# Modeling Avian Influenza Immunity Distribution Profile Through the Poultry Production Network in Egypt: A Decision Tool for Zoonotic Influenza Management

**M.Peyre [1], M.Choisy [2], H. Sobhy [3], W.H. Kilany [3,4], A. Tripodi[5], G. Dauphin[5], M. Saad[6], F. Roger [1], J.Lubroth[5], and Y. Jobre [3]**

[1] Cirad AGIRs, France; [2] IRD MIVEGEC, France & OUCRU, Vietnam; [3]FAO ECTAD, Egypt; [4]RLQP, Cairo, Egypt; [5]FAO Rome, Italy; [6]GOVs, Egypt

## ABSTRACT

**Vaccination against avian influenza (AI) is currently applied worldwide with inactivated vaccines. Since November 2012, a novel recombinant rHVT-AIH5 (Herpesvirus of turkeys as vector) vaccine has been commercialized and applied to day-old chicks (DOC) in some industrial hatcheries in Egypt *(Kilany, 2014; Kilany, 2012)*. The objectives of this study were to assess the cost-effectiveness of AI DOC vaccination in hatcheries and the feasibility of implementing AI DOC vaccination in the different production sectors in Egypt.**

**A model of the Egyptian poultry production network was combined with a model on flock immunity to simulate the distribution profile of AI immunity according to different vaccination scenarios (including DOC vaccination or not). The model estimated the levels of vaccine coverage for each node of the network and vaccination scenario and positive sero-conversion levels and the duration of sero-protection.**

**The model predicted that targeting DOC AI vaccination in industrial and large size hatcheries would increase immunity levels in the overall poultry population in Egypt and especially in small commercial poultry farms (from <30% to >60%). This strategy was shown to be more efficient than the current strategy using inactivated vaccines. Improving HPAI control in the commercial poultry sector in Egypt would have a positive impact effect to improve disease control.**

**This innovative way to analyze the outcome of AI immunity predictive model supports the design of a more efficient HPAI disease control plan in Egypt. This model may be replicated in other AIV endemic countries that wish to better manage infections or emerging disease threats.**

## STUDY OBJECTIVES

**We combined network analysis of poultry production systems with an immunity model to study the distribution profile of avian influenza immunity in flocks through the commercial poultry production network in Egypt.**

The specific objectives were:

1. **To model the movement of DOC within the poultry value chain of Egypt**
2. **To estimate vaccine coverage and sero-conversion levels according to different vaccination scenarios including DOC vaccination.**

### NETWORK MODELING

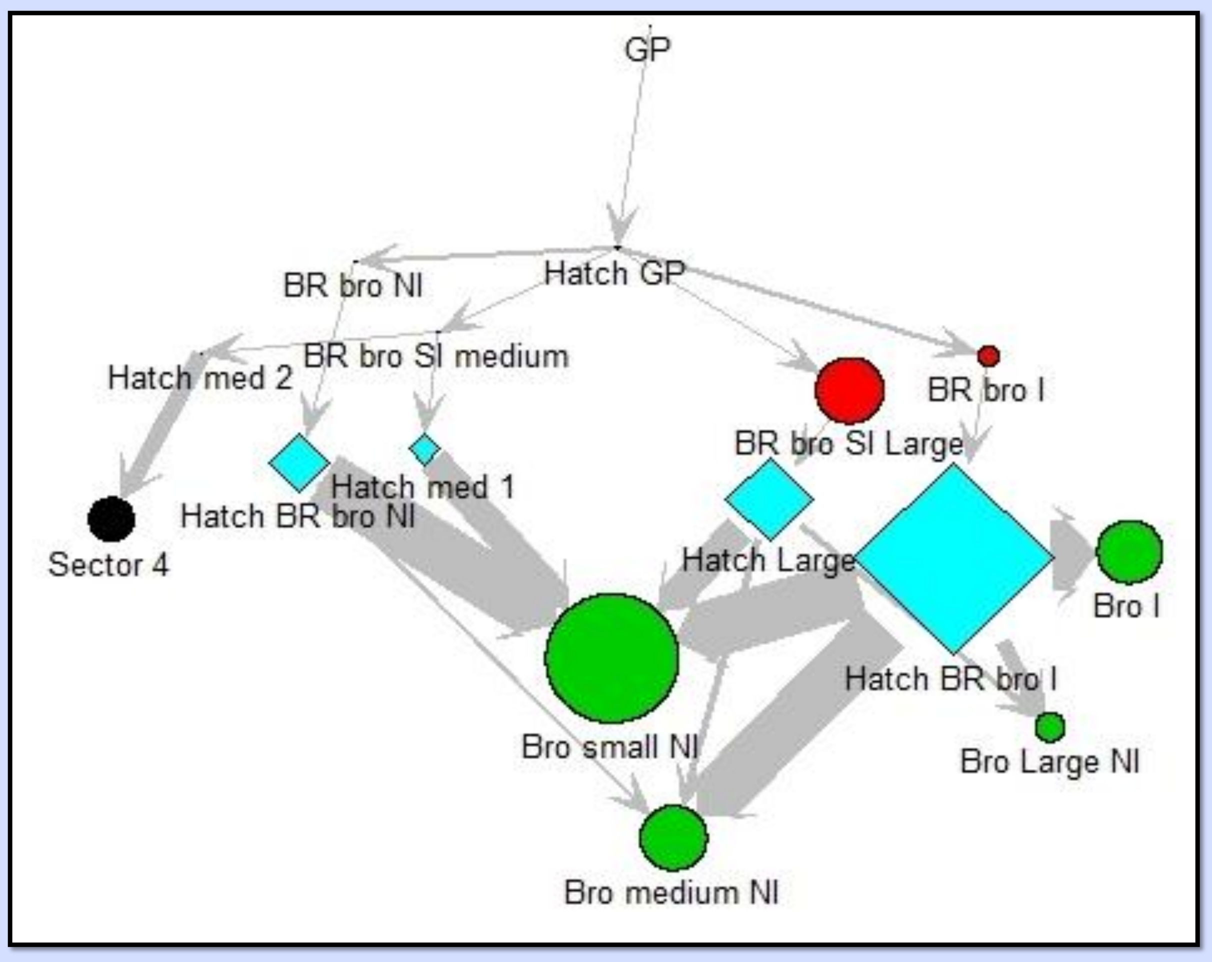


**Fig. 1: Network of the Egyptian poultry industry.** A model network of the poultry industry was built up and analysed using Social Network Analysis method .

**Data were collected** via literature review and cross sectional survey in a random selection of farms (n=140). Individual interviews with key stakeholders were performed to complete the data set.

**Analysis of network connectivity** using the cut-point analysis was performed to assess the structure of the network and to identify nodes which have a key role in distribution of DOC through the network. Network connectivity and structural equivalence analysis were used to define the different DOC vaccination scenarios to be tested in the study.

**This network was used to model the distribution of the immunity profile within each node of the network based on different vaccination scenarios (Table 1).**

Immunity was assessed in terms of:

- **Vaccine coverage** defined as the proportion of vaccinated birds from the total population considered**.**
- **Positive sero-conversion** level was defined as the proportion of birds within the vaccinated population with haemagluttinin inhibition (HI) titers > 4Log2 *(OIE, 2012)***.**

**Table 1. VACCINATION SCENARIOS**

| DOC source | Integrated hatcheries | | Non-Integrated hatcheries | | |
|---|---|---|---|---|---|
| **DOC destination** | **Integration** (Sector 1) | **Clients (Large & Medium farms)** (Sector 2) | **Large farms** (Sector 2) | **Medium farms** (Sector 2 & 3) | **Small farms** (Sector 3) |
| **Scenario 1** | Farm vaccination | Farm vaccination | Farm vaccination | Farm vaccination | Farm vaccination |
| **Scenario 2** | **Hatchery** | Farm vaccination | Farm vaccination | Farm vaccination | Farm vaccination |
| **Scenario 3** | **Hatchery** | **Hatchery** | Farm vaccination | Farm vaccination | Farm vaccination |
| **Scenario 4** | **Hatchery** | **Hatchery** | **Hatchery** | Farm vaccination | Farm vaccination |
| **Scenario 5** | **Hatchery** | **Hatchery** | **Hatchery** | **Hatchery** | Farm vaccination |
| **Scenario 6** | **Hatchery** | **Hatchery** | **Hatchery** | **Hatchery** | **Hatchery** |

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Together, beyond animal health

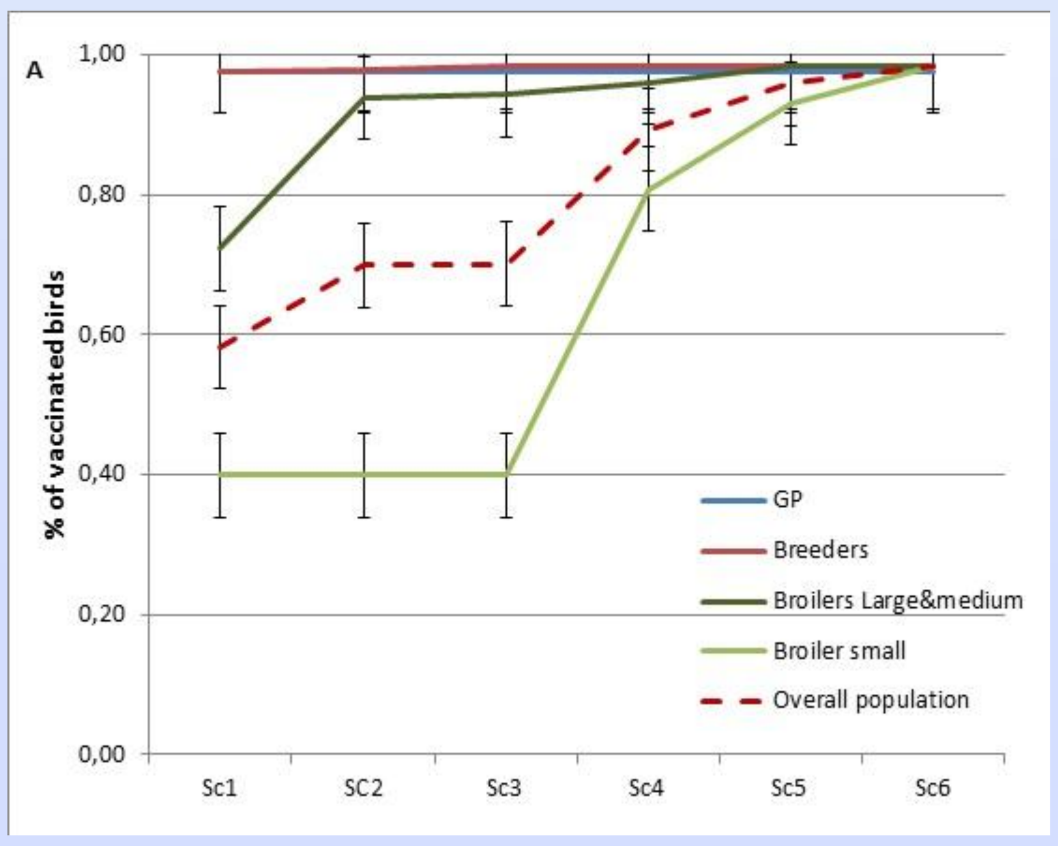



**Figure 2(A). Evolution of the vaccine coverage rate per poultry production type, according to the different vaccination scenarios.** Under baseline scenario (farm vaccination only), only the GP, breeders and integrated broilers have a sufficient level of coverage (>80%)

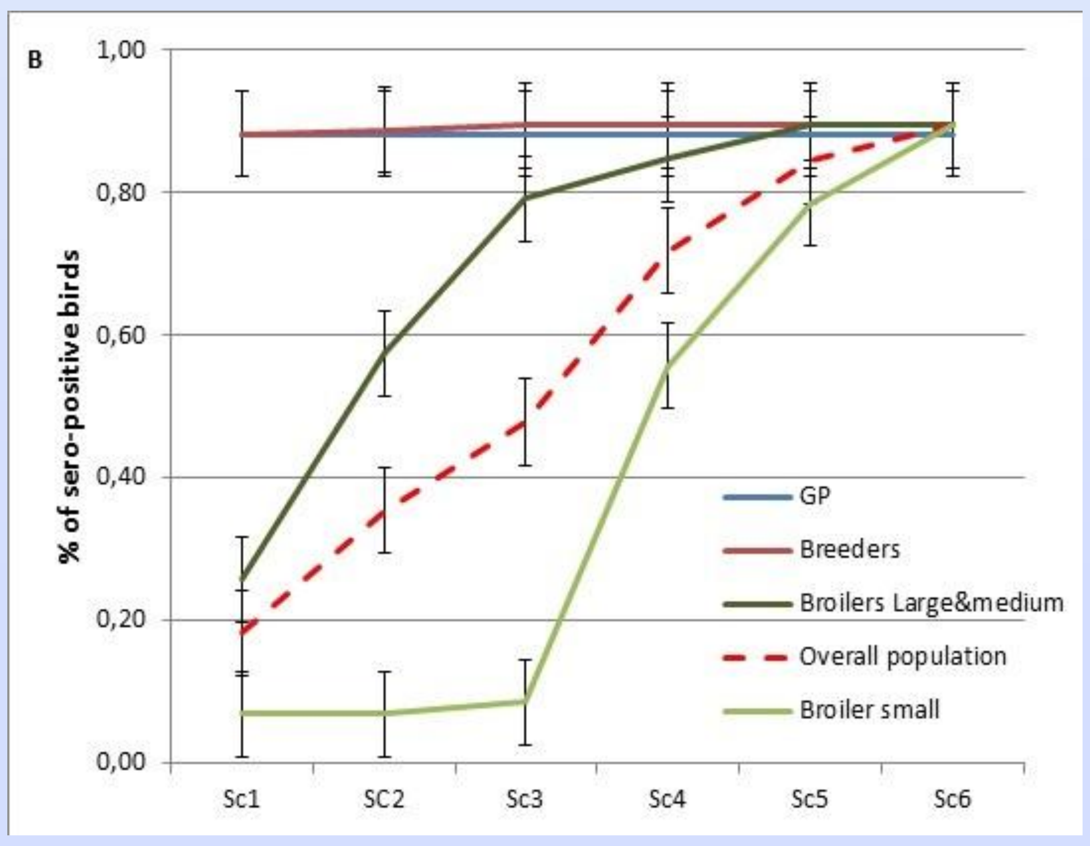



**Figure 2(B). Evolution of the positive sero-conversion rate per poultry production type, according to the different vaccination scenarios.** Under baseline scenario (farm vaccination only), only the GP, breeders have a sufficient level of sero-protection (>60%).

## RESULTS

**The model demonstrated a statistically significant increase of vaccination coverage (>80%;** p<0.05) **within the total population if hatchery vaccination was implemented in integrated and large farms** (Sc. 4; Fig. 2(A)). By only vaccinating integrated DOC (Sc. 2), vaccine coverage in large and medium-sized farms would reach 80%.

**The model predicted that targeting DOC AI vaccination in industrial and large size hatcheries** (Sc. 4) **would increase immunity levels in the overall poultry population in Egypt and especially in small commercial poultry farms (from <30% to >60%) (Fig. 2(B))** *(Bouma, 2009)***.**

**Spatial analysis of AI immunity distribution demonstrated that under Sc.4 the immune level density (both in terms of coverage and sero-protection) would increase above the threshold levels in the most at risk Governorates (Fig 3).**

**DOC vaccination would be cost-effective either as prime-boost strategy with one boost of inactivated vaccine or as single dose vaccination both for long cycle and broiler birds** whatever the current inactivated vaccination protocol in place (Table 2) .

***Table 2. Cost -Effectiveness Analysis***

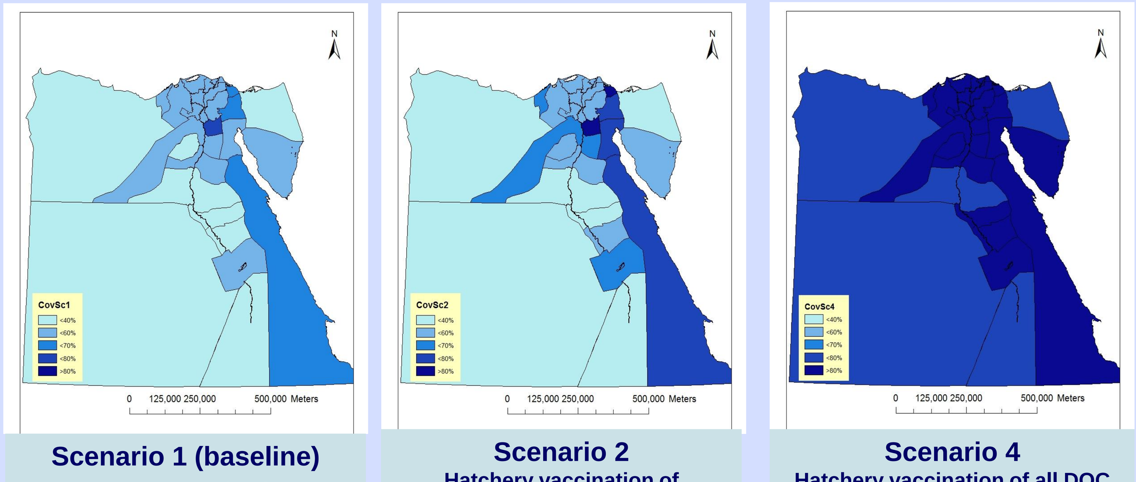
| Bird Type | Vaccine | N° Doses | Protection (%) | Vaccination cost* (EPD**/100D) |
|---|---|---|---|---|
| **Breeders** | Inactivated | 3-5 | 63-92% | 84-140 |
| | Vector+ Inactivated | 1 | 92% | 59.5 |
| **Broilers** | Inactivated | 1 | 10-33% | 28 |
| | Vector | 1 | 50-80% | 31.5 |
| | Vector+ Inactivated | 1 | 66% | 59.5 |

* Costs considered: vaccinator salary/ vaccinator supervision/ Vaccine cost/ DOC or bird losses/ Equipment/ Transportation
**EPD = Egyptian Pounds

The **duration of sero-protection** in long cycle birds (breeders and layers) could be significantly increased (up to 48%) with the prime boost vector/inactivated strategy (p<0.05). Implementing this prime boost strategy would also **reduce the vaccination costs** from 30 to 60% when compared to 3 or 5 doses inactivated vaccine protocols respectively.

The results of the cost-benefit and break-even analysis highlighted the limitation of the current vaccination of broilers with inactivated vaccine which could never be efficient even if the risk of infection was 100%. The use of vector vaccines at day-old would be an efficient strategy to be used in the broiler production even at medium to low incidence levels (1% to 4% for prime-boost or single dose strategies respectively).

### *Spatial Analysis: vaccine coverage*



**Scenario 1 (baseline)** Farm vaccination

**Scenario 2** Hatchery vaccination of Integrated broilers

**Scenario 4** Hatchery vaccination of all DOC from integrated hatcheries + DOC raised in independant large farms

**Figure 3**. **Spatial analysis of immunity distribution profiles** was performed to account for spatial clustering of the different poultry production types (e.g. GP production is concentrated in 3 Governorates; 80% of the breeders are located in 6 Governorates; 70% of the layers in 5 Governorates; 60% of the broilers and the total poultry population is concentrated in 4 Governorates).

## CONCLUSIONS and PERSPECTIVES

**This study demonstrated the interest of combining network analysis and immunity modelling to assess the efficacy of AI vaccination scenarios in Egypt.**

The model predicted that **targeting DOC AI vaccination in integrated and large hatcheries would increase immunity levels in the overall poultry population in Egypt**, and especially in small commercial poultry farms, up to sufficient levels to improve HPAI disease control in Egypt.

**This strategy was shown to be more efficient than the current strategy using inactivated vaccines**. This approach would have only marginal impact on immunity levels in Sector 4 household poultry. However, improving HPAI control in commercial poultry sector in Egypt could have positive spill over effect on the epidemiological situation of the disease in the household sector (Sector 4).

Effectiveness assessment of this strategy and therefore field validation of the model outputs could be done by assessing the impact of DOC AI vaccination in pilot areas in Egypt, where it is already being implemented in Sector 1 and 2 hatcheries. Moreover, the impact of commercial DOC AI vaccination on the epidemiological situation of the disease in Sector 4 could be assessed by increasing disease prevalence surveillance in LBMs in the areas where the AI vaccinated DOC would be applied.

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