Original Article

Optimization of avian influenza surveillance for human health and poultry production in Benghazi, Libya

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Abstract. The Bioagent Transport and Environmental Modeling System: Avian Influenza Surveillance Index (BioTEMS AISI) model produces a quantitative index that can be evaluated for utility against observed data. The BioTEMS AISI has been demonstrated to correlate with biotic and abiotic factors, particularly biodiversity and physical and chemical soil properties. Highly Pathogenic (HP) H5N1 has not been identified to date in the Eastern U.S. However, numerous strains have been collected from waterfowl. Similar biotic and abiotic factors that may influence the presence and survival of HP H5NI occur in Benghazi, Libya as well as other coastal areas globally. Given the concern by Libyan and U.S. Governments in protecting the Libyan people and poultry from influenza, the BioTEMS AISI model was used to identify optimal monitoring sites for avian influenza in and around Benghazi, Libya. International and state agriculture agencies, health departments, poultry farmers, and poultry processors, can use this technology proactively to monitor for avian influenza virus in the environment. Similar BioTEMS surveillance systems can be developed for monitoring foot and mouth disease and sporadic cases of plague and anthrax in Libya.

Key words: H5N1, avian influenza, epidemiology, Mediterranean, Libya

1. Introduction

The Bioagent Transport and Environmental Modeling System (BioTEMS™) is a robust modeling system capable of integrating biological factors, such as pathogen survival and host and vector population dynamics, with abiotic factors such as temperature, elevation, and soil type to predict where pathogens introduced or endemic to an area are likely to survive or amplify. This model has applications to surveillance for many pathogens, including influenza. For the past several years there has been heightened monitoring of the spread of the H5N1 strains of influenza in Asia, Europe and Africa. However, there is the known potential for viral genes from Eurasia to reach North America as clearly demonstrated by the isolation in the Eastern US of avian influenza (AI) virus that carries matrix genes closely related to those of Eurasian AI viruses. Isolates since 1986 include: A/Red knot/Delaware/2552/87 H9N5; A/Ruddy Turnstone/Delaware/34/93 H2N1; A/Ruddy Turnstone/Delaware/2589/87 H11N4; A/Laughing gull/New Jersey/798/86 H2N7; A/Sanderling/NewJersey/766/86 H2N7; A/Herring gull/Delaware/471/86 H13N7 (1). Eurasian virus and viral genes can reach the Americas through a number of routes, the most likely of which is through Alaska. However, less likely routes are also possible, and monitoring of locations along additional flyways, e.g. the eastern flyway of North America, has merit. Similarly, numerous strains of avian influenza may be transported among the flyways of the Middle East and North Africa. At least two sublineages of H5N1 have circulated in Europe in 2006 as seen in Germany, indicating sublineages from outside of Africa. These sublineages seem to have followed the east African/west Asian and Black Sea/Mediterranean flyways of migratory birds (2). In reaction to the threat of avian influenza in the Mediterranean region, Turkey has implemented surveillance for avian influenza viruses across (3,4).

Monitoring and surveillance efforts become more feasible if resources can be focused on sites likely to yield representative isolates of circulating virus strains (5). Models can be used
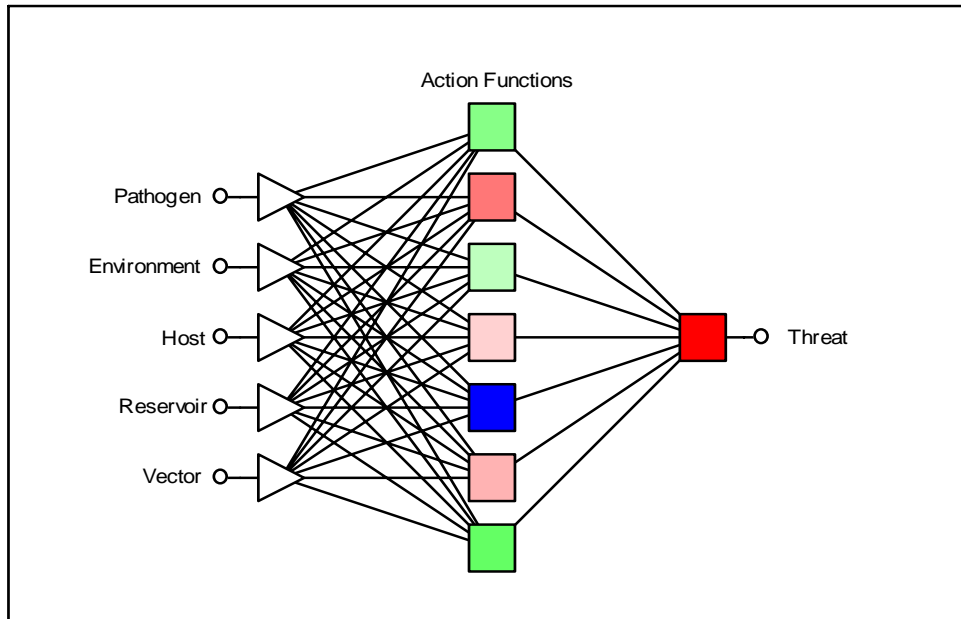
Fig. 1. General Additive Neural Network Model of BioTEMS Avian Influenza Surveillance.

as a tool for identifying the location of optimal sites so that limited resources can be applied most effectively in the effort of sampling wild birds, the environment, or placement of sentinel flocks. BioTEMS™ is a unique biology-based system for evaluating the threat posed by the introduction and spread of pathogens. BioTEMS technology uses abiotic and biotic variables to rapidly identify bioagent dispersal, environmental spread and amplification. A method to quickly and economically identify optimal surveillance sites for AI virus was developed using an Avian Influenza Surveillance Index (AISI) and geographic information systems (GIS) (6). BioTEMS AISI, was used to identify optimal monitoring sites in the Eastern United States the output which was used to develop an avian influenza risk assessment in Benghazi, Libya.

2. Methods and materials

Biotic and abiotic variables including elevation, slope, physical and chemical soil characteristics, e.g. salinity, water soil composition, soil pH, soil type other physical and chemical characteristics of soil, vegetation, microbial diversity, species diversity were evaluated using BioTEMS (Figure 1). BioTEMS uses parametric and non-parametric statistics, fuzzy logic and neural networks to analyze biotic and abiotic variables. Habitat (estuary, fresh water or terrestrial) was scored on a scale of 1-4 in accordance with the method used in the US Interagency Strategic Plan; and the waterfowl species diversity and density was

scored in accord with the Shannon-Weiner Index of Species Diversity. The AISI for each site was linked to the geographic coordinates to produce information layers using geographic information system (GIS) software (ArcMap, ESRI, Inc.). AISI values for selected sites were validated through direct observation of habit and species diversity in Chesapeake Bay Washington, D.C. area and Georgia. FalconView (Georgia Institute of Technology) was used to test whether AISI could be used to enable aircraft to conduct aerial surveillance and monitoring of avian influenza potential in the environment. FalconView is a navigational tool used by civilian and military aircraft that can incorporate numerous layers in the flight navigation system.

3. Results

Physical and Chemical Characteristics of Soil were significantly correlated with Avian Influenza Surveillance Index, R=.0.69, SS=6, MS=6, F=11.09, p≤ 0.01, (Figure 2). Site-to-site variation was observed for the AISI calculated for selected locations in Chesapeake Bay Washington DC area and GIS files were uploaded in Google Earth Pro (Figure 3). These factors were also used to produce a AISI risk assessment map for Benghazi (Figure 4). FalconView aeronautical navigation system was successfully used to upload and identify AISI sites in Georgia for aerial monitoring of potential sites for avian influenza of waterfowl breeding and feeding areas and poultry farms (Figure 5).

4. Discussion

Experts in Libya correctly suggest that prevention of influenza is better than a cure since the effectiveness of influenza vaccines is arguable. The high variation in the genes of the influenza viruses dnable these viruses to evade preexisting immunity (7). Variation in influenza viruses in waterfowl and poultry in the Middle East pose a threat to North Africa because these waterfowl share overwintering grounds in Northern Europe. Influenza viruses circulating in the Middle East maintain H5N1-like genes, possibly contributing to the spread of H5N1 viruses through regional cocirculation and infection (8). In neighboring Egypt, the first outbreak in birds in a season usually preceded the first human cases and regional differences in zoonotic risk and/or surveillance effectiveness
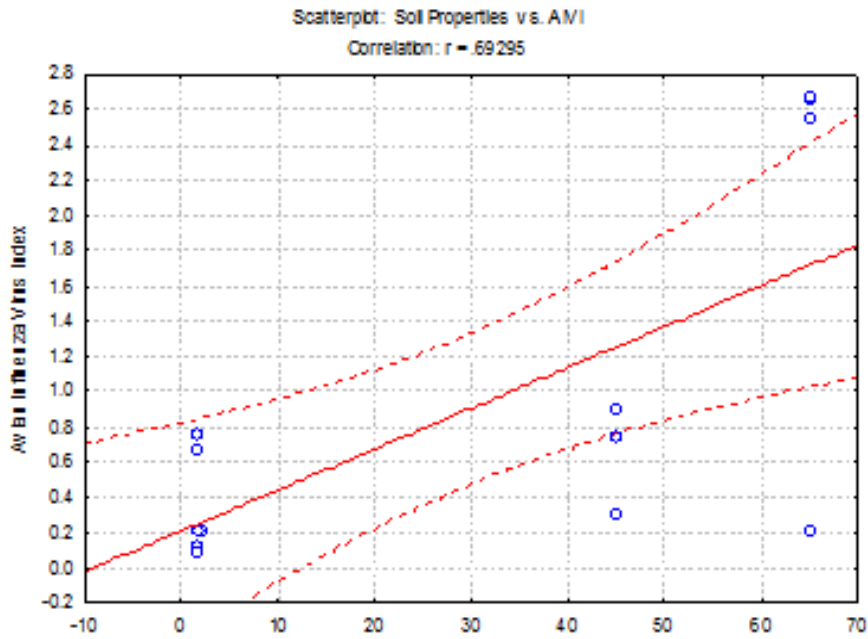

Fig. 2. Physical and Chemical Characteristics of Soil were significantly correlated with Avian Influenza Surveillance Index, $p \leq 0.01$)
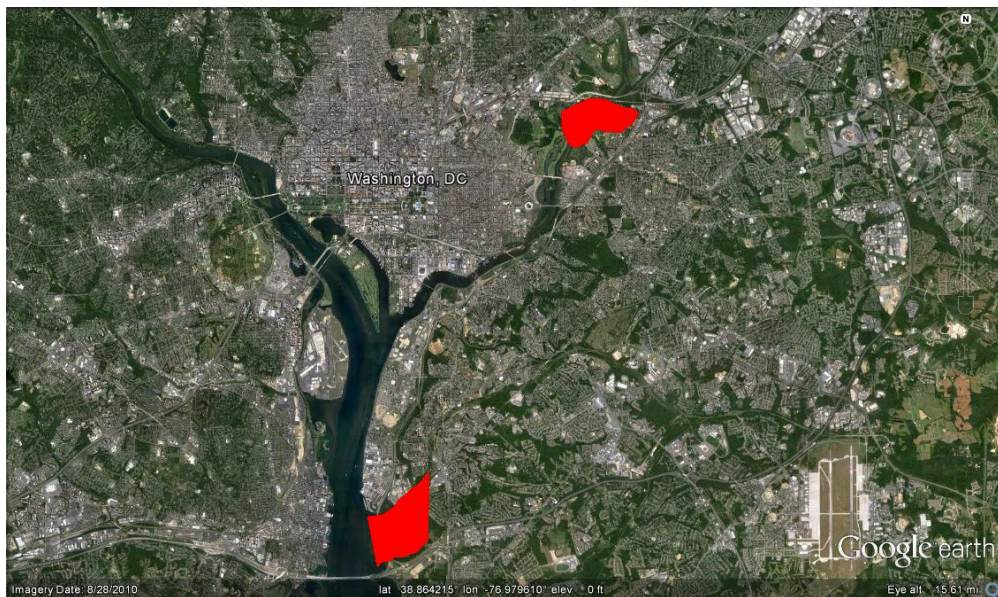

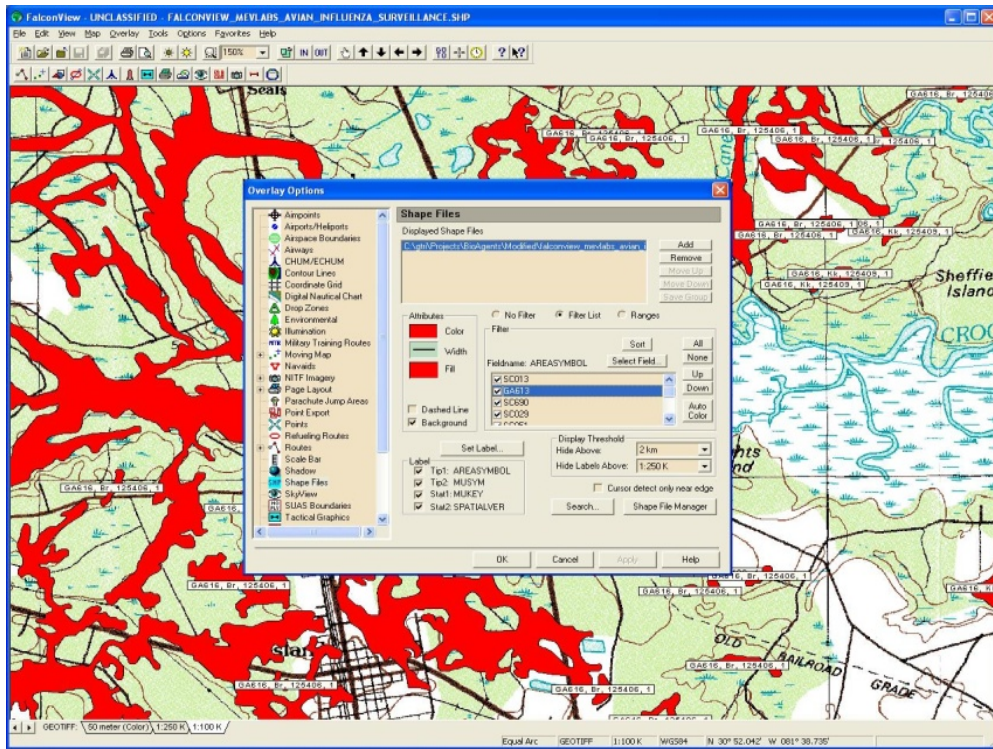Fig. 3. BioTEMS Avian Influenza Surveillance Sites Identified in Washington DC.

Fig. 4. Coastal Areas of Georgia identified for surveillance and upload into FalconView Aeronautic Navigation System for Aerial Monitoring of Avian Influenza Potential (Courtesy Daniel Longhurst, Georgia Institute of Technology).

Fig. 5. BioTEMS Avian Influenza Surveillance Sites identified in the Area of Benghazi, Libya.

for HP Avian influenza viruses varied widely (9). To date there have been over 150 cases of HP H1N1 reported in Egypt (10). Monitoring and surveillance of H5N1 and other influenza viruses is important both in Egypt and adjacent countries to reduce the risk of outbreaks.

Egypt exports poultry to other countries, with local breeds of particular interest in other countries because the local breeds are adapted to sub-optimal nutritional and harsh environmental conditions (11). The importance of international cooperation in surveillance of avian influenza in

Libya is recognized. For example, the U.S. Department of Health and Human Services and the U.S. Department of Defense have had active influenza surveillance collaboration with the Libyan government. The main goal of the Libyan project was to expand health and medical surveillance and response capacity in the Libya East through pandemic preparedness grants (12).

The results indicate that the BioTEMS AISI can be used to optimize surveillance efforts for sentinel flocks and to identify sampling sites for the isolation of virus from wild waterfowl, poultry and the environment. The AISI values provide an objective score for potential surveillance sites. In addition to microbial density and biotic diversity, soil AISI was strongly correlated with soil physical and chemical characteristics. Biotic factors and soil chemical and physical characteristics provided the optimal AISI values for the study sites. The BioTEMS modeling system capable of integrating biological factors, such as pathogen survival and reservoir dynamics, with environmental factors to predict where pathogens introduced or endemic to an area are likely to survive or amplify. This model has applications to many pathogens, including avian influenza virus surveillance. BioTEMS output can be imported into many current GIS and flight systems such as ESRI ArcView, Google Earth, and FalconView for aeronautics. The BioTEMS Avian Influenza Surveillance Index (AISI) was first developed to rapidly identify optimal surveillance and sampling sites along the shoreline of the Chesapeake Bay, Washington DC along the Eastern United States. There has been no confirmed outbreaks of HP H5N1 documented in the Eastern U.S. or in Benghazi. BioTEMS AISI has been developed for Benghazi, Libya to assist public and veterinary health professions in assessing and conducting environmental surveillance. BioTEMS AISI can be used in endemic and non-endemic areas to conduct a risk assessment for avian influenza by: 1) optimizing waterfowl and poultry surveillance, 2) identifying environmental sample sites, and 3) prioritizing remediation sites and culling. International and state agriculture agencies, health departments, poultry farmers, and poultry processors can use this technology proactively to monitor for avian influenza virus in the environment. Similar BioTEMS surveillance systems and FalconView can be developed for monitoring and surveillance of foot and mouth disease and sporadic cases of plague and anthrax in Libya.

Acknowledgement

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