Pro-Poor Livestock Policy Initiative
A Living from Livestock
Research Report

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Development of the Epidemiological Component of SPADA (Strategic Pathogen Assessment for Domestic Animals)

R. Soares Magalhaes

1. Summary

This report summarizes the activities from a visiting scientist mission conducted for the FAO between the 19th September and 16th December 2005, involving a field mission to Northern Viet Nam from 18th to the 28th of October 2005.

HPAI H5N1 outbreaks in Viet Nam mainly affect sector 3 and sector 4 farms. The report describes the epidemiological framework intended to enable the parameterization of the risk pathways leading to the spread of infection in Viet Nam. Networks for data collection were established to obtain the most complete data available to model the HPAI H5N1 dynamics in sectors 3 and 4. Data collected is being analyzed and used to inform a stochastic state dependent disease transmission model that permits a scenario-based approach to the assessment of the efficacy of HPAI H5N1 control options, which will be used to develop control options to suit the dominant epidemiological heterogeneities of HPAI H5N1 infection in the region.

2. Background

The HPAI Disease Control Modelling component of SPADA aims at the systematic analysis of relevant predictors for the efficacy and subsequently socio-economic impact of HPAI control and preventive interventions in Viet Nam and Thailand at the local, national and regional level. It

constitutes an important 'pilot case' for a proposed generic approach of wider applicability. In support of the development of the epidemiological component of the SPADA framework, and using HPAI H5N1 in Viet Nam as prototype case, the purpose of the mission was to:

- develop a generic risk and risk mitigation framework that can be applied to a wide range of diseases of livestock and humans;
- define sources of epidemiological data from which to derive quantitative estimates of risk and risk mitigation for the case of HPAI in Viet Nam;
- identify potential data providers in Viet Nam and develop collaborative links;
- obtain relevant data from data providers and import it into a standardised database format (MS Access);
- derive quantitative estimates of key epidemiological parameters for use in the HPAI Socio-Economic Impact of Disease Control Modeling project; and
- produce a document describing in detail the methodological framework, data sources and analytical techniques.

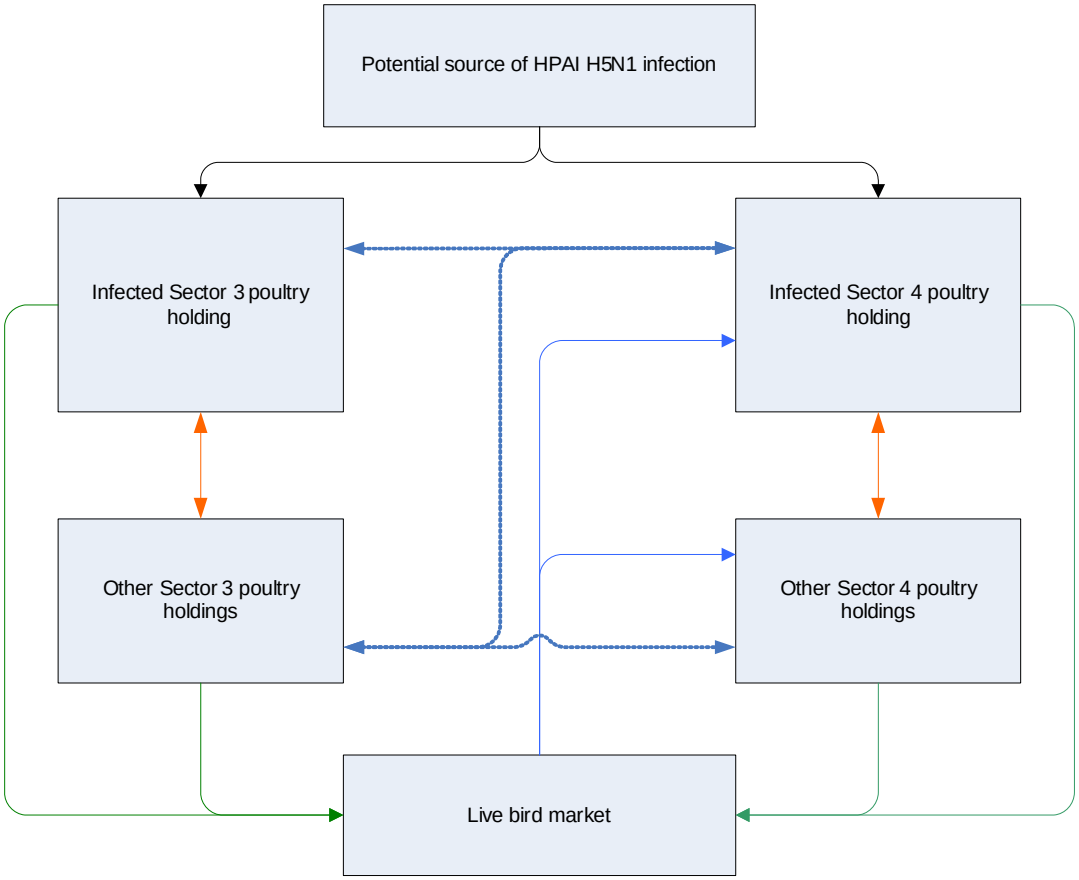
3. Materials & Methods

Generic risk and risk mitigation framework applied to HPAI H5N1 infection in poultry holdings

Risk pathways leading to the introduction and spread of avian influenza type A viruses of the H5N1 subtype in Viet Nam poultry holdings

The definition of the contact network between different actors in the circulation of HPAI H5N1 infection is a prerequisite for the systematic evaluation of the risk pathways leading to infection. Analysis of outbreak data from Viet Nam from the 2003/04 and 2004/05 waves highlighted the significance of backyard family farms (sector 3 farms) and small commercial familiar farms (sector 4 farms) for disease occurrence. The diagram presented in Figure 1 considers the contact network between sector 3 and sector 4 poultry holdings and live bird markets and their relative contribution to the introduction, circulation and spread of HPAI H5N1 infection. The definition of Viet Nam poultry farm sectors 1 to 4 used in this study follows (FAO 2004b).

Figure 1: Structure of contact network between HPAI H5N1 infected and non-infected sector 3 sector 4 poultry holdings and live bird markets. The boxes represent the main actors in the network while the risk pathways leading to introduction, circulation and spread of infection are highlighted by arrows. The arrows in orange represent the risk pathways for infection due to the movement of unfinished birds between poultry holdings of the same sector whereas the green arrows represent the movement of finished poultry to live bird markets. The dashed blue arrows represent the risk pathways leading to infection due to lateral contact between farms of different sectors. The full blue arrow describes the risk pathways for infection due to the retrograde movement of poultry from the live markets back to the farms of origin.



The risk pathways outlined in Figure 1 can be broadly categorized as *husbandry-related* and as *marketing-related* risk pathways. For the quantitative characterization of these two categories a stepwise approach was employed which involved (1) the definition of the risk factors documented in previous studies in the region and (2) the construction of a dataset framework for which relevant up-to-date data should be sought.

Risk factors leading to the active circulation of HPAI H5N1 virus in Viet Nam poultry holdings

The realization of the contact network as depicted in Figure 1 is entirely dependent on the husbandry and marketing characteristics of poultry farms in Viet Nam. Marketing and husbandry risk factors associated with HPAI H5N1 outbreaks have been assessed elsewhere and the data

tabulated in Table 1 is a qualitative appreciation of the impact of selected risk factors to sector 3 and sector 4 farms taking into account available information.

Table 1: Relative impact of marketing and husbandry practices on the circulation of HPAI H5N1 in Vietnamese sector 3 and sector 4 poultry holdings.

Risk factors	Viet Nam poultry Holdings	
	Sector 3	Sector 4
Marketing of poultry		
Sale of poultry at live bird markets	++++	+
Major cultural festivals with peak sale / consumption	++++	NA
Pre-marketing health checks	+++	NA
Movement of poultry between holdings	++++	++++
Movement of poultry across administrative borders	+++	++++
The return to the holding of origin of birds that were for sale in markets	+	++++
Husbandry of poultry		
Farming of multiple species within one farm unit	++	++++
Movement of fomites into the poultry holdings	++	++++
Keeping poultry over or near ponds and rice fields	+++	++++
Birds entering homes where other birds are housed as pets	++	++++
Use of untreated chicken feces as fertilizers or livestock feed	NA	++++
Lack at adoption of “all in – all out” husbandry system	++++	NA
Use of untreated water for human or animal consumption	++++	++++
Disposal of dying and dead birds	++++	++++

Sources: (Gilbert, Wint et al. 2004; Rushton, Viscarra et al. 2004; Veterinaires Sans Frontieres 2004; Morris, Jackson et al. 2005; Pfeiffer 2005)

NA: Not applicable; +: low impact; ++: medium impact; +++: moderate impact; ++++: high impact

The movement of birds between holdings is a marketing risk factor that is ranked high for poultry farms from both sectors whereas risk factors associated with the husbandry of poultry have been ranked differently depending on the sector farm type.

Epidemiological data from which to derive quantitative estimates of risk and risk mitigation for the case of HPAI in Viet Nam

Core to the epidemiological framework is the quantitative determination of the risk pathways leading to infection and risk mitigation options for HPAI at the farm level for Viet Nam. Quantitative data was sought to inform a disease transmission model to achieve desired

resolution at farm level. Table 2 lists the data requirements for the quantitative determination of the risk pathways to enable the characterization of the transmission dynamics at different spatial scales.

Table 2: Data requirements for the quantitative definition of risk pathways leading to HPAI H5N1 infection of sector 3 and sector 4 poultry farms in Viet Nam.

Risk Factor / Pathway	Actors in the Model	Data Type
Marketing		
Sale of finished poultry to live poultry markets	Sector 3; Sector 4; live bird market	Proportion of poultry moved
		Distances to market
		Intermediaries
Movement of unfinished poultry between sector farms	Sector 3; Sector 4	Proportion of poultry moved
		Distances between actors
Return of poultry to farm of origin	Sector 4	Proportion of poultry returning to farm.
Major cultural events	Sector 3; Sector 4; live bird market	Poultry price fluctuation at the farm gate
Husbandry		
Farming of multiple species	Sector 3; Sector 4	Number of farms per commune (in case of sector 3, disaggregated by farm type)
		Number of poultry kept disaggregated by species
		Characterization of production stages
Potential infection sources		
Infected farms	Sector 3	Number of affected farms per commune disaggregated by farm type
	Sector 4	Number of affected farms per commune
	Sector 3; Sector 4	Serological data
Environmental contamination	Sector 3; Sector 4	Recovery data from environmental samples

Data providers, collaborative links and relevant data obtained for Viet Nam

Given several constraints regarding data availability for farm-level resolution for the whole country, data collection was confined to two provinces in the North (Vinh Phuc and Ha Tay) and two provinces in the South of Viet Nam (Vinh Long and Tien Giang). The maps in Figure 2 show the geographic localization of these areas.

Figure 2: Geographic localization of the provinces of (A) Vinh Phuc, Ha Tay and (B) Vinh Long and Tien Giang from which complete data was retrieved. Commune boundaries as of January 2006 are shown to the right of the maps.

Figure 2A

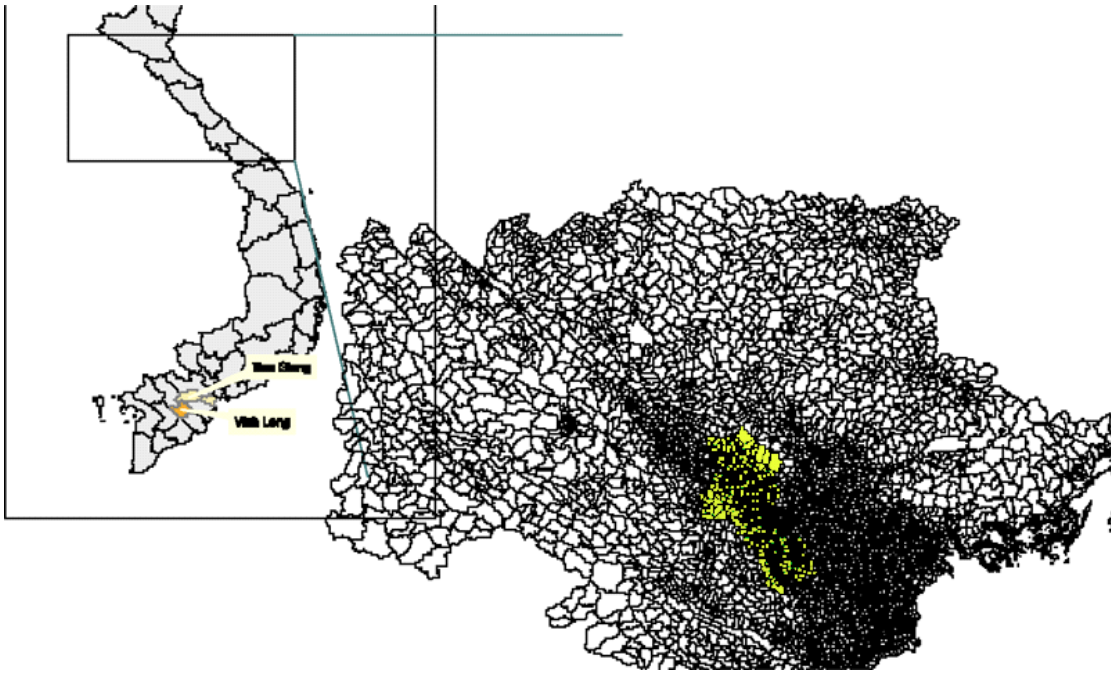
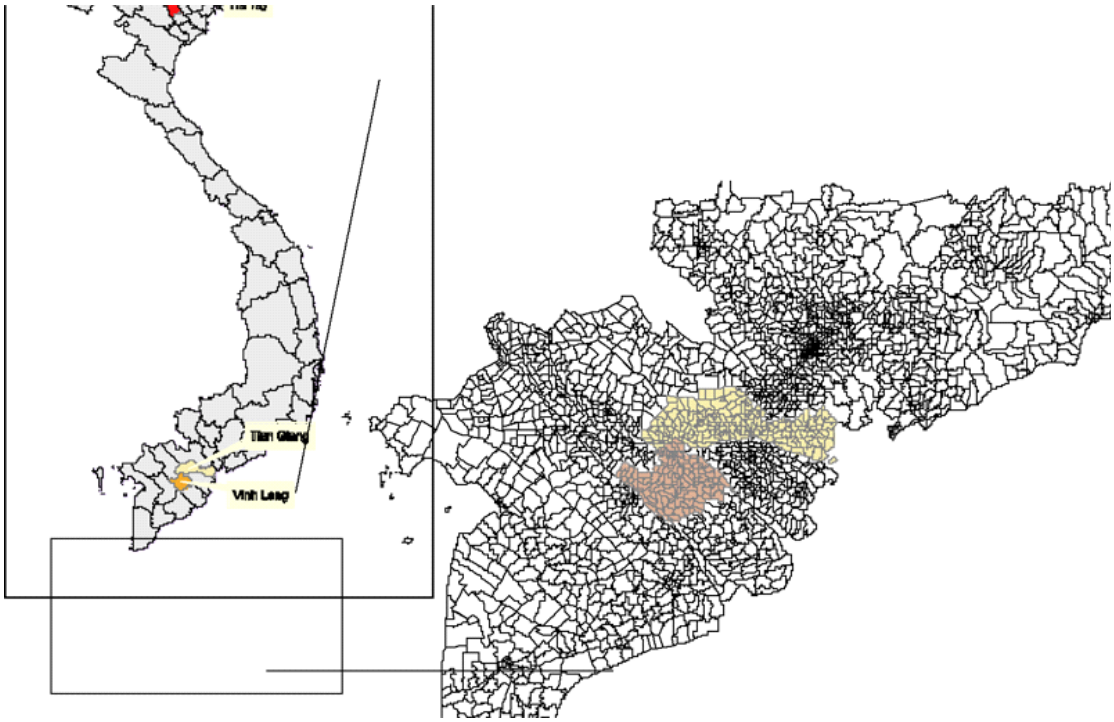


Figure 2B



The rationale behind focussing on data from these four provinces is based on heterogeneities in poultry production and administrative set-up between Northern and Southern Viet Nam as well as the different outbreak patterns for both outbreak waves in the two regions (Delquigny, Edan et al. 2004; FAO 2004a; Veterinaires Sans Frontieres 2004; Dinh Xuan, Nguyen Thu et al. 2005; Pfeiffer 2005).

Table 3 summarizes the data retrieved during the field mission which was entered into a standardised database format (MS Access).

Table 3: Data obtained and data sources for development of the epidemiological framework of the HPAI H5N1 transmission model. Data was requested and made available for sector 3 and sector 4 poultry holdings from the provinces of Vinh Phuc, Ha Tay, Vinh Long and Tien Giang, unless otherwise stated.

Data required	Data obtained	Data source	Collaborative Links
Proportion of finished poultry moved to the markets	Proportion of poultry sold to the market for sector 3 Vietnamese poultry holdings	(Dinh Xuan, Nguyen Thu et al. 2005)	Thung DINH XUAN - GSO
Distances to market	NA	Estimated	
Intermediaries	Description of poultry marketing channels for Viet Nam	(Dinh Xuan, Nguyen Thu et al. 2005)	Thung DINH XUAN - GSO
Proportion of unfinished poultry moved between farms	NA	Estimated	
Distances between actors	Distances between administrative boundaries from GIS shape files as of January 2006.	Estimated	Dung HUU DO - DAH
Proportion of poultry returning to farm.	Proportion of poultry returning to sector 4 holdings	Estimated	
Poultry price fluctuation at the farm gate	Price of live poultry in North and South Viet Nam for 2000.	(Dinh Xuan, Nguyen Thu et al. 2005)	Thung DINH XUAN - GSO
Number of farms per commune (in case of sector 3, disaggregated by farm type)	Farm census as of June 2001 for all four study provinces	GSO, Vie Nnam	Dung HUU DO - DAH
Number of poultry kept disaggregated by species	Animal census as of August 2005 (before vaccination campaign) for all four study provinces	Epidemiology Division, Department of Animal Health Ministry of Agriculture and Rural development, Hanoi, Viet Nam	Dung HUU DO - DAH

Data required	Data obtained	Data source	Collaborative Links
Characterization of production stages	Differences of husbandry practices in sector 3 and sector 4 poultry holdings between North and South Viet Nam	(Delquigny, Edan et al. 2004)	Patrice Gautier - VSF
Number of affected farms per commune disaggregated by farm type	Number of affected farms per commune	Epidemiology Division, Department of Animal Health Ministry of Agriculture and Rural development, Hanoi, Vietnam	Dung HUU DO - DAH
Serological data	NCVD Pilot Serological Survey, 2004	(National Center for Veterinary Diagnostics 2005)	Lien SONG PHUONG – NCVD Director Than LONG TO– NCDV Vice-Director
Recovery data from environmental samples	NCVD Pilot Serological Survey, 2004	(National Center for Veterinary Diagnostics 2005)	Lien SONG PHUONG – NCVD Director Than LONG TO– NCDV Vice-Director

GSO: General Statistics Office, Viet Nam; NA: Not Available; NCDV: National Centre for Veterinary Diagnostics

The data provided by collaborative links along with other in the scientific literature is used to define the farm level behaviour of the HPAI H5N1 transmission simulation model.

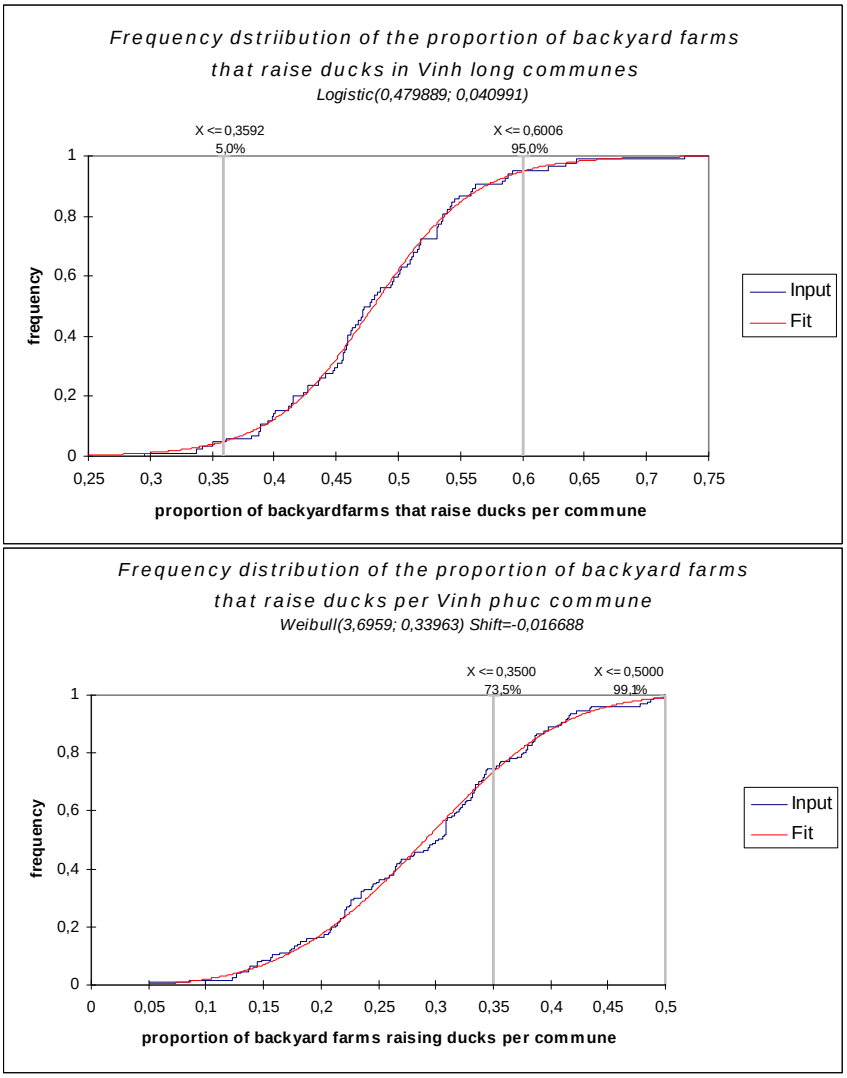
Derivation of quantitative estimates of key epidemiological parameters for use in the HPAI Socio-Economic Impact of Disease Control modelling project

A stochastic state dependent disease transmission model is currently being developed and tested to simulate the relative impact of different control options for HPAI H5N1 outbreaks. The simulation model is composed of 9 components, which can be classified as (1) husbandry-related components, (2) marketing-related components and (3) HPAI H5N1 virus-related components. The components of the model were built using Powersim Studio 2005 software.

Husbandry-related components and attribute modulation for assessment of HPAI H5N1 control options

Sector 3 and sector 4 farm husbandry has been modelled separately. Analysis of the data provided has shown significant differences amongst the population characteristics for both sectors between the Northern and the Southern provinces of Viet Nam. Figure 3 shows the difference between the frequency distribution of the proportion of sector 4 poultry farms that raise ducks between North and South Viet Nam provinces.

Figure 3: Frequency distributions of the proportion of sector 4 farms (a) Vinh Phuc province (North Viet Nam) and (b) Vinh Long (South Viet Nam Province)



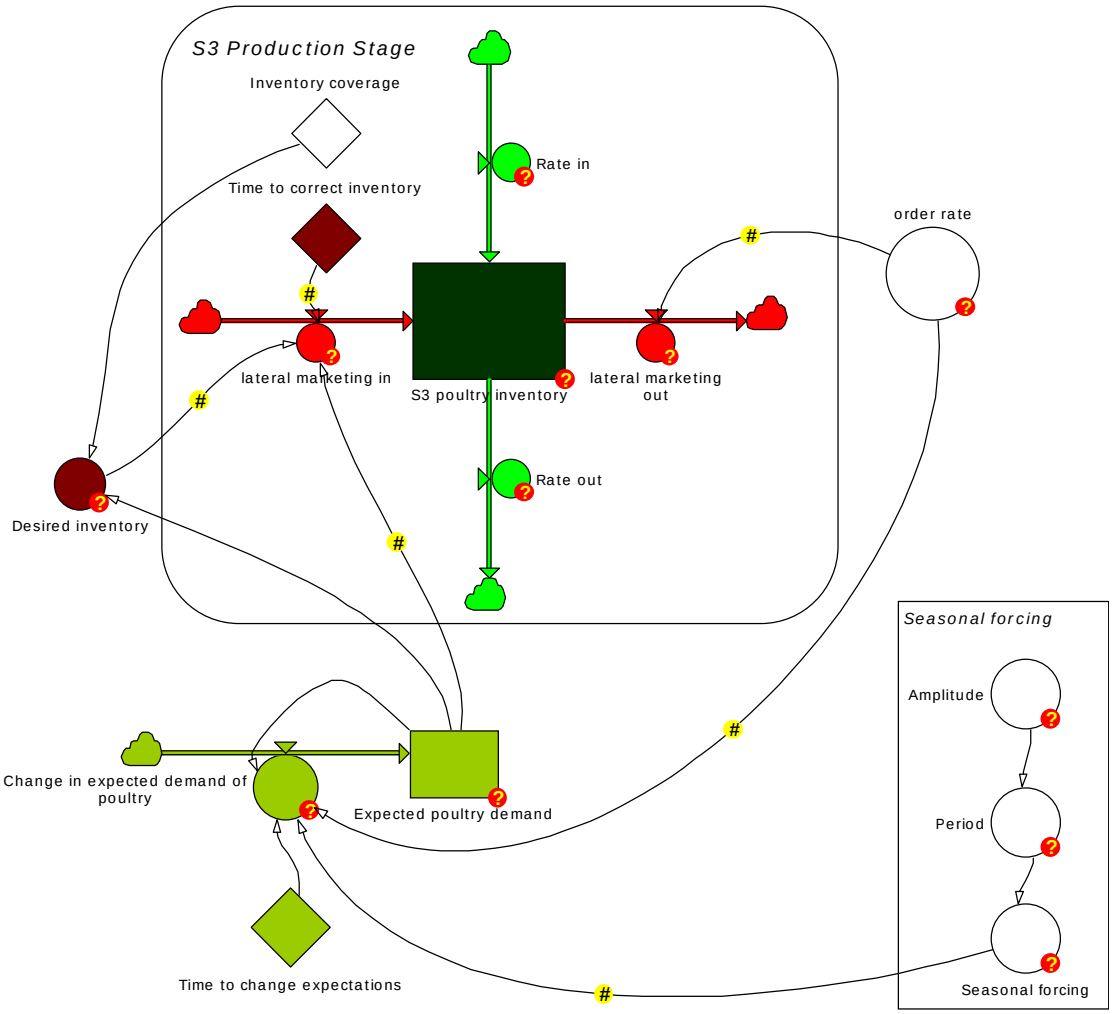
Apparently there are significant differences between regions with respect to the proportions of ducks in the backyard system. Sensitivity analysis on a set of parameters, ie modulation of attributes, within these components provides insights into the relative contribution of different culling strategies or other measures aimed at increasing the distances between populations at risk as measures for the control an on going HPAI H5N1 outbreak.

Marketing-related components and attribute modulation for assessment of HPAI H5N1 control options

The movement of finished and unfinished poultry within and between sectors is the most uncertain attribute to be modelled. This is due to the lack of data on the numbers of animals involved in these interactions as well as the relative contribution of seasonal fluctuations in the marketing behaviour of sector 3 and sector 4 farms. The movement between farms and between

farms and the markets is modelled using different sets of intermediaries to capture the spatial probability of infection. Figure 4 shows the model for the simulation of the movement between production stages within sector 3 farms.

Figure 4: Model structure of the marketing of unfinished poultry within a certain production stage between sector 3 farms considered in the transmission model.

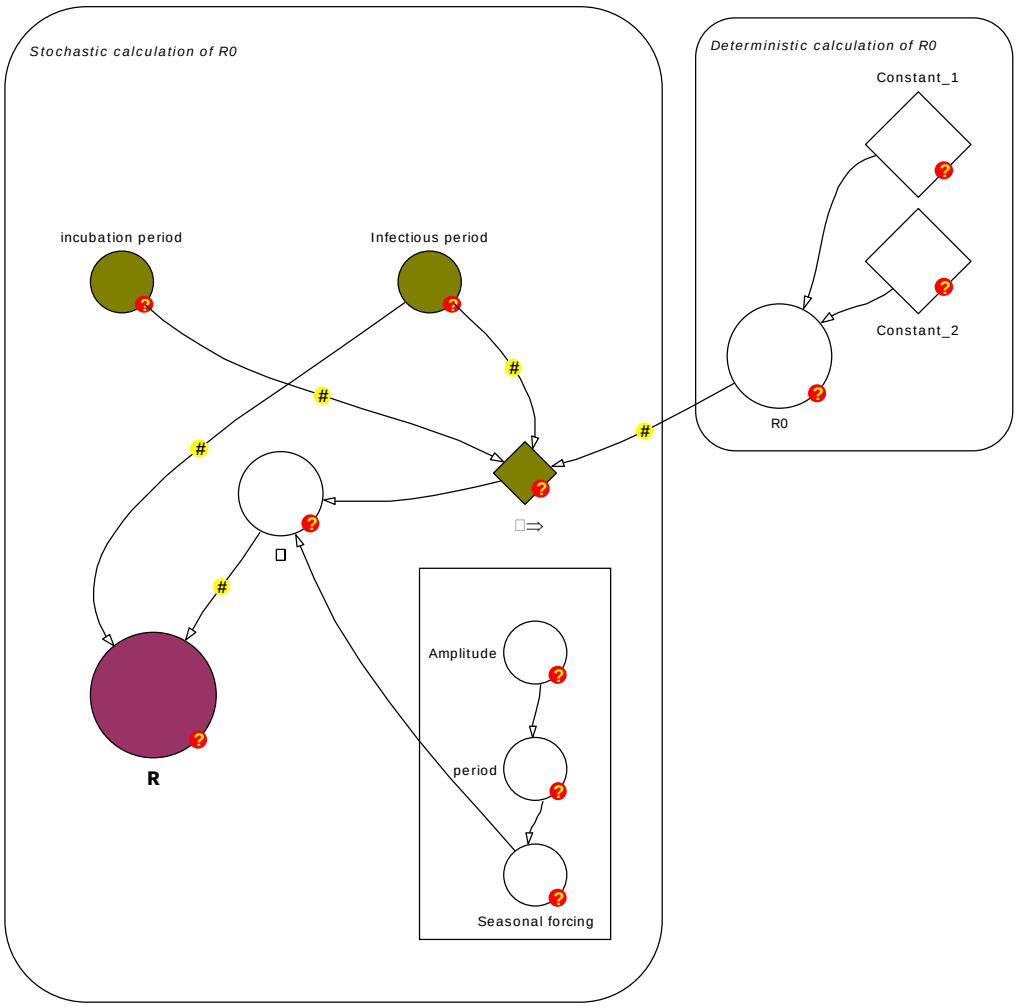


In the initial simulations it is assumed that the seasonal force responsible for the observed movements, which contributes to the differential contact rate between farms, is driven by the seasonal fluctuation of poultry price. Analysis of (Dinh Xuan, Nguyen Thu et al. 2005) data show that the farm gate price of poultry differs between the northern and southern provinces and follows a periodic function peaking in the weeks around the Tet holiday. Modulation of attributes of these components informs respectively about the potential relative contribution of movement stand-still at different spatial scales as well as about the impact of price control as an alternative control option, during an HPAI outbreak and as a measure of preventing further viral spread.

HPAI H5N1 related components and attribute modulation for assessment of HPAI H5N1 control options

The simulation model of HPAI H5N1 infection incorporates 3 components. Together they model the infectious status of the hosts and the probability of acquiring HPAI H5N1 through different sources. A SEIR state transition model is used where a bird can move from a susceptible stage (S) to an exposed stage (E) and becomes infectious (I) given exposure and is allowed to recover (R) given a HPAI-specific mortality rate. The transition rates between states are estimated by data derived through the other components that are linked together to reflect the characteristics of the poultry population at risk. The major output from the HPAI-related components is the determination of the basic reproductive number (R0) which is an estimate of the number of secondary cases produced by the introduction of an infectious animal into a fully susceptible population. Calculation of R0 enables the stochastic determination of the reproductive number (R) of HPAI H5N1 infection while an outbreak wave is ongoing where alterations to the susceptibility status of the population are introduced. An outline of the model that is being tested to calculate HPAI H5N1 transmission parameters is shown in Figure 5.

Figure 5: Model structure for the deterministic and stochastic estimation of the (basic) reproductive number of a HPAI H5N1 infectious animal.



The modulation of the attributes of these components provides information on the relative impact of controlling HPAI H5N1 by reducing the size of the susceptible population, for example through the implementation of a vaccination campaign aimed at sector 3 and sector 4 farms. The relative impacts of other control options modulated elsewhere in the transmission model are evaluated by changes reflected by the values of R.

4. Next Steps

Control options used for the containment of HPAI H5N1 in Viet Nam aim at (1) the reduction of the number of susceptible birds in the poultry population, (2) increasing the physical distance between susceptible and infected individuals and/or (3) the reduction of the number of infected birds before they become infectious. These theoretical principles are currently being put in place by the implementation of an active vaccination policy, the culling of populations at risk within a certain radius of an index premise, through the implementation of movement stand still and by

intensified surveillance (Delquigny, Edan et al. 2004; FAO-RAP 2004; FAO 2004b; FAO/OIE/WHO 2005; Sims 2005). Nevertheless, despite intensification of control activities, HPAI H5N1 outbreaks continue to occur in the country.

A scenario-based epidemiological assessment for HPAI H5N1 control options at several administrative levels is the final step of the study. This will be achieved by the analysis of the transmission model outputs given differential modulation of variables within the model components, providing quantitative information regarding the best-suited set of control options for specific epidemiological scenarios to be integrated with the economic modelling component (IPALP) within the wider strategic assessment framework of SPADA.

5. References

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Joachim Otte
Programme Coordinator - Pro-Poor Livestock Policy Facility
Food and Agriculture Organization - Animal Production and Health Division
Viale delle Terme di Caracalla 00153 Rome, Italy
E-mail: joachim.otte@fao.org
PPLPI website at: http://www.fao.org/ag/pplpi.html

David Roland-Holst
Rural Development Research Consortium
223 Giannini Hall University of California Berkeley, CA 94720 - 3310 USA
E-mail: dwrh@rdrc.net

Dirk Pfeiffer
Royal Veterinary College
Epidemiology Division, Dpt. Veterinary Clinical Sciences
Hawkshead Lane, North Mymms, Hatfield, Herts, AL9 7TA
E-mail: pfeiffer@rvc.ac.uk