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Exploring contacts facilitating transmission of influenza A(H5N1) virus between poultry farms in West Java, Indonesia: A major role for backyard farms?

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ABSTRACT

Highly pathogenic avian influenza virus (HPAIV) H5N1 has been reported in Asia, including Indonesia since 2003. Although several risk factors related to the HPAIV outbreaks in poultry in Indonesia have been identified, little is known of the contact structure of farms of different poultry production types (backyard chickens, broilers, layers, and ducks). This study aims to quantify the contact rates associated with the movement of people, and movements of live birds and products and equipment that affect the risk of HPAIV H5N1 transmission between poultry farms in Indonesia. On 124 poultry farms in 6 districts in West Java, logbooks were distributed to record the movements of farmers/staff and visitors and their poultry contacts. Most movements in backyard chicken, commercial native chicken, broiler and duck farms were visits to and from other poultry farms, whilst in layer farms visits to and from poultry companies, visits to egg collection houses and visit from other poultry farms were most frequent. Over 75% of persons visiting backyard chicken and duck farms had previously visited other poultry farms on the same day. Visitors of backyard chicken farms had the highest average contact rate, either direct contact with poultry on other farms before the visits (1.35 contact/day) or contact during their visits in the farms (10.03 contact/day). These results suggest that backyard chicken farms are most at risk for transmission of HPAIV compared to farms of the other poultry production types. Since visits of farm-to-farm were high, backyard farms could also a potential source for HPAIV transmission to commercial poultry farms.

1. Introduction

The emergence of multiple highly pathogenic avian influenza virus (HPAIV) H5N1 sublineages in China between 2000 and 2002 was followed by rapid and widespread virus dissemination resulting in disease outbreaks in poultry and wild birds across Asia, the Middle East, Europe, and Africa between 2003 and 2005 (Kilpatrick et al., 2006; Vijaykrishna et al., 2008). Indonesia is one of the countries severely affected by HPAIV H5N1 infection with poultry outbreaks first reported in late 2003 (Vijaykrishna et al., 2008). The economic losses were estimated at least U$ 330 million during 2004–2008 due to culling of poultry, decreasing demand of poultry products, and the costs of disease control (Basuno, 2008). Moreover, H5N1 virus infection in humans has been associated with a high case fatality rate (84%, 168 deaths from

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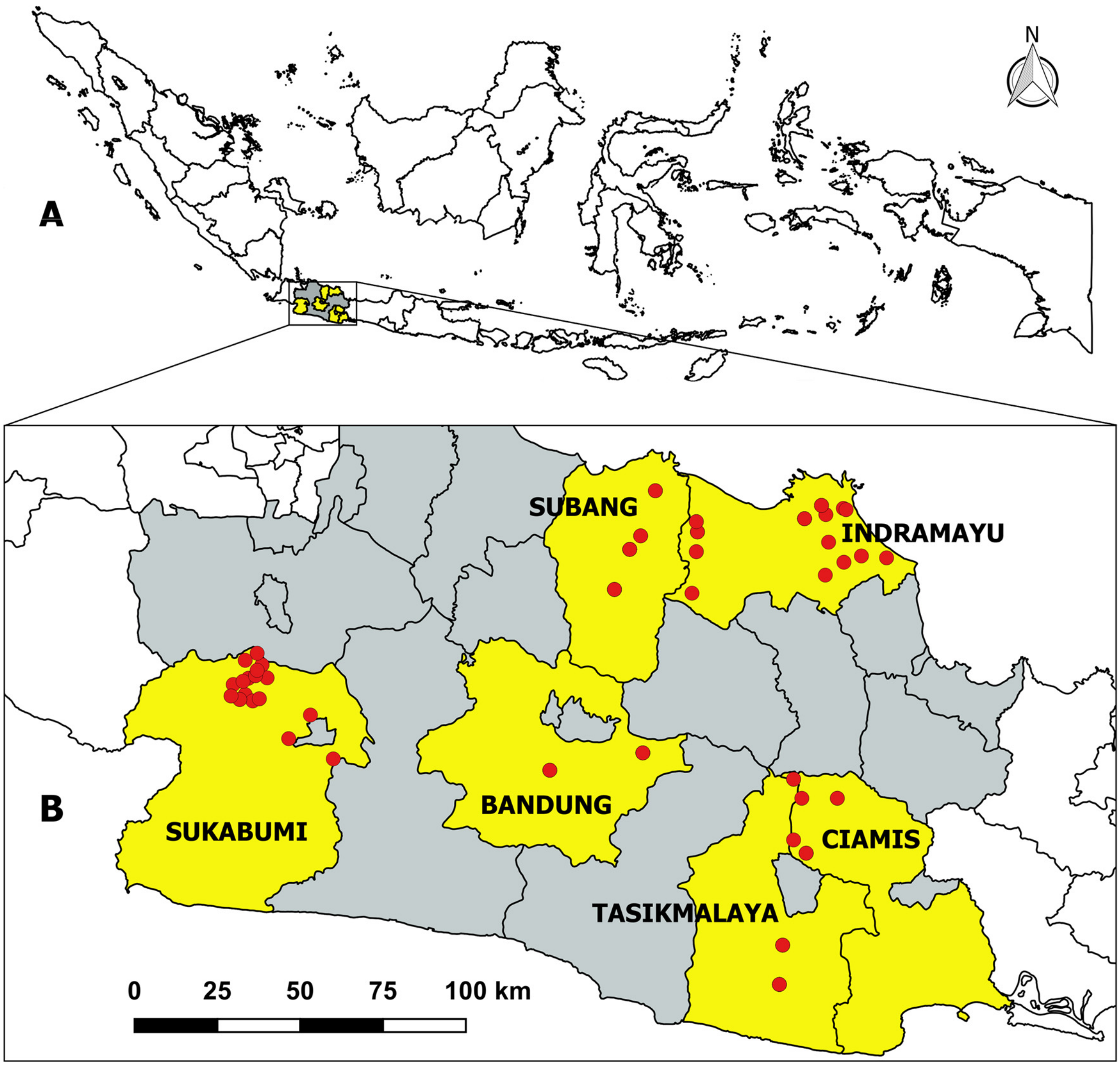

Fig. 1. The geographical map of the Republic of Indonesia and the study area.
(A) Provincial boundaries of Indonesia with the West Java Province are highlighted. (B) The West Java Province showing the district boundaries with approximate locations of poultry farms are shown. Districs where enquiries were conducted are yellow coloured and farms are represented as red-round dots. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

200 confirmed cases in Indonesia up to September 2017) (WHO, 2017). Several measures to control HPAIV have been implemented by the Government of Indonesia resulting in a reduction of disease outbreaks in poultry since 2012 (FAO, 2012) and human H5N1 cases have decreased substantially since 2013 (WHO, 2017). However, HPAIV H5N1 continues to pose a threat to public health as evidenced by reports of outbreaks in poultry to date (DGLAHS, 2017) and a report of a fatal case in humans in September 2017 (WHO, 2017).

The poultry production sector in Indonesia is highly diverse. It includes backyard poultry farms with minimal biosecurity and a small number of birds per farm for local consumption (Sector 4); small- to medium-scale commercial poultry farms, housing broilers, layers, or ducks with low biosecurity and birds/products are usually sold through live bird markets (Sector 3); medium- to large-scale commercial poultry farms, mainly housing broilers or layers with moderate to high biosecurity and birds/products are sold through slaughterhouses or poultry markets (Sector 2); and large industrial integrated poultry farms with high biosecurity and bird/products are always marketed commercially (Sector 1) (FAO, 2004; Azhar et al., 2010). Poor biosecurity practices, for instance uncontrolled movements of live poultry, have been associated with HPAIV virus transmission within and between poultry farms and spread between regions (Sims et al., 2005; Soares Magalhaes et al., 2010; Ssematimba et al., 2013). The difficulty in controlling HPAIV H5N1 spread through poultry movements within and between production sectors and related marketing chains, including trade in live bird markets, is considered as an important reason why the poultry sector in Indonesia is still confronted with outbreaks (McLeod et al., 2009; Millar et al., 2015). Quantitative knowledge of the contact structure of poultry farms is required to improve HPAIV control in Indonesia. For instance, such knowledge could help the Indonesian Government to educate farmers to make them aware of the frequency of contacts in order to become more critical on who they admit to their farm, and if whether they can have access to poultry and where they will pay visits themselves.

Mathematical modelling has been extensively used to increase insight in understanding disease dynamics and interpret epidemiological data. Moreover, it can be used to support decisions on measures to control infectious diseases (Dorigatti et al., 2010; Stegeman et al., 2010; Patyk et al., 2013) and knowledge of the contact structure and contact rates is important for such modeling (Ortiz-Pelaez et al., 2006; Dent et al., 2008; Park and Bolker, 2017). In relation to HPAIV transmission, there are only a few published studies on the contact structure of poultry farms in Indonesia (de Glanville et al., 2010; Henning et al., 2016; Kurscheid et al., 2017). Whilst de Glanville et al. (2010)

performed a quantitative risk assessment of HPAIV transmission amongst smallholder broiler farms in West Java, Henning et al. (2016) and Kurscheid et al. (2017) used a network analysis to investigate the patterns of duck movements in Central Java and poultry movements on/off live bird markets in Bali and Lombok, respectively. In the present study, we aimed to quantify the rate of poultry contacts from different poultry sectors and production types in West Java. Moreover, we determined whether there was direct contact with poultry and which type of contact that most likely contribute to HPAIV virus transmission to poultry farms. Quantitative knowledge of these poultry contacts is important to understand the endemicity of HPAIV H5N1 in Indonesia and may indicate possibilities to reduce the contact rate and HPAIV transmission between farms.

2. Material and methods

2.1. Data collection and management

The study was conducted in West Java Province, the province that produces most poultry within Indonesia (DGLAHS, 2016a) and has repeatedly reported HPAIV H5N1outbreaks (DGLAHS, 2016b). The target population are the poultry farms in West Java Province. We then selected six districts within this province (Bandung, Ciamis, Indramayu, Subang, Sukabumi, and Tasikmalaya) (Fig. 1) because of their: (1) high poultry density, (2) various poultry production systems and (3) HPAIV H5N1 outbreaks reported between 2013 and 2015 (CENTRAS, 2015). The source population consisted of poultry farms of different production types (broilers, layers, ducks, native or local chickens) and different sectors (Sector 1–4) in those six districts.

A farm logbook was developed based on the literature (Ssematimba et al., 2013) as well as interviews from local experts (veterinarians, poultry technical services, and senior animal health officers of district livestock agencies) to collect general data of the poultry farms, contact types, and certain risks factors. It contained a combination of filling sections and questions to describe specific poultry contacts, including: details of farmer, location, poultry population, and period of recording and description of HPAI history (Supplementary Material). In addition, farmers and staff of farms were asked to record their movements outside the farm ("*outbound visit*"), including visits to: other farms, traditional markets, poultry companies, poultry slaughterhouses, egg collection houses, and other places. The farmers were also asked to register the movements of visitors into the farm ("*inbound visit*"), as well as to record their intention to visit the farm and whether they had been in contact with poultry on the day before arriving at the farm ("*off-farm contact*") and contact to poultry during their visit on the farm ("*on-farm contact*"). For the inbound visit, the same places as outbound visit were considered as possible sites where they had been on that same day before visiting the farm. The farm owners and staff were trained how to fill out the logbook before starting the recording of the logbook. The farm logbooks were distributed in June 2015 and the farmers were asked to fill out their logbook for one month. To ensure that the farmers have properly recorded the visits in the logbook, the officials of district livestock agency checked the logbook, at least, once during the period of study.

Traditional markets in Indonesia trade both poultry products (mainly meat and eggs) and live birds for trade or for slaughter. Therefore, these markets are considered and referred to herein, as live bird markets as previously described (Indriani et al., 2010). Poultry companies in this study include core companies (Sector 1 that have agribusiness contracts with commercial farms of Sector 3 for raising poultry, particularly broilers), feed or pharmaceutical companies (for broiler and layer farms), and poultry-product shops and retailers (for duck, commercial and backyard chicken).

To determine whether different poultry production types have different characteristics of visit purposes, the inbound visit was further analysed by examining the intention of visitors to come to the farms. This includes visits with the purpose of: (a) observing poultry (to get compliance whether or not purchasing poultry), (b) buying or collecting poultry and related products (harvest ready-to-slaughter broilers, purchase/collect dead birds or manure in broiler and layer farms, purchase eggs in layer, ducks and commercial native chicken farms, or purchase live birds for restocking or consumption in backyard chickens, commercial native, or ducks), (c) selling or offering poultry and related products (promote information of poultry [e.g. day old chicken/duck/pullet], feed or pharmaceutical products like poultry vaccines/drugs/vitamins), (d) transporting feed, poultry or equipment, (e) inspecting farm or poultry health, (f) vaccination or health treatment, (g) other work at the farm (e.g. renovation of farm premises or poultry houses, service for farm equipment, and so on), and (h) social relationships.

Random selection of poultry farms was not possible, because there is no poultry farm database comprising farmers from all poultry sectors (sector 1–4) in the study area. As the next best option, livestock officials with expertise of local poultry productions selected farms in the districts aiming for a representative sample of the major poultry producing farms in the region. But, they were depending on the willingness of farmers to participate in the study, resulting in underrepresentation of sector 1 and sector 2 farms. As a results, the logbooks were distributed to 150 different poultry farms representing sector 3-commercial farms and sector 4-backyard farms. Poultry collector houses and live bird markets were not included in the study, as they have been studied previously (Kurscheid et al., 2017).

From 150 distributed logbooks, 146 were collected and the data were compiled and entered in a Microsoft Excel file after excluding 21 farm logbooks because of incomplete or inconsistent data. Data from quail farms were not included in the analysis since only one good quality logbook was available. Thus, a dataset from 124 farm logbooks were analysed. This dataset was imported into an open-source integrated R environment for statistical computing and graphics (version 3.3.3, https://www.r-project.org).

2.2. Data analysis

An open-source geographic information system QGIS (version 2.18 Las Palmas, https://www.qgis.org) was used to map the locations of poultry farms. The proportion of outbound visits by farmers/staff and inbound visits by visitors were calculated. Differences in proportions of visits based on the purpose of visitors coming to the farm were also examined. The rates of off-farm and on-farm poultry contacts by visitors were estimated using a *generalized linear mixed-effect model* (GLMM) with Poisson distribution and a log link using *lme4* package for R (https://cran.r-project.org/package=lme4). Furthermore, the risk ratio (RR) of poultry contact per day was calculated. Total number of off-farm or on-farm contacts in the one month period represented the respective dependent variables; whereas district, poultry sector, farming system, poultry production types, farm size and HPAI history were added as independent categorical-fixed effect-variables, and observed poultry farm was added as a random effect. Since the length of the period farmers recorded the logbook varied from 22 to 45 days (median: 30 days), a natural logarithm (*ln*) of these observation times was included as offset variable. To build the model, a univariable logistic regression analysis using GLMM was firstly carried out to examine the association of each independent variable with the dependent variable. Then, a full multivariable logistic regression analysis was performed using all the independent variables with a *p*-value less than 0.25 from the univariable analysis. After backward stepwise procedures applied, poultry sector and subsequently farming system were excluded because the multivariable analyses indicated a rank deficient matrix due to collinearity (O'Brien, 2012); whereas all the other independent variables were maintained in the final multivariable analysis. We used Akaike's information criterion (AIC) to test goodness of fit of the model, selecting the one with lowest AIC (Motulsky and Christopoulos, 2004). All analyses were performed in R (version 3.3.3, https://www.r-project.org).

3. Results

3.1. Descriptive analysis

We collected data from 114 commercial and 10 backyard poultry farms in the study area (Fig. 1) and poultry types including broilers, layers, ducks and native chickens. Three different native chickens were found: the Indonesian-local village chickens that are raised traditionally in household backyard (hereafter referred as "*backyard chicken*"), the male of local village chickens and the cross-breed chickens between the Belgian-Braekel chickens and the local village chickens that both are housed in a fenced area within the farm yard. The last two types of native chickens were raised for commercial purposes (hereafter referred as "*commercial native chicken*"), particularly for meat and egg production, respectively.

The number and type of poultry production included in the study varied between the districts: Subang (23 farms: all broiler farms), Bandung (16 farms: 5 backyard chicken, 6 commercial native chicken and 5 duck farms), Ciamis (14 farms: all broiler farms), Indramayu (34 farms: 5 backyard chicken, 28 duck and 1 layer farms), Sukabumi (24 farms: 7 commercial native chicken, 10 broiler and 7 layer farms), and Tasikmalaya (13 farms: 6 broiler and 7 layer farms) (Fig. 2). Backyard chicken farms raised 20–100 birds/farm and flock sizes observed in commercial native chicken farms ranged from 60–30,000 birds/farm. The numbers of birds housed on layer farms varied from 1000 to 60,000 birds, whereas most broiler farms housed between 1000 and 10,000 birds and most duck farms housed between 100 and 1000 birds. A small proportion of poultry farms in this study had a size of more than 30,000 birds. The proportion of poultry farms reporting a previous HPAIV history in backyard chickens and in commercial native chickens were more or less similar (approximately 60%). Few HPAIV outbreaks were reported from layer farms (7%) and broiler farms (20%), whereas most duck farms (85%) had experienced HPAIV outbreaks in the past.

3.2. Outbound and inbound visits

Amongst poultry production types, visits to and from other poultry farms were most frequent (Fig. 3). Over 75% of persons visiting backyard chicken and duck farms had previously visited other poultry farms on the same day. Higher proportions of visits to live bird markets by farmers/staff of backyard chicken, commercial native chicken and broiler farms were observed (24–31%), when compared with farmers/staff of layer and duck farms that showed higher proportions of visits to poultry companies (35% and 27%, respectively) and to egg collection houses (39% and 20%, respectively). Broiler farms had more outbound visits to live bird markets (30%) than to poultry slaughterhouses (5%); on the other hand, they had only few inbound visits from live bird markets (1%). In addition, the proportion of visits from poultry companies to broiler and layer farms were higher (23% and 36%, respectively) than to farms of the other poultry types (3–8%).

A high proportion of visits had the objective to buy/collect poultry and related products (19–30%) (Fig. 4). Only a small proportion of inbound visits had the aim to sell/offer poultry and related products (1–7%), to vaccinate or treat poultry (0–4%), or to have other work at the farm (2–10%). Backyard chicken and duck farms showed a higher proportion of visits to observe poultry (20–21%), than visits to transport feed, poultry or equipment (8–14%). Commercial native chicken, broiler and layer farms had more visits to transport feed, poultry or equipment (15–37%) than to inspect farm and poultry health (13–23%).

Visits related to social relationships were commonly found (14–39%) in all poultry production types. Additionally, we observed that the frequency of visits to transport feed, poultry or equipment and to inspect farm and poultry health was associated with an increase in the farm size; while there was a negative association between the farm size and the frequency of visits for observing poultry, purchasing poultry or products, and social visits (Fig. 3).

3.3. Contacts of visitors to poultry

The rate of off-farm and on-farm contacts differed significantly per district, production type and farm size categories (Table 1). The probability of off-farm contact per day amongst poultry farms in Ciamis and in Tasikmalaya were 2–3 times higher (RR: 2.15 [95% CI:1.05–4.44] and (RR: 2.91 [95% CI:1.26–6.78], respectively) than that of poultry farms in the reference district (Subang). Also, their on-farm contact RR was higher although this difference was not significant. On the other hand, on-farm contacts amongst poultry farms in Bandung and in Indramayu were very low (RR: 0.03 [95% CI: 0.00–0.29]). Backyard chicken farms had significantly higher off-farm contact rate (1.35 contact/day on average) and on-farm contact rate (10.03 contact/day) than the other poultry farm types. There were no significant differences in the contact rate of poultry farms with small (1,001–10,000 birds/farm) and with moderate population sizes and 10,001–30,000 birds/farm). However, poultry farms with the biggest population (30,001–60,000 birds/farm at 1 broiler and 3 layer farms) showed a significant increase in off-farm poultry contact (RR: 23.56 [95% CI:4.06–137.75]). At last, although there was no significant difference on the contact rate between farms which had experienced HPAIV outbreak and those that did not, their on-farm contact rate was about 7 times higher than off-farm contact rate (Table 1).

4. Discussion

This study identified that the most frequent movements in backyard chicken, commercial native chicken, broiler and duck farms were associated with visits to and from other poultry farms, whilst in layer farms visits to egg collection houses, visits from other farms, and visits to and from poultry companies were most frequent. Risks of HPAIV exposure could arise from visits by farmers/staff or visitors to or from a farm experiencing H5N1 infection. If such a contact occurs and no adequate biosecurity protocols are in place, between farm HPAIV transmission might occur directly or indirectly (Idris et al., 2010; Fasina et al., 2011; Ssematimba et al., 2013; Durr et al., 2016). Apart from visits to other farms, farmers/staff of backyard chicken, commercial native chicken and broiler farms in this study showed more visits to live bird markets than those of the other farm types. Visits to these sites bear a high risk of HPAIV exposure as they are considered as a source of virus (Indriani et al., 2010; Samaan et al., 2011) and facilitate HPAIV transmission and large-scale disease spread (Sims et al., 2005; Fournie et al., 2013).

The intention of visitors was evaluated to examine whether during the farm visit direct contact with poultry would occur. Visits with the aim to purchase or collect poultry and related products pose a higher risk for virus transmission since these are mostly acted by middleman who can have multiple visits and have direct contact with poultry on different farms on the same day (Idris et al., 2010; Henning et al., 2013; Durr et al., 2016). Commercial farms with a larger farm size tend to have more poultry contacts, as shown in this study where farms housing more than 30,000 birds showed substantial increase in the likelihood of poultry contacts of visitors before visiting the farm (RR: 23.56 [CI:4.06–137.75]). This might be associated with contacts via movements of visitors across different farms to supply live birds, feed and equipment, or to inspect farm or poultry health. Previous studies indicated that persons who are commonly in charge for checking flock health (poultry technical services or veterinarians) have been considered risk factors promoting virus transmission, if they do not follow proper biosecurity practices during the visit (Idris et al., 2010; Ssematimba et al., 2013; Osmani et al., 2014). In addition, layer farms with a larger population size usually have a number of flocks of different ages; thus, more frequent visits for bird replacement were observed (Durr et al., 2016). A small proportion of visits were aimed to

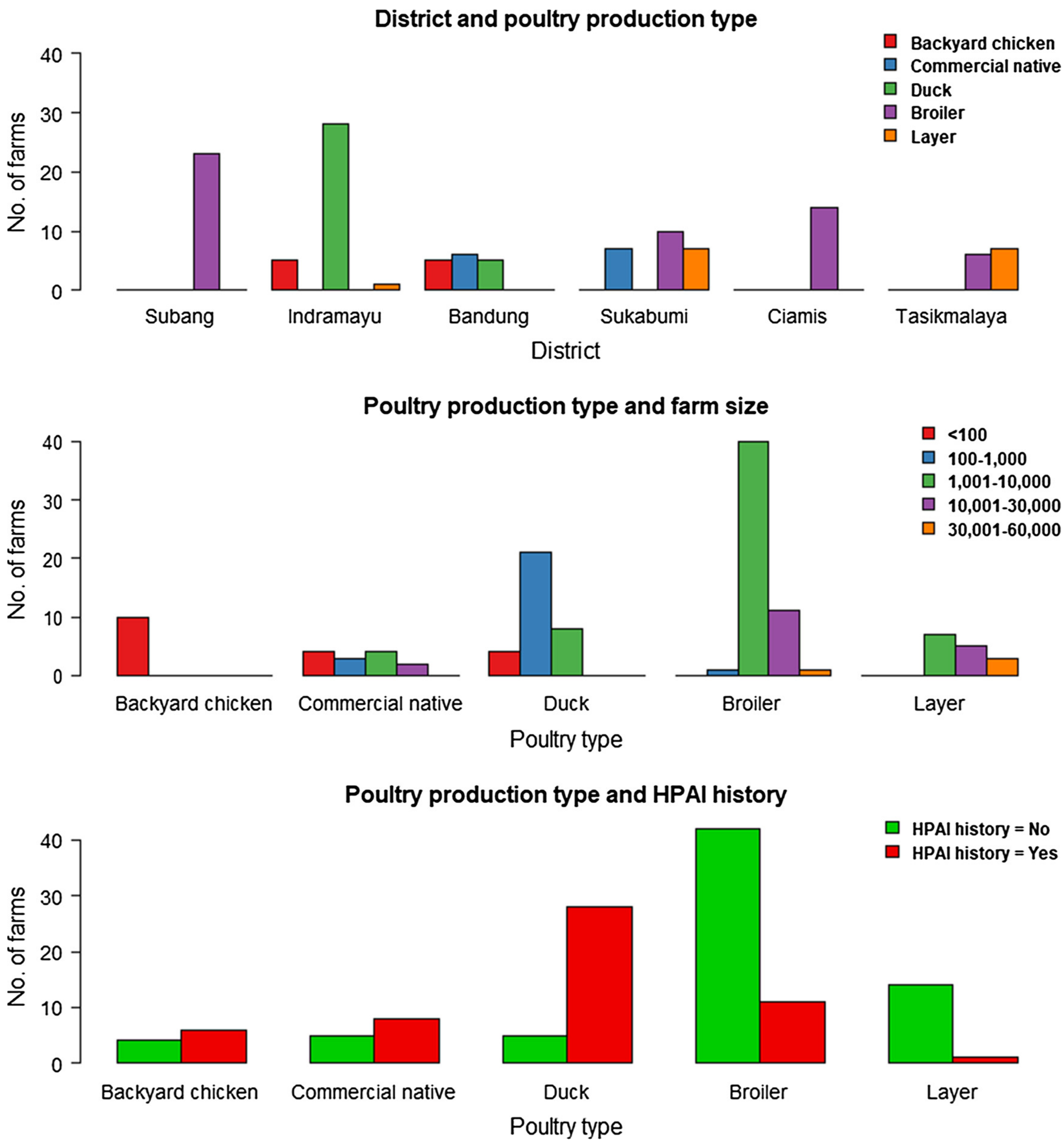

Fig. 2. Distribution of poultry farms across district, production type, farm size and HPAI history.

vaccinate broiler and/or layer flocks which could be directed not only to protect against HPAIV H5N1 but also against other avian pathogens. Such visits will occur less frequently to broiler flocks as vaccination is less common because of the shorter-life span of broilers compared to layers. In addition, layer farms often can manage vaccination by own resources (layer farms in Indonesia usually have equipment and staff members who have been trained for vaccination).

HPAIV outbreaks in duck farms have been frequently reported since the introduction of H5N1 Clade 2.3.2.1c in poultry in Indonesia in 2012 (Wibawa et al., 2012). The present study shows that a higher number of duck farms with HPAI history was observed in comparison to the other farm types. However, the contact rates amongst poultry farms that had or had not experienced HPAIV outbreaks in this study were not significantly different. Because the infection history may have influenced the contact structure, we could not certainly infer from this that contact structure is not influencing HPAIV transmission. In addition, incoming visitors having direct contact with poultry inside farm, either with or without HPAI histories, were seven times higher than farmers/staff having direct contact with poultry outside farms, suggesting that the majority of poultry farms in this study lacks proper biosecurity protocols for visitors.

HPAIV can be transmitted between commercial farms or between commercial farms and backyard farms through several pathways involving direct bird-to-bird contacts or indirect contacts of infected birds via environment or fomites (de Glanville et al., 2010; Ssematimba et al., 2012). De Glanville et al. (2010) estimated that the probability of HPAIV H5N1 transmission from infected to susceptible flocks in Sector 3-broiler farms in Bogor District, West Java, were 0.032–0.130 per contact of poultry collectors and 0.029 to 0.095 per contact of animal health workers. In addition, Ssematimba et al. (2012) estimated that during the 2003 HPAIV H7N7 epidemic in the Netherlands, per-contact probability of a susceptible layer farm infected by H7N7 virus from an infectious farm were between 0.0414 and 0.308, depending the type and purpose of visits. Although estimating the probability of virus transmission per contact was beyond the goal of this study, we could show that the average daily contact of visitors to poultry varied amongst production types; visitor-to-poultry contact in backyard chicken farms was significantly higher (10.03 contact/day) than contacts in farms of ducks (4.19), commercial native chickens (0.15), broilers (0.11) and layers (0.06). This is no surprise since many

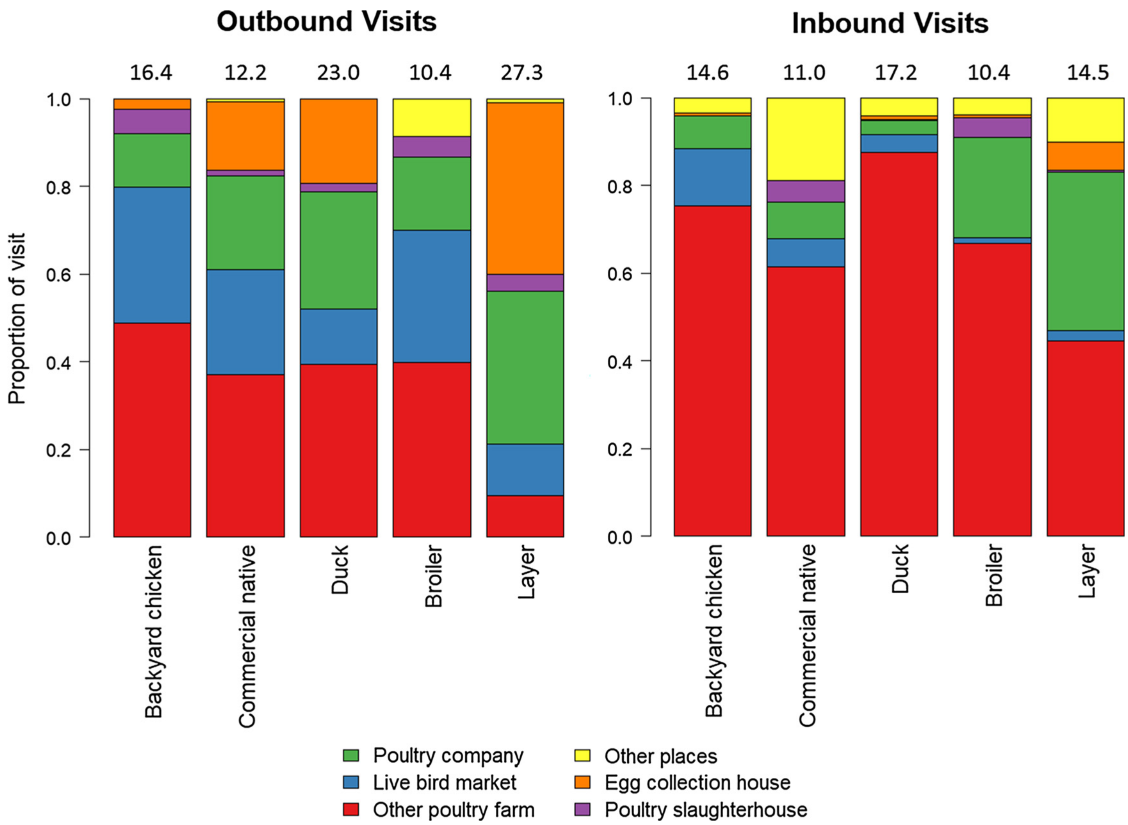

Fig. 3. Outbound and inbound visits amongst poultry production types.
The proportion of each visit (e.g. visit to other farm) to the sum of all visit types per farm is shown using stacked-column barplots with the average number of visit per farm is indicated above each bar.

backyard chickens lack permanent confinement and poultry owners might not be familiar with basic biosecurity measures and let their chickens roam freely around the house.

A higher poultry contact in backyard poultry is likely associated with type and purpose of visits that show more visits of farm-to-farm and farm-to-live bird market with aims to observe birds or to purchase live birds and products. This indicates that Sector 4-backyard poultry in Indonesia retains the highest risk to be exposed by HPAIV from other poultry sectors as well as to be a potential source of infection, particularly towards small-scale commercial sector farms (de Glanville et al., 2010; Idris et al., 2010). It could also contribute to the course of HPAIV transmission between commercial farms through spill-over infection (Smith and Dunipace, 2011). Moreover, both Sector 4-backyard and Sector 3-commercial poultry farms have been reported to have a higher probability of HPAIV infection (Durr et al., 2016) and a higher proportion of disease outbreaks in Indonesia (DGLAHS, 2016b); hence, they are considered to play a role in maintaining the infection cycle of HPAIV in poultry within the country (Idris et al., 2010; Henning et al., 2013).

Various studies reporting risk factors for HPAIV H5N1 have been published (Biswas et al., 2009; Desvaux et al., 2011; Fasina et al., 2011; Henning et al., 2016), but to our knowledge, analytical epidemiological studies in quantifying contacts in different poultry production types are scarce, particularly for Indonesia. Nevertheless, the results of this study should be interpreted with caution because it might have been subject to selection bias since the poultry farms were not randomly selected. In the context of HPAI control strategy in Indonesia, however, we consider that the results still relevant because the selected farms represented poultry sectors where most HPAIV outbreaks are reported. In addition, to minimise inconsistency in reporting, farmers were trained how to fill the logbook and we excluded incomplete logbooks. The poultry contacts by farmers/staff outside the farm as well as hygiene and biosecurity implementation could also be important risk factors associated with HPAIV transmission, but we were unable to evaluate these as they were not recorded.

In conclusion, this study identified that Sector 4-backyard farms showed the highest in and outbound contact rates compared to farms of the other poultry production types in West Java, Indonesia. Since many Sector 3-commercial farms in Indonesia are situated amongst Sector 4-backyard farms (Idris et al., 2010) and both sectors are directly or indirectly connected to a bigger and complex market network involving live bird markets (McLeod et al., 2009; Kurscheid et al., 2017), between farms transmission of HPAIV H5N1 could occur at any time as the proportion visits of farm-to-farm or farm-to-live bird markets in these sectors were also high. In accordance with reports of previous quantitative studies (Roberts and Heesterbeek, 2003; Smith and Dunipace, 2011), our study indicates that HPAIV control strategies should not only focus on one host type or one poultry sector, but also emphasizes the need for efforts eliminating potency of both backyard and commercial poultry farms as well as live bird market to become “a house” for HPAIV H5N1 circulation. This study suggests that in order to help with control and eradication of HPAIV H5N1 in Indonesia, restructuring the poultry husbandary is necessary, particularly for sector 3-commercial and sector 4-backyard farms to have an improvement on biosecurity, production and marketing practices.

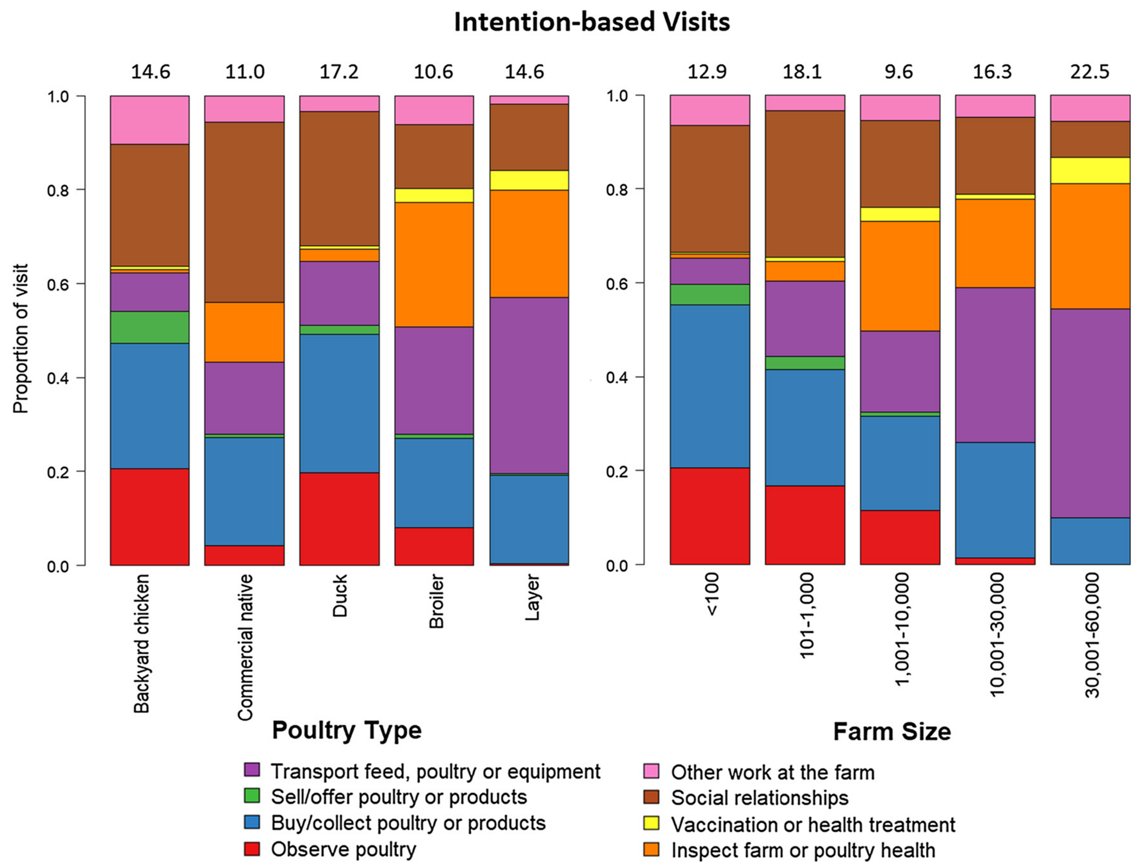

Fig. 4. The visit purposes of visitors to poultry farm based on the production type and the farm size.
The proportion of each visit purpose to the sum of all visit types per farm is shown using stacked-column barplots with the average number of visit per farm.

Table 1
Results of multivariable logistic regression analysis of off-farm contact rate and on-farm contact rate in West Java and its association with district, production type, farm size and HPAI history.

Independent Variable	Poultry contact by visitors (dependent variable)			
	Off-farm contact		On-farm contact	
	Contact rate	RR [95%CI]	Contact rate	RR [95%CI]
District:				
Subang	1.35	1.00	10.03	1.00
Bandung	0.24	0.18 [0.03–1.23]	0.28	0.03** [0.00–0.29]
Ciamis	2.90	2.15* [1.05–4.44]	16.79	1.67 [0.93–3.01]
Indramayu	0.22	0.16 [0.02–1.15]	0.30	0.03** [0.00–0.29]
Sukabumi	0.64	0.47 [0.17–1.31]	6.90	0.69 [0.31–1.52]]
Tasikmalaya	3.93	2.91* [1.26–6.78]	13.44	1.34 [0.67–2.68]
Poultry production:				
Backyard chicken	1.35	1.00	10.03	1.00
Broiler	0.02	0.01*** [0.00–0.10]	0.11	0.01*** [0.00–0.11]
Commercial native chicken	0.04	0.03*** [0.00–0.15]	0.15	0.01*** [0.00–0.13]
Duck	0.29	0.21** [0.07–0.66]	4.19	0.42 [0.16–1.06]
Layer	0.00	0.00*** [0.00–0.02]	0.06	0.01*** [0.00–0.06]
Farm size (No. of birds):				
< 100	1.35	1.00	10.03	1.00
100–1.000	3.49	2.59 [0.86–7.86]	9.92	0.99 [0.37–2.63]
1.001–10.000	3.26	2.41 [0.70–8.45]	8.87	0.88 [0.30–2.65]
10.001–30.000	5.00	3.70 [0.85–16.28]	11.59	1.16 [0.33–4.10]
31.000–60.000	31.81	23.56*** [4.06–137.75]	24.81	2.47 [0.55–11.23]
HPAI history:				
No	1.35	1.00	10.03	1.00
Yes	1.55	1.15 [0.68–1.94]	10.73	1.07 [0.69–1.67]

Contact rate refers to the average poultry contact by visitors per day.
Risk ratio (RR) with asterisks indicate significant differences (p-values: ***p $\leq$ 0.001, **p $\leq$ 0.01, *p $\leq$ 0.05) followed by 95% confidence intervals. Categorical factor that was set as reference in multivariable analysis is italicised.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.prevetmed.2018.04.008.

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