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Redefining Farm Risk: A Biosecurity and Proximity-Based Evaluation Matrix

Hamid Ragab Orban^{1*}

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ABSTRACT

Biosecurity, in current farm evaluation procedures, is typically assessed through general inspection checklists that often presume compliance with the stipulated minimum distance requirements. However, such assumptions may overlook the nuanced role of biosecurity in mitigating disease risks. Additionally, farm assessments conducted for import certification or domestic recognition frequently lack standardized criteria, resulting in inconsistent and potentially inequitable evaluations. This article introduces a structured, risk-based farm evaluation matrix comprising eight criteria, categorized into severity and probability dimensions. Each criterion is rated at three levels, low, medium, and high, with corresponding numerical weights (5, 10, and 15) to enable consistent scoring. The Risk-Based Farm Score (RBFS) is calculated by multiplying the average scores of severity-related and probability-related criteria. To evaluate the matrix's applicability, all attributes were held constant except for regulatory compliance and proximity to neighboring farms, each tested at three levels. Results demonstrate a clear inverse relationship between regulatory compliance and (RBFS), with higher regulatory compliance associated with lower risk scores. In contrast, proximity to other farms correlates with higher (RBFS), though its influence is less significant than that of regulatory compliance. Standard deviation analysis reveals greater variability in (RBFS) across compliance levels, underscoring the critical role of regulatory adherence in determining farm risk. Adoption of the developed farm evaluation matrix globally could enhance transparency, reduce trade barriers, and promote safer agricultural trade.

INTRODUCTION

Livestock and poultry production significantly impacts the environment, affecting water quality, air pollution, and soil health (Scanes, 2018). The impact of the animals is proportional to their numbers. Furthermore, the World Trade Organization set a legal framework that organizes trade between countries, the objective of the framework is to eliminate trade barriers and ease trade without compromising countries' rights to protect their domestic trade. Among the negative impacts of animals on the environment, the risks of transboundary pests and diseases is receiving more attention by countries and international organizations, this is intensified after the COVID-19 pandemic. Organizations like the World Organization for Animal Health (WOAH) and the Food and Agriculture Organization of the United Nations (FAO), together with the World Health Organization (WHO), set the health and sanitary measures to minimize the spread of transboundary diseases. Individual countries set their domestic standards and legislations to protect themselves from these diseases. The set standards and legislations in most of the cases include minimum distances between the different plant and animal activities. Furthermore, almost all countries assure the safety and quality of the food and feed consumed by the inhabitants and animals regardless of their origin, that is imported or domestically produced. In case of imported food, most of the countries conduct visits to evaluate the control procedures in the exporting countries, this evaluation is

based on the importing country's criteria. The use of the importing country's criteria might encore extra costs on the exporting country resembling a burden and a possible trade barrier.

Currently there are hundreds of criteria and attributes which are used and can be used by countries to evaluate agriculture farms and livestock farming, however there is no common matrix that uses predefined and agreed evaluation criteria that can be used by different countries to minimize the variation in the evaluation outcomes while considering the discretion of each country.

The current article argues that the development of a unified global farm evaluation matrix, featuring clear, standardized, and easily measurable attributes, has the potential to eliminate trade barriers between countries. By reducing discrepancies in biosecurity and quality standards between importing and exporting nations, such a matrix would facilitate smoother agricultural trade and promote the global exchange of agricultural commodities while ensuring the stipulation of strict biosecurity measures that minimize the negative impact of animal farming on the environment.

LITERATURE REVIEW

Biosecurity is defined by the World Organization for Animal Health (WOAH) as a set of management and physical measures designed to reduce the risk of introduction, establishment and spread of animal diseases, infections or infestations to, from and within

¹ Abu Dhabi Agriculture and Food Safety Authority, Abu Dhabi, United Arab Emirates

* Corresponding author's e-mail: hamidorban@outlook.com

an animal population (World Organization for Animal Health, 2023). Several approaches for assessing on-farm biosecurity exist varying in their purpose, implementation, and outputs (Alarcón *et al.*, 2021; Fathelrahman *et al.*, 2020; Gelaude *et al.*, 2014; Martínez-Guijosa *et al.*, 2021; Sasaki *et al.*, 2020; Tilli *et al.*, 2022; Zaabar *et al.*, 2025).

Maye and Chan (2020) reported that biosecurity is a complex, multi-layered and increasingly problematic term that manifests variously around agriculture and animal disease as forms of discourse, socio-material practice and risk politics. Furthermore, Huber *et al.* (2022) defined biosecurity measure (BSM) as the implementation of a segregation, hygiene, or management procedure, excluding medically effective feed additives and preventive/curative treatment of animals, that specifically aims at reducing the probability of the introduction, establishment, survival, or spread of any potential pathogen to, within, or from a farm, operation or geographical area. Zanon *et al.* (2024) reported that despite the suboptimal adoption of biosecurity measures, which they attributed to structural limitations in mountain farms and farmers awareness gaps, the economic significance of biosecurity adoption is evident. Moreover, Fadel *et al.* (2012) recommended that serious decisions should be taken by local authorities to remove poultry farms from urban areas to protect investments, society and the environment. However, Fathelrahman *et al.* (2020) reported that in the United Arab Emirates, poultry farms address biosecurity preparedness

differently based on the scale, that is, large or small, and on the purpose of production, that is, broilers or layers. The authors findings indicated the low influence of the distance to the nearest farm on the vaccination use.

MATERIALS AND METHODS

Current procedures for assessing livestock farms' compliance with the regulations often assume the adherence of the farms to the distance requirements, where such requirements exist. Additionally, biosecurity compliance is typically evaluated through its inclusion in the general inspection checklists. This tends to obscure the critical importance of biosecurity, regardless of the weight assigned to its components within the checklist.

It is common for official authorities to evaluate and qualify farms in other countries for import-related purposes. Similarly, domestic farm competitions and awards are frequently held, however, the evaluation methods used for these purposes vary widely, often lacking standardized or shared assessment attributes.

Farm Evaluation Matrix

In the current article, eight criteria were defined and utilized as components of the severity and probability dimensions within the farm evaluation matrix. Each criterion was categorized into three evaluation levels: low, medium, and high. Table 1 presents the eight evaluation criteria along with their definitions.

Table 1: Farm Evaluation Matrix

Evaluation Dimension	Criteria	Description
Severity	Distance D	Compliance to the distance requirement as per the pertaining regulations in the country.
	Farm Age Fage	Considers the age of the farm buildings, in general the older the building the higher the biosecurity risks.
	Number of farms within 10 KM Radius Fn	For most of the diseases, emergency responses require testing and restricting movement within a set radius. 10 kilometers is the commonest of the radii for most of the animal diseases. The more the neighboring farms within the radius, the higher the risks.
	Number of Activities An	It is not uncommon that a farm practices more than an activity, which are mostly complementary to the main farm activity. The more the activities in a farm the higher the risks.
	Activity Risk Level RL	Each activity has a risk which varies according to the risk leveling methodology adopted by the authority. Activities with high risks will impact the Farm Evaluation Result FER
Probability	Production Size Psize	The production of the farm is related to the farm size and/or the production intensity. The larger the farm production, the higher the risks.
	Regulatory Compliance RC	Results of the compliance of the farm to the pertaining regulations in the country and or to the international standards reflect its compliance to biosecurity. It will not be uncommon if a separate checklist for the biosecurity compliance is developed and used for the evaluation of the FER.

	Disease Outbreaks Dout	Generally, the stricter the implementation of biosecurity measures in a farm, the lower the probability of disease outbreaks. The number of disease outbreaks reported during the data collection period can serve as an indicator of the farm's compliance with biosecurity protocols.
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Risk-Based Farm Score (RBFS)

The farm evaluation formula uses the evaluation result of the severity and probability criteria as shown in the following formula:

$$RBFS = \bar{x} (D, Fage, Fn, An, Rl) * \bar{x} (Psize, RC, Dout)$$

Where,

RBFS : farm evaluation result

D : distance from nearest farm

Fage : age of the farm constructions

Fn : number of farms within 10 kilometers radius

An : number of activities in the farm

Rl : risk level of the farm activity

Psize : production size

RC : regulatory compliance

Dout : number of disease outbreaks

Criteria Range (Width)

The range, or width, of each criterion level should be determined through a simple calculation based on the distribution of available data. Once established, this range is divided into three distinct categories: low, medium, and high. To facilitate quantitative evaluation, numerical weights are assigned to each category, 5 for low, 10 for medium, and 15 for high. This structured approach enables consistent scoring and comparison across farms, enhancing the reliability of the evaluation matrix.

Risk-Based Farm Score (RBFS)

The performance of a farm against the criteria listed in Table 1, excluding the distance from the nearest farm, can typically be assessed using data from the inspection database. However, when the evaluation is conducted by an importing country, it is advisable to perform an on-site biosecurity inspection during the visit. This

inspection should follow a standardized checklist that has been shared in advance with the relevant authority in the exporting country to ensure consistency and transparency. The Risk-Based Farm Score (RBFS) is calculated by multiplying the average score of the severity-related criteria by the average score of the probability-related criteria, as outlined in the proposed formula. A lower Final Evaluation Result FER indicates better overall farm performance in terms of biosecurity and risk management.

RESULTS AND DISCUSSION

The current article defines the attributes of a risk-based farm evaluation matrix designed to assess the risk level of farms. To evaluate its applicability, all risk attributes listed in Table 1 were held constant, except for distance from the nearest farm and regulatory compliance. Each of these two variables was tested at three levels, low, medium, and high, and the corresponding Risk-Based Farm Score (RBFS) was calculated. Figure 1 illustrates the results, showing a consistent decline in the Risk-Based Farm Score (RBFS) as the level of regulatory compliance increases from low to high. This decline coincides with the increase in the level of compliance to the distance from neighboring farms. The lowest and highest Risk-Based Farm Score (RBFS), 58.3 and 105.0, were observed at the combination of the high and low levels of the two attributes respectively. This finding implies that strict compliance with regulations is associated with lower farm risk under the current scoring framework, potentially due to increased operational constraints or reporting rigor. The distance from the nearest farm shows a reverse relationship with Risk-Based Farm Score (RBFS), that is the closer a farm is to its neighbors, the higher its Risk-Based Farm Score (RBFS).

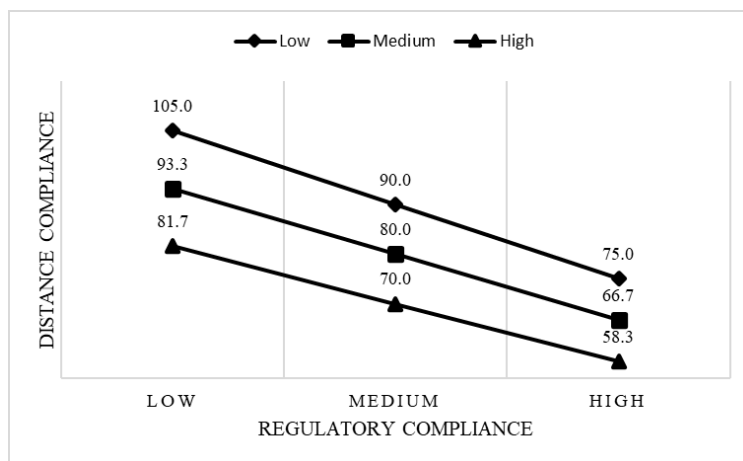


Figure 1: Effect of Distance and Regulatory Compliance on Risk-Based Farm Score (RBFS)

Upon visualization of the standard deviations SD of the Risk-Based Farm Score (RBFS) results in Table 2, the small standard deviation value of the mean of the Risk-Based Farm Score (RBFS) at the high distance score indicates the homogeneity of the results

Moreover, further insights can be drawn from the standard deviation values of the Risk-Based Farm Score (RBFS) across the low, medium, and high levels

of the evaluation matrix, as presented in Table 2. These values reveal greater variability in the (RBFS) results, which could primarily be attributed to differences in the regulatory compliance among farms. In practical terms, this suggests that regulatory compliance has a more pronounced impact on (RBFS) than the distance from neighboring farms.

Table 2: Risk-Based Farm Score (RBFS)

Regulatory Compliance Score	Distance Score			
	Low	Medium	High	Mean $\pm$ SD
High	81.7	70.0	58.3	70.00 $\pm$ 9.55
Medium	93.3	80.0	66.7	80.00 $\pm$ 10.86
Low	105.0	90.0	75.0	90.00 $\pm$ 12.25

Remarkably, although farms located in close proximity to others tend to exhibit higher Risk-Based Farm Score (RBFS) values, this spatial factor appears to exert a relatively minor influence on the farm risk score compared to regulatory compliance. These findings align with Fathelrahman *et al.* (2020), who observed that proximity to neighboring farms has limited impact on the adoption of vaccination as a biosecurity measure. Similarly, the current study supports the conclusions of Zanon *et al.* (2024), emphasizing the critical role of biosecurity measures in minimizing the risk score of the farm.

However, the results of the developed Risk-Based Farm Score (RBFS) matrix do not support the recommendations of Fadel *et al.* (2012), which advocated for the relocation of poultry farms away from urban areas. The current findings suggest that such recommendations lack empirical support, as spatial proximity alone does not significantly influence the farm risk under the proposed evaluation matrix.

Moreover, in countries where farm distance regulations were developed after the establishment of some existing farms, the Risk-Based Farm Score (RBFS) results from this study indicate that stipulating the regulations retrospectively will have a minimal impact on the overall farm risk. This finding highlights the limited effectiveness of distance-based regulations when not integrated into initial planning frameworks. More importantly, it underscores the need to contextualize risk attributes, particularly regulatory compliance, as central to effective biosecurity management. Prioritizing evidence-based regulatory compliance measures over spatial requirements offers a more accurate and practical approach to assessing and mitigating biosecurity risks in agricultural systems.

CONCLUSION

The current study presents a novel approach to evaluating farm risk by applying risk analysis principles within a structured matrix of eight attributes, five related to risk severity and three to risk probability. Each attribute is clearly defined, categorized into three levels, and assigned

numerical weights, enabling a consistent and quantifiable assessment of farm performance. The case study findings reveal that regulatory compliance has a significantly greater influence on the Risk-Based Farm Score (RBFS) than proximity to neighboring farms, underscoring the critical role of biosecurity in protecting agricultural systems.

In the context of international trade, the findings of this study support the adoption of the proposed matrix to harmonize farms assessment both within and across countries. Such a standardized framework would enhance transparency, build trust among trading partners, and facilitate the safe and efficient global exchange of agricultural commodities. inconsistencies and potential trade barriers.

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