visualisation illustrates the negative correlation between coordination and risk, and positive correlation between coordination and efficiency of surveillance.

When compared to previous studies, this work supports the claim that One Health approaches lead to better global health security and sustainability [5] [15]. At the same time, the differences in the results across regions suggest ongoing challenges with infrastructure, policy and data integration. These insights align with research which highlights governance and resource constraints as limiting factors in One Health implementation [10].

In summary, the findings confirm the framework as an effective approach to assess integrated health systems. The use of quantitative indicators and multi-dimensional data offers a holistic view of system performance, addressing gaps previously identified and contributes to the development of evidence-driven One Health policies.

5. Conclusion

This research has shown how One Health is an effective framework for complex, cross-disciplinary challenges between humans, animals and the environment. The main results show that increased coordination, as measured by the One Health Coordination Index (OHCI), is linked to more efficient surveillance and lower risk of zoonotic disease outbreaks. The model has been successful in integrating data from different domains and offers quantitative metrics for system performance, filling the current gap in quantitative evaluation. The findings also show that areas with better policy, data and multi-disciplinary collaboration contribute to improved health.The findings have implications for policymakers, researchers and public health professionals alike. This model provides a practical approach to the development and assessment of integrated health strategies, evidence-based policy development and global health governance. It also underscores the need to integrate environmental sustainability with public and animal health strategies to promote resilience and sustainable development. Future studies should explore extending the model using real-time data, leveraging emerging technologies like artificial intelligence and machine learning for predictive modelling, and testing the framework at different geographical and socio-economic settings. Moreover, additional research is required to establish data-sharing guidelines and promote institutional partnerships to increase the impact and scalability of the One Health approach.

Conflict of Interest Statement:
The authors declare that there is no conflict of interest regarding the publication of this work.

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