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ORIGINAL

Methodological architecture of territorial intelligence for the delimitation of potential epidemiological corridors of the New World screwworm Cochliomyia hominivorax in central Mexico

Arquitectura metodológica de inteligencia territorial para la delimitación de corredores epidemiológicos potenciales del gusano barrenador del ganado Cochliomyia hominivorax en el centro de México

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ABSTRACT

Objective: To develop a methodological architecture of territorial intelligence to integrate agroclimatic, epidemiological and territorial information, with the purpose of delimiting potential epidemiological corridors of the cattle screwworm Cochliomyia hominivorax in the Region of the Volcanoes, State of Mexico. Methodology: An observational and retrospective design was used based on three sources of information: official outbreak records from SENASICA and WOAH, data from the GORRIÓN Agroclimatic Network and territorial connectivity variables. The architecture integrated four complementary components: the GORRIÓN Borer Risk Index, the Epidemiological Proximity Index, the Territorial Connectivity Index and the Integrated Territorial Risk, combined through a multi-criteria analysis scheme within a geographic information system. Results: The integration of the variables allowed the identification of potential epidemiological corridors, understood as spatial hypotheses in which favorable agroclimatic conditions, epidemiological pressure and high territorial connectivity converge. The identified corridors do not represent confirmed dispersal routes, but rather priority areas to strengthen preventive surveillance, guide animal health monitoring, and optimize resource allocation. Conclusion: The proposed architecture constitutes a reproducible methodological basis for integrating multiple sources of information in territorial intelligence systems applied to animal health surveillance. It can also contribute to the preventive identification of risk areas and be transferred, with the corresponding adaptations, to the study of other emerging animal diseases.

Keywords: Cochliomyia hominivorax; territorial intelligence; animal health surveillance; spatial epidemiology; Multi-criteria evaluation.

RESUMEN

Objetivo: Desarrollar una arquitectura metodológica de inteligencia territorial para integrar información agroclimática, epidemiológica y territorial, con el propósito de delimitar corredores epidemiológicos potenciales del gusano barrenador del ganado Cochliomyia hominivorax en la Región de los Volcanes, Estado de México. Metodología: Se empleó un diseño observacional y retrospectivo basado en tres fuentes de información: registros oficiales de brotes de SENASICA y WOAH, datos de la Red Agroclimática GORRIÓN y variables de conectividad territorial. La arquitectura integró cuatro componentes complementarios: el Índice de Riesgo Barrenador GORRIÓN, el Índice de Proximidad Epidemiológica, el Índice de Conectividad Territorial y el Riesgo Territorial Integrado, combinados mediante un esquema de análisis multicriterio dentro de un sistema de información geográfica. Resultados: La integración de las variables permitió identificar corredores epidemiológicos potenciales, entendidos como hipótesis espaciales en las que convergen condiciones agroclimáticas favorables, presión epidemiológica y alta conectividad territorial. Los corredores identificados no representan rutas confirmadas de dispersión, sino áreas prioritarias para fortalecer la vigilancia preventiva, orientar el monitoreo zoosanitario y optimizar la asignación de recursos. Conclusión: La arquitectura propuesta constituye una base metodológica reproducible para integrar múltiples fuentes de información en sistemas de inteligencia territorial aplicados a la vigilancia zoosanitaria. Asimismo, puede contribuir a la identificación preventiva de zonas de riesgo y ser transferida, con las adaptaciones correspondientes, al estudio de otras enfermedades animales emergentes.

Palabras clave: Cochliomyia hominivorax; inteligencia territorial; vigilancia zoosanitaria; epidemiología espacial; evaluación multicriterio.

INTRODUCTION

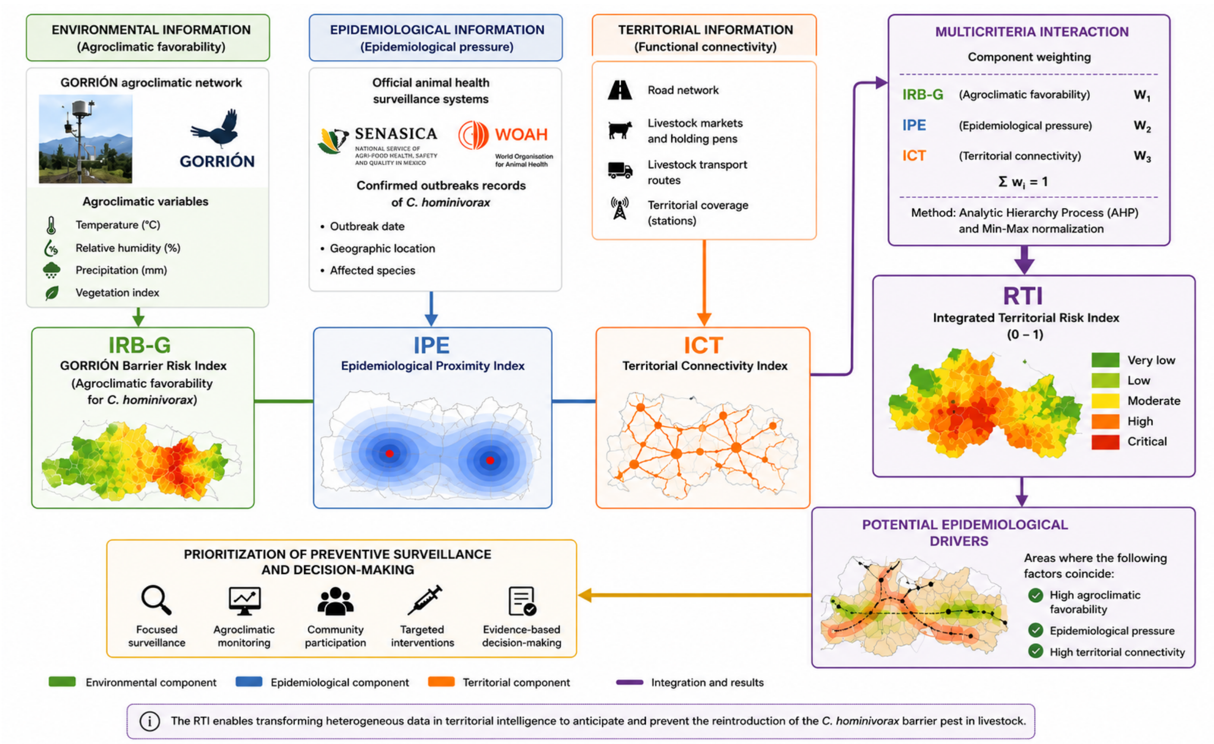
The screwworm (Cochliomyia hominivorax Coquerel, 1858) is one of the ectoparasites with the greatest health, economic, and productive impact on livestock in the Americas. Its larvae develop exclusively on living tissue of homeothermic vertebrates, causing traumatic myiasis that compromises animal welfare, reduces livestock productivity, and, in severe cases, leads to the death of the host [1,2]. In addition to its repercussions on animal production, the recent occurrence of human cases in Mexico reinforces the need to address its surveillance from an integrated health approach that recognizes the interaction between animal health, human health, and environmental conditions.

During the second half of the twentieth century, the application of the Sterile Insect Technique, complemented with zoosanitary campaigns and epidemiological surveillance, allowed the eradication of the species from Mexico and much of Central America [3]. However, the reappearance of outbreaks in southern Mexico and Central America demonstrates that eradication is not a permanent condition and that prevention requires surveillance systems capable of anticipating priority territories before the appearance of new foci.

Several investigations have shown that the potential distribution of C. hominivorax is closely related to environmental variables such as temperature, humidity, and precipitation. Using ecological niche models, Moo-Llanes et al. [2] identified large regions of Mexican territory with favorable conditions for the establishment of the species and noted that these areas could change under climate change scenarios. However, agroclimatic favorability represents only an ecological condition for the insect's development and does not by itself explain the occurrence of infestations. The presence of susceptible hosts, proximity to active outbreaks, and territorial connectivity simultaneously intervene in the epidemiological dynamics [4,5].

In parallel, the official surveillance systems coordinated by the National Service of Health, Safety and Agro-Food Quality (SENASICA) and the World Organisation for Animal Health (WOAH) provide reliable information on the spatial and temporal distribution of confirmed outbreaks [6-8,18]. However, these systems are primarily oriented towards the recording and monitoring of events that have occurred, so there is an opportunity to strengthen their preventive capacity through the integration of environmental and territorial information.

Figure 1. Conceptual architecture of Integrated Territorial Risk for preventive surveillance of the cattle screwworm



Source: own elaboration, field work 2026.

In recent years, spatial epidemiology has incorporated tools such as Geographic Information Systems, real-time environmental monitoring, and multicriteria models to understand the interaction between ecological processes, animal mobility, and land organization [9,10]. From this perspective, health risk is no longer interpreted exclusively as the presence of a biological agent but rather as the result of the convergence of multiple environmental, epidemiological, and territorial factors.

In this context, the GORRIÓN Project has developed a community-based agroclimatic monitoring network aimed at strengthening territorial intelligence through real-time environmental information. As a background to this line of research, Sánchez Jiménez [11] proposed the GORRIÓN Screwworm Risk Index (IRB-G), an eco-agroclimatic model designed to estimate environmental favorability for C. hominivorax. The IRB-G explicitly distinguishes between agroclimatic favorability and epidemiological risk, establishing that meteorological conditions are only a single component involved in the establishment of the insect.

Despite these advances, a methodological gap persists. Most available research independently analyzes the potential distribution of the species, the location of outbreaks, or the conditions of the territory. Proposals that simultaneously integrate agroclimatic information, official epidemiological surveillance, and territorial connectivity within the same analytical framework to support preventive surveillance are scarce.

With the aim of contributing to this line of research, this work proposes a methodological architecture composed of four complementary components: the GORRIÓN Barrenador Risk Index (IRB-G), which represents agroclimatic favorability; the Epidemiological Proximity Index (IPE), which incorporates the spatial and temporal influence of officially confirmed outbreaks; the Territorial Connectivity Index (ICT), which represents the potential interaction derived from infrastructure, livestock mobility, and territorial continuity; and the Integrated Territorial Risk (RTI), obtained through the multi-criteria integration of the three previous components.

The Volcanic Region of the State of Mexico was selected as a case study due to its high environmental heterogeneity, intense agricultural and livestock activity, and connectivity with strategic regions of central Mexico. Likewise, it constitutes the operational area of the GORRIÓN Agrometeorological Network, which allows the availability of high-resolution meteorological information to integrate the environmental dimension with the official epidemiological surveillance records.

Consequently, the objective of this research is to develop and describe a methodological architecture of territorial intelligence that integrates agroclimatic, epidemiological, and territorial information to delineate potential epidemiological risk corridors of screwworm in central Mexico.

The Potential Epidemiological Corridors (PEC) identified through this architecture are defined as territories where favorable environmental conditions, proximity to officially confirmed outbreaks, and high functional connectivity converge. In this study, these corridors should be interpreted as spatial hypotheses to guide the prioritization of preventive surveillance actions, rather than as confirmed dispersal routes or validated epidemiological predictions. Consequently, the RTI is proposed as a methodological approach subject to calibration and validation through longer time series, new epidemiological records, and sensitivity analysis.

METHODS

Study Design

This research corresponds to an observational, retrospective and spatial methodological study, aimed at the development of a territorial intelligence tool for the preventive surveillance of the cattle screwworm (Cochliomyia hominivorax) vector in central Mexico. The study integrates information from three independent sources: i) official epidemiological surveillance, ii) community agroclimatic monitoring and iii) territorial connectivity variables.

The integration of these sources enabled the construction of a multicriteria model aimed at identifying potential epidemiological risk corridors, understood as territories where favorable environmental conditions, proximity to active foci, and high functional connectivity converge. The methodological approach is based on the principles of spatial epidemiology and territorial intelligence, which recognize that the distribution of diseases depends on ecological, environmental, and socioeconomic processes that interact simultaneously across the territory [9,10].

Study Area

The study was developed using the Volcanos Region, located in the eastern part of the State of Mexico, as a reference territory. This region mainly comprises the municipalities of Amecameca, Atlautla, Ecatzingo, Ozumba, and Tepetlixpa, characterized by mountain peasant systems, altitudinal gradients above 1,800 m a.s.l., rainfed agriculture, small-scale livestock production, and intense territorial interaction with the states of Morelos, Puebla, and the Metropolitan Area of the Valley of Mexico. The region also constitutes the operational area of the GORRIÓN Agroclimatic Network, comprising automatic weather stations that generate continuous environmental information to support territorial monitoring processes.

Sources of information

Official records of Cochliomyia hominivorax outbreaks were obtained from the national dashboard of the National Service of Health, Safety and Agri-Food Quality [6,7] and from the international system World Animal Health Information System [8,18], which provided the geographical location of confirmed outbreaks, date of occurrence, and affected species. The agroclimatic variables were retrieved from the GORRIÓN IOZUMB2 station, operated by the Polytechnic University of Atlautla (GORRIÓN Project, 2026), whose records primarily include air temperature, relative humidity, accumulated precipitation, and wind speed.

For this study, the main source used was the records from the GORRIÓN-01 station, located in Atlautla. The third source incorporated territorial information derived from road infrastructure, continuity of livestock areas, regional livestock marketing centers, and general livestock mobility patterns obtained through official cartography and geospatial analysis.

Methodological architecture

The proposed methodological architecture was structured through four complementary components that represent different but interdependent dimensions of territorial risk associated with Cochliomyia hominivorax. Instead of assuming that a single variable explains the potential distribution of the insect, the proposal integrates environmental, epidemiological, and territorial information within a hierarchical multicriteria evaluation scheme.

A hierarchical architecture comprising four complementary indices was designed. The first corresponds to the GORRIÓN Screwworm Risk Index (IRB-G), whose purpose is to estimate the agroclimatic favorability for the establishment of the insect. This index synthesizes the influence of meteorological variables on the biological development of C. hominivorax and exclusively represents the environmental dimension of risk [11].

The second component corresponds to the Epidemiological Proximity Index (IPE), designed to quantify the spatial influence of officially confirmed outbreaks. The index simultaneously considers the distance between the study territory and active foci, as well as the age of epidemiological records, giving greater weight to recent and nearby events. The third component corresponds to the Territorial Connectivity Index (ICT), whose objective is to represent the potential ease of interaction between territories through road infrastructure, continuity of the livestock landscape, livestock markets, and regional mobility.

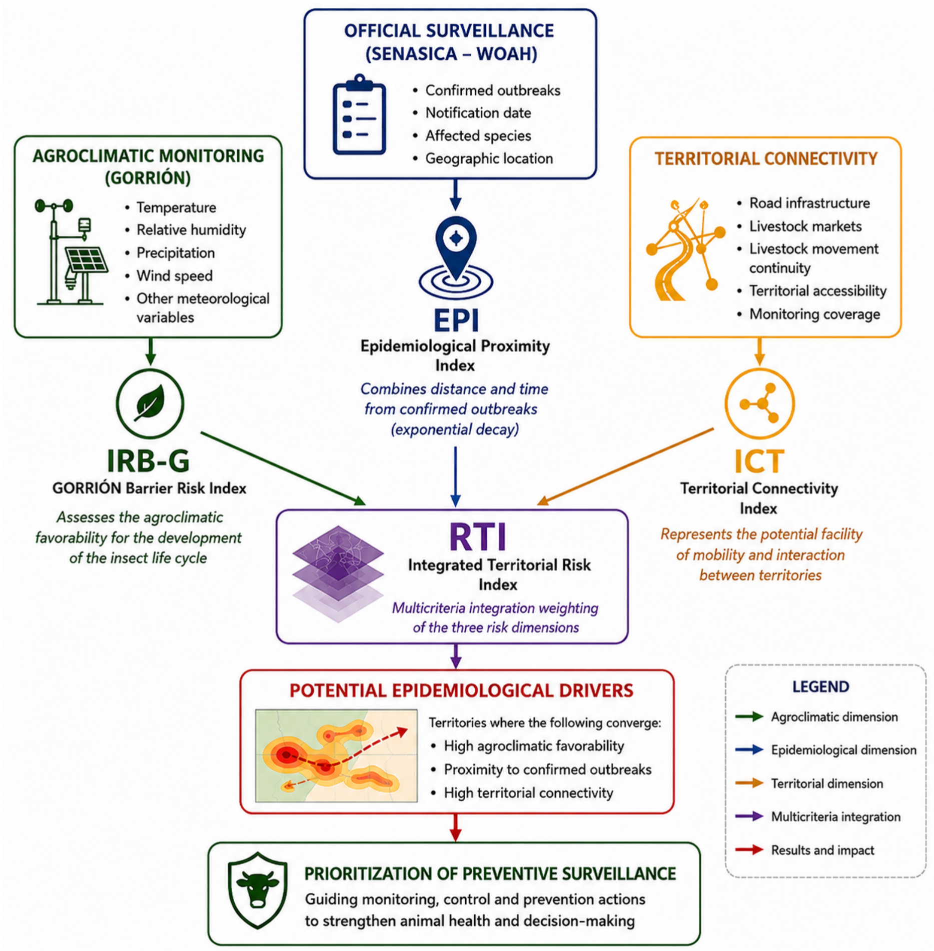
Together, these components form a methodological architecture of territorial intelligence aimed at integrating information from different sources within a reproducible procedure for spatial risk assessment. Its purpose is not to replace official surveillance systems, but to provide a methodological framework that strengthens the identification of priority territories for preventive monitoring.

Mathematical formulation of the indices

To guarantee the reproducibility of the proposed model and facilitate its application in other territorial contexts, each index in the methodological architecture was expressed using specific mathematical formulations. These equations represent the ecological, epidemiological, and territorial processes considered in the study and allow the transformation of information from different sources into normalized indicators within the interval [0,1].

Subsequently, these indicators were integrated through a multicriteria framework to construct the Integrated Territorial Risk (RTI).

Figure 2. RTI architecture for the preventive surveillance of the screwworm



Source: own elaboration, fieldwork 2026.

The mathematical formulation follows the principle of decomposing risk into independent but complementary components, avoiding redundancies between variables and facilitating future calibrations or adaptations of the model for other animal health surveillance systems in specific contexts and situations, with the aim of adapting these instruments to other realities.

The IRB-G represents the agroclimatic favorability of the territory for the development of the biological cycle of Cochliomyia hominivorax. The index integrates environmental variables obtained by the GORRIÓN Agroclimatic Network, including mean temperature, relative humidity, accumulated precipitation, and other factors derived from local meteorological behavior. Each variable was normalized and weighted to generate a continuous surface of environmental suitability expressed between 0 (very low favorability) and 1 (very high favorability). The general formulation of the index is given by the following equation:

$$\boxed{IRB_G=f(T,HR,P,\ldots)}$$

On the other hand, the Epidemiological Proximity Index (IPE) quantifies the epidemiological pressure exerted by officially confirmed outbreaks of Cochliomyia hominivorax. The influence of each outbreak progressively decreases as the distance from the focus and the time elapsed since its notification increase, following an exponential decay function widely used in spatial epidemiology [9]. The general formulation is presented in the following equation:

$$\boxed{IPE=e^{-\lambda d}\cdot e^{-\mu t}}$$

Another index, the Territorial Connectivity Index (ICT), represents the functional capacity of the territory to facilitate the potential mobility of risk through the integration of road infrastructure, livestock marketing networks, territorial accessibility, and spatial monitoring coverage. Each component was normalized and weighted to construct a continuous index between 0 and 1. The general formulation corresponds to the following equation:

$$\boxed{ICT=\sum_i w_i C_i}$$

Spatial integration

All variables were georeferenced within a Geographic Information System (GIS). Epidemiological records were associated with their spatial location, while agroclimatic stations provided continuous environmental information for each analyzed period. Territorial connectivity was represented through spatial analysis considering proximity to road corridors, territorial continuity of livestock systems, and regional interaction zones. Subsequently, all variables were normalized on a scale between 0 and 1 to allow their integration into the multicriteria model.

Construction of the Integrated Territorial Risk (RTI)

The methodological integration followed a weighted additive approach widely used in multicriteria evaluation models [12]. Instead of multiplying the indices, a weighted linear combination was chosen because each component represents an independent dimension of risk. The RTI integrates agroclimatic favorability (IRB-G), epidemiological proximity (IPE), and territorial connectivity (ICT). The initial weights were defined based on epidemiological criteria and can be refined through subsequent calibration and sensitivity analysis processes. In this research, the model should be interpreted as a methodological approach for territorial prioritization and not as a probabilistic model of infestation. Finally, the RTI integrates the three previous indices through a multicriteria procedure based on normalized weights. The general equation is:

$$\boxed{RTI=w_1(IRB_G)+w_2(IPE)+w_3(ICT)}$$

subject to: $\boxed{\sum w_i=1}$

Where w_1, w_2, and w_3 represent the weights assigned to each component of the model. These weights were defined based on epidemiological and territorial intelligence criteria, ensuring that the sum of the weights was equal to one in order to maintain the normalized scale of the integrated index. The weighted linear mix was selected because each index represents a conceptually independent dimension of risk. This strategy allows future weights to be modified as new data become available, without altering the overall structure of the methodological architecture.

Risk classification

For operational purposes, the Integrated Territorial Risk was classified into four categories: Low, Moderate, High, and Critical. This classification facilitates the translation of model results into easily interpretable information for institutions responsible for zoosanitary surveillance and community monitoring networks. It is important to note that these categories represent relative levels of territorial prioritization and not absolute probabilities of outbreak occurrence.

Table 1. Variables used for the research

RTI	Level	Recommended action
0–0.25	Low	Routine surveillance
0.26–0.50	Moderate	Enhanced monitoring
0.51–0.75	High	Intensive surveillance
>0.75	Critical	Immediate response

Source: own elaboration, fieldwork 2026.

Conceptual validation

The model evaluation constituted a methodological validation based on the conceptual consistency of the proposed architecture. Consequently, the objective of this research was not to validate the predictive capacity of the RTI, but to evaluate the logical coherence of integrating agroclimatic, epidemiological, and territorial information to delineate potential epidemiological corridors that could guide preventive surveillance.

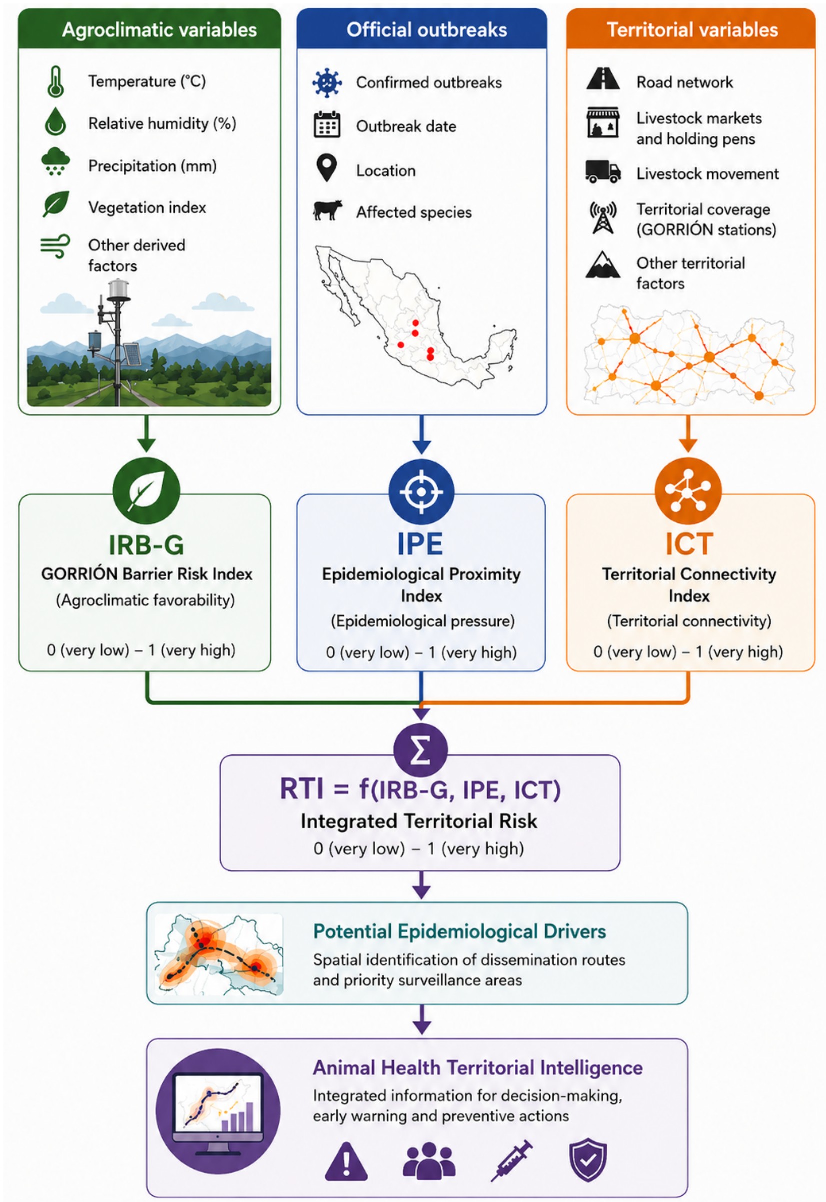
The model validation relied on conceptual consistency among the four components of the methodological architecture. Unlike purely statistical models, the proposal developed in this research is exploratory and seeks to establish a territorial intelligence framework that can be calibrated as new epidemiological records and time series from the GORRIÓN Agroclimatic Network or from other existing networks in potential territories become available.

Under this approach, the study does not aim to demonstrate actual dispersion routes of the screwworm, but to identify potential epidemiological corridors where favorable environmental conditions, proximity to official outbreak foci, and high territorial connectivity converge.

These corridors constitute spatial hypotheses that guide preventive surveillance actions and optimize the allocation of institutional resources. Consequently, the model is conceived as a complementary tool for official surveillance systems, strengthening anticipatory capacity by integrating agroclimatic, epidemiological, and territorial information within a territorial intelligence framework applicable to emerging and reemerging diseases of agricultural importance.

The main methodological innovation of this research is the proposal of a multicriteria territorial risk assessment architecture, structured into four complementary components: the GORRIÓN Screwworm Risk Index (IRB-G), the Epidemiological Proximity Index (IPE), the Territorial Connectivity Index (ICT), and the Integrated Territorial Risk (RTI). This architecture integrates agroclimatic, epidemiological, and territorial information within a reproducible territorial intelligence procedure aimed at strengthening preventive surveillance of livestock screwworm. Rather than developing a new risk index, the proposal establishes a methodological framework open to adaptation, calibration, and validation for different epidemiological and territorial contexts.

Figure 3. Mathematical architecture of the RTI model



Source: Own elaboration, based on fieldwork 2026.

RESULTS

Agroclimatic suitability for the establishment of Cochliomyia hominivorax

The integration of meteorological information from the GORRIÓN Agroclimatic Network allowed the identification of the spatial distribution of environmental favorability for Cochliomyia hominivorax in the Volcán Region using the GORRIÓN Screwworm Risk Index (IRB-G). Unlike traditional potential distribution models, the IRB-G uses agroclimatic information recorded in real time, which provides a dynamic representation of the environmental conditions that favor the development of the insect's biological cycle.

The results show that agroclimatic favorability presents high spatiotemporal variability mainly associated with changes in temperature, relative humidity, precipitation, and wind speed. This variability reflects the characteristic environmental heterogeneity of peasant mountain systems in central Mexico, where small altitudinal changes produce important differences in local microclimates. From an epidemiological perspective, this behavior indicates that environmental favorability constitutes a dynamic process and not a permanent condition of the territory. Consequently, the same site can transition between low and high environmental risk scenarios depending on the evolution of meteorological conditions.

This behavior coincides with recent studies showing that larval development, adult survival, and reproductive activity of C. hominivorax are closely responsive to climatic variability [2]. A relevant aspect of the IRB-G is that its interpretation avoids establishing a direct causal relationship between climate and infestation. The index only represents the degree of environmental favorability for the establishment of the insect and not the occurrence of outbreaks. This methodological distinction constitutes an important difference from numerous ecological niche studies, where environmental favorability is often interpreted as epidemiological risk.

In accordance with Hall and Wall (1995), disease development also requires the interaction of susceptible hosts, open wounds, insect population density, and spatial dispersal processes. These results support the methodological proposal developed by Sánchez Jiménez [11], who states that agroclimatic information should be understood as the first dimension within an integrated system of territorial intelligence and not as an independent predictor of infestation.

Spatial distribution of epidemiological proximity

The incorporation of official records from SENASICA and WOAH allowed the construction of the Epidemiological Proximity Index (IPE), whose objective is to represent the spatial influence exerted by officially confirmed outbreaks on the study territory. Unlike conventional case maps, the IPE simultaneously incorporates the geographical distance between outbreaks and the analyzed area, as well as the temporality of epidemiological records.

As a result, recent outbreaks exert a greater influence than those recorded months ago, allowing the representation of the changing dynamics of epidemiological pressure. Spatial analyses show the existence of a continuous gradient of epidemiological influence around active foci. Instead of observing abrupt boundaries between risk zones and free zones, the results show a progressive decrease in epidemiological influence as distance from confirmed outbreaks increases.

This behavior coincides with widely documented principles in spatial epidemiology, where the intensity of interaction between territories decreases with distance, although it never disappears completely [9]. Likewise, the model allows the incorporation of new outbreaks as they are officially reported, generating a dynamic update of territorial risk. The results also show that the exclusive use of case maps can lead to an underestimation of risk in neighboring territories that do not yet have confirmed infestations but maintain high epidemiological pressure due to their spatial proximity. From this perspective, the IPE constitutes a complementary tool to strengthen preventive surveillance before the appearance of new cases.

Territorial Connectivity and Identification of Functional Corridors

Territorial connectivity analysis enabled the incorporation of a dimension that is frequently absent in traditional screwworm surveillance models. Whereas most research focuses on the environmental distribution of the insect, the Territorial Connectivity Index (TCI) considers the functional structure of the territory using variables related to road infrastructure, continuity of agricultural landscape, livestock markets, and regional mobility. The results indicate that territorial connectivity is not homogeneously distributed.

On the contrary, areas are identified where multiple elements converge that favor the interaction between livestock production units. These spaces correspond mainly to regional highway corridors and areas of intense commercial activity. Several authors have pointed out that connectivity is one of the main determinants of the spread of infectious diseases because it increases the frequency of interaction between susceptible populations [13,10].

In this sense, the ICT does not aim to represent the biological dispersal of the insect, but rather the structural capacity of the territory to facilitate processes of epidemiological interaction. The results show that the incorporation of this dimension substantially modifies the interpretation of territorial risk. There are sectors with high agroclimatic favorability but limited connectivity, while others present moderate environmental conditions accompanied by intense regional interaction. This difference demonstrates that the potential distribution of the insect depends simultaneously on ecological and territorial processes.

Integration of Integrated Territorial Risk (RTI)

The main methodological contribution of this study is the integration of the GORRIÓN Burrowing Risk Index (IRB-G), the Epidemiological Proximity Index (IPE), and the Territorial Connectivity Index (ICT) within the Integrated Territorial Risk (RTI). The combination of these three dimensions enabled generating a more robust spatial representation of potential risk than that obtained by any of the indices separately. While the IRB-G identifies environmentally favorable territories, the IPE incorporates the epidemiological pressure derived from official outbreaks, and the ICT represents the functional structure of the territory.

As a result of this integration, three Potential Epidemiological Corridors (PECs) were identified for the Volcanes Region: Southern Corridor, associated with territorial interaction with the state of Morelos; Northern Corridor, related to connectivity to Chalco and eastern Valle de México; and Metropolitan Corridor, linked to territorial interaction processes from Milpa Alta, Xochimilco, and Tlalpan. It is important to note that these corridors do not represent confirmed dispersal routes of the screwworm, but rather areas where favorable environmental conditions, epidemiological proximity, and high territorial connectivity converge. Consequently, they constitute spatial hypotheses aimed at strengthening preventive surveillance and optimizing the allocation of institutional resources.

From a methodological point of view, RTI demonstrates that integrating multiple dimensions reduces the limitations inherent in univariate models. While environmental favorability explains the ecological potential for insect establishment, epidemiological proximity represents the pressure exerted by recent outbreaks, and territorial connectivity incorporates the functional structure of the landscape. This framework aligns with international trends toward surveillance systems based on territorial intelligence, where the integration of heterogeneous information enables improving the anticipatory capacity against emerging diseases [9,10].

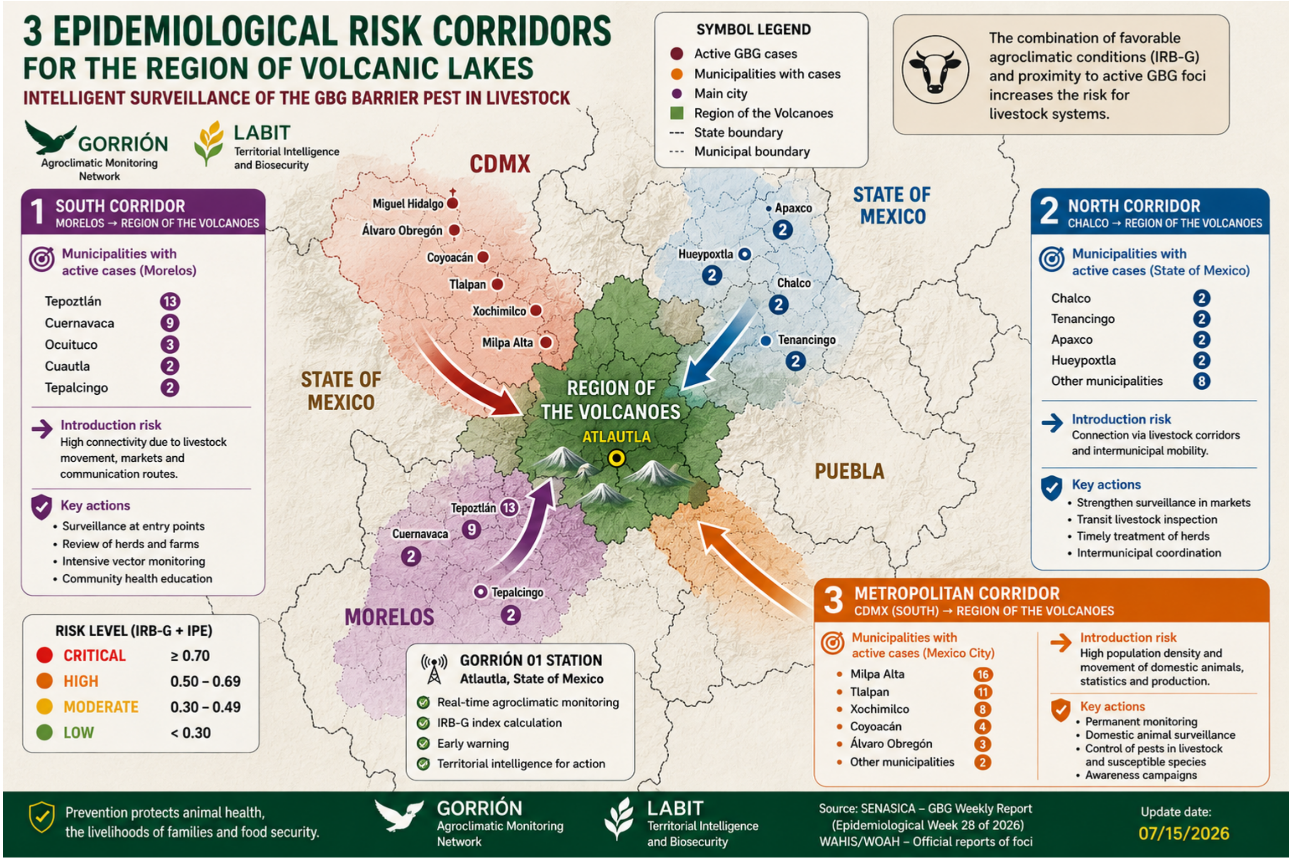
Overall, the results support the research hypothesis by demonstrating that the integration of agroclimatic, epidemiological, and territorial information provides a more comprehensive approach to delimiting potential risk corridors. The developed methodology represents a novel contribution to screwworm surveillance in Mexico by proposing an operational model that can be continuously updated as new records from the GORRIÓN Agroclimatic Network, as well as from other stations and official surveillance systems, are incorporated. Likewise, it lays the foundation for consolidating a territorial intelligence system applicable to other agriculturally important diseases, where prevention depends on understanding the dynamic interaction between environment, epidemiology, and territory.

DISCUSSION

Methodological Scope of the RTI

The main contribution of this research is to propose a methodological architecture that integrates agroclimatic, epidemiological, and territorial information within a single risk evaluation scheme. While most available studies on Cochliomyia hominivorax have focused on potential distribution models or the spatial description of outbreaks, the RTI incorporates 3 complementary dimensions that represent distinct processes of territorial risk. This integration responds to the need to simultaneously consider favorable environmental conditions, proximity to officially confirmed foci, and the functional connectivity of the territory, avoiding interpreting any of these components as a sufficient predictor by itself.

Figure 4. Epidemiological corridors for the Volcanes Region, State of Mexico



Source: own elaboration, fieldwork 2026.

In this sense, the RTI should be understood as a tool for information integration rather than as a predictive model. Its purpose is to support territorial prioritization of surveillance by identifying areas where multiple factors associated with possible insect circulation converge. This approach is consistent with the trend in spatial epidemiology toward multi-criteria schemes that combine environmental and geographic information to support decision-making [9,10].

Comparison with previous studies

This study proposes a methodological architecture that integrates agroclimatic, epidemiological, and territorial information to support the spatial prioritization of screwworm surveillance. Unlike approaches focused exclusively on the potential distribution of the species or on the location of confirmed outbreaks, the RTI model incorporates three complementary dimensions: agroclimatic favorability (IRB-G), epidemiological proximity (IPE), and territorial connectivity (ICT). This integration enables the construction of a territorial representation aimed at identifying areas where multiple risk-associated factors converge, without assuming that such convergence constitutes evidence of actual insect dispersal.

The results are consistent with previous research that has pointed to the importance of environmental conditions for the establishment of Cochliomyia hominivorax [1,2]. However, the proposal developed in this paper broadens this perspective by considering that agroclimatic favorability represents only one of the dimensions of risk. This interpretation coincides with studies of species distributions that warn that environmental suitability should not be equated with the presence or transmission of an organism, due to the influence of additional ecological, historical, and territorial processes [4,5].

The incorporation of the Epidemiological Proximity Index and the Territorial Connectivity Index responds to this need to broaden the interpretation of risk.

While the EPI introduces the spatio-temporal dimension derived from official surveillance records, the TCI incorporates elements related to the functional organization of the territory, such as infrastructure, livestock mobility, and spatial continuity. Together, these components allow the exploration of an integrated approach to territorial risk that is consistent with the principles of contemporary spatial epidemiology, where disease distribution depends on the interaction between environmental, biological, and territorial processes [9,10].

From this perspective, the Potential Epidemiological Corridors identified in the Region of the Volcanoes should not be interpreted as proven routes of screwworm dispersal. Their usefulness lies in identifying territories where conditions converge that justify strengthening zoosanitary surveillance, guiding agroclimatic monitoring, and prioritizing the allocation of institutional resources. Consequently, the proposed corridors constitute spatial hypotheses that can be contrasted as new epidemiological records and temporal monitoring series become available.

This interpretation is especially relevant to avoid overreading of the results. The RTI model does not estimate infestation probabilities nor replace official surveillance systems. Its purpose is to integrate information from different sources to generate a decision-support framework from a territorial perspective. In this sense, the study should be understood as a methodological proposal capable of adaptation and refinement as new sources of information are incorporated.

Implications for Surveillance

A key strength of the model is the use of agroclimatic information generated by the Red GORRIÓN, which allows the incorporation of meteorological data with high spatial and temporal resolution. Unlike models based exclusively on historical climatologies or bioclimatic products at a regional scale, this approach facilitates the continuous updating of the environmental dimension and opens the possibility of developing dynamic surveillance systems supported by community monitoring networks.

However, the research has limitations that must be explicitly acknowledged. First, the weights used to integrate the RTI are based on initial methodological criteria and require subsequent calibration through sensitivity analysis and validation with new data series. Second, the study was conducted in a specific region of central Mexico, so transferring the model to other contexts should account for environmental, productive, and territorial differences. Finally, the validation performed corresponds to a conceptual consistency assessment between the model components, not a predictive validation based on independent occurrence of outbreaks. These limitations are already recognized in the methodology and constitute a research agenda for later stages of RTI development.

Based on these results, future research may incorporate information derived from livestock mobilization, network analysis, remote sensing images, and epidemiological records with longer temporal coverage to evaluate model performance under different scenarios. Likewise, it will be pertinent to compare the capability of the RTI with other risk assessment approaches and to develop external validation procedures that allow estimating its operational utility in different regions of the country.

Overall, the findings obtained suggest that the integration of agroclimatic, epidemiological, and territorial information constitutes a promising pathway to strengthen preventive surveillance of the screwworm from a territorial intelligence perspective. Rather than offering a completed predictive model, the RTI provides a methodological basis for organizing heterogeneous information, formulating spatial hypotheses, and guiding future monitoring and risk assessment strategies.

Study Limitations

The results should be interpreted considering several limitations. First, the weights used to integrate the RTI correspond to an initial methodological proposal and require subsequent calibration processes through sensitivity analyses. Second, the evaluation was carried out using information corresponding to a specific region in central Mexico, so its application in other territories will require adjustments derived from their environmental, epidemiological, and productive conditions. Finally, the validation carried out was conceptual and methodological; therefore, the predictive utility of the model should be evaluated through longer time series, new epidemiological records, and independent external validation exercises.

CONCLUSIONS

The present research developed a methodological architecture of territorial intelligence to integrate agroclimatic, epidemiological, and territorial information with the purpose of supporting the delimitation of potential epidemiological corridors of the screwworm (Cochliomyia hominivorax) in central Mexico. The main contribution of the study is to show the methodological feasibility of integrating these three dimensions within a multicriteria scheme that expands the territorial risk assessment beyond approaches based exclusively on environmental variables or isolated epidemiological records.

The proposal explicitly distinguishes between agroclimatic favorability and epidemiological risk, recognizing that the existence of favorable environmental conditions does not constitute evidence of insect infestation or dispersal. Based on this conceptual differentiation, the Integrated Territorial Risk (RTI) incorporates proximity to officially confirmed outbreaks and the functional connectivity of the territory to construct a more comprehensive spatial representation of risk. Consequently, the RTI should be understood as a methodological architecture for information integration, and not as a fully validated predictive model.

The Potential Epidemiological Corridors (PEC) identified through this methodology represent spatial hypotheses derived from the convergence of agroclimatic favorability, epidemiological pressure, and territorial connectivity. Therefore, their utility lies in guiding the territorial prioritization of surveillance, monitoring, and prevention actions, without assuming that they constitute confirmed routes of dispersion of the screwworm.

From an applied perspective, the research highlights the potential of integrating information generated by official zoosanitary surveillance systems with community-based agroclimatic monitoring networks, such as the GORRIÓN Project. This articulation can strengthen early warning systems, improve territorial targeting of preventive actions, and contribute to a more efficient allocation of resources for sanitary surveillance, especially in regions characterized by high environmental and productive heterogeneity.

Nevertheless, the results should be interpreted considering the limitations of the study. The proposed multi-criteria integration requires subsequent calibration and external validation processes using longer time series, new epidemiological records, and sensitivity analyses to assess the model’s robustness under different scenarios. Likewise, future research should incorporate information related to livestock mobility, commercial networks, remote sensing, environmental sensors, and machine learning techniques to strengthen the operational performance of the RTI and expand its transferability to other territorial contexts.

Taken together, this research establishes a methodological basis for the development of territorial intelligence systems applied to zoosanitary surveillance. Although the study focused on Cochliomyia hominivorax, the proposed architecture is potentially transferable to other health problems whose dynamics depend on the interaction between environmental, epidemiological, and territorial processes.

Rather than proposing a new risk index, this work outlines a methodological architecture for integrating multiple information sources within a territorial intelligence framework, providing a conceptual and operational basis for the development of preventive surveillance systems capable of supporting decision-making in animal health under scenarios of increasing environmental and territorial complexity.

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CONFLICT OF INTEREST

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