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Measuring and defining the factors affecting adoption of biosecurity on smallholder poultry farms in Indonesia

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Abstract

Highly Pathogenic Avian Influenza (HPAI) is endemic in most provinces in Indonesia. Its presence in the country since 2003 has provided the impetus for the Indonesian Government (GoI) to encourage the adoption of biosecurity in smallholder broiler and layer farms. In order to identify cost-effective biosecurity for these farms it is first necessary to identify the biosecurity activities already adopted and the reasons behind this level of adoption.

This paper builds on past papers by the authors which identify the biosecurity activities already adopted by farmers, and the farm and farmer characteristics that influence this adoption. This paper develops the discussion of how to measure adoption and then use these measures as dependent variables in identifying the factors that influence adoption. The two methods are; the construction of an aggregated Biosecurity Control Score which simply ranks and aggregates farmers' adoption of 44 Biosecurity Control Indicators and construction of a modified BCS using Principle Components Analysis (PCA).

Initial analysis indicates that both models identify similar factors as being important indicating that either method of constructing the BCS is useful.

Keywords: biosecurity, poultry farm, adoption, Indonesia

1. Introduction

1.1. Background

Highly Pathogenic Avian Influenza (HPAI) continues to be an economically and socially important disease in Indonesia. It is endemic in 31 of the 33 provinces in Indonesia and is the focus for significant Indonesian and donor resources and support. With other poultry diseases such as Newcastle disease (ND) also causing economic loss in the Indonesian poultry industry, improving farm biosecurity is one area that can potentially improve the economic and social livelihoods of Indonesian small-scale commercial poultry producers. Biosecurity is is regarded as key to controlling poultry diseases and improving both poultry and human health.

To provide better understanding of the smallholders' decision making process with regard to biosecurity adoption, it is first necessary to measure present levels of adoption and identify the factors that influence adoption. The ACIAR project *AH-2006-169 – Cost-effective biosecurity for NICPS operations in Indonesia* aims to identify and encourage implementation of cost-effective biosecurity for Non-Industrial Commercial Poultry Sector (NICPS) farms in Indonesia (ACIAR, 2007). To do this, the project seeks to understand what smallholders are currently doing, their economic circumstances, their understanding of risks and consequences and their capacity to implement biosecurity.

1.2. Poultry biosecurity in Indonesia

Biosecurity is defined as a set of preventive measures designed to reduce the risk of disease transmission. These measures are a combination of systems and practices that are a response to the specific risks faced by producers. In poultry farming, biosecurity is defined as management to keep diseases out of the flock. It ranges from simple, low cost measures such as putting locks on gates to the more costly measures such as using high-pressure water sprayers to clean cars and constructing shower blocks to secure visitors and workers as they enter the farm. Some biosecurity activities are management changes, which may be low cost but require commitment from owners and farm workers to implement successfully. These include allocating a specific worker to a shed and not allowing staff to move from shed to shed. There are several factors that may influence the types of biosecurity measures adopted by broiler and layer smallholders poultry farmers in Indonesia. These include; farmer's attitude to risk, farm and farmer characteristics, management and marketing systems, access to information and capital, the importance of poultry as an income source.

In order to provide a recommendation for improving farm biosecurity, more information is required on current biosecurity implementation at farm level, and a better understanding of the factors that influence the adoption of biosecurity measures.

2. Objectives

This paper has two objectives;

1. Develop a useful method of measuring and comparing biosecurity adoption on NICPS farms and;
2. Identify the factors that influence biosecurity adoption on non-industrial commercial poultry sector (NICPS) broiler and layer farms in Indonesia

This paper is divided in four sections. ***Firstly***, data collection is discussed. Farmers were surveyed in order to collect data on the dependent variables and the potential independent variables. ***Secondly,*** the potential independent variables are defined. These are factors, which may influence the ability of farmers to implement biosecurity measures. ***Thirdly***, the dependent variable is defined. This will represent the farmers' responses to their particular set of disease risks and farm and farmer characteristics. ***Fourthly***, factors affecting biosecurity are identified.

A better understanding of present levels of biosecurity adoption is necessary if appropriate government policy and market incentive structures can be established that encourage the reduction in poultry disease prevalence. This reduction in disease will benefit farmers (higher income), consumers (food safety) and society (a reduction in the pandemic risk from diseases such as HPAI). The results from this study will be used to identify further the specific biosecurity activities that are cost-effective and able to be adopted by NICPS layer and broiler farmers.

3. Data collection

A survey of smallholder layer and broiler producers was undertaken in Bali and West Java in 2010. In Bali 120 smallholders were surveyed through face-to-face interviews. The survey in Bali included 60 broiler and 60 layer smallholders. In West Java 108 smallholders were surveyed; 67 broiler and 41 layer smallholders. These were randomly selected from FAO and Provincial Department of Agriculture census data in West Java and Bali respectively. The appropriateness and structure of the questions were discussed with the relevant government and university experts and the questionnaire tested on poultry smallholders before it was finalized. The surveying was undertaken by trained enumerators from Udayana University (Bali) and Indonesian Centre for Agriculture and Socio-economic Policy Studies (ICASEPS).

4. Potential factors affecting biosecurity adoption on NICPS farms

The following section introduces the potential factors that may influence adoption. It outlines the expected effect of each factor on adoption and initial descriptive results obtained for each factor from the survey. Initial summaries of the farmer characteristics are provided in Table 1.

Table 1: Characteristics of poultry farmers in West Java and Bali

Item	West Java		Bali	
	Layer	Broiler	Layer	Broiler
Age (year)	43.7	40.8	43.2	44.1
Education (year)	11.1	10.0	10.5	9.7
Household size (person)	4.5	4.2	4.3	4.0
Farm experience (year)	9.7	6.7	14.2	6.3
Household head – poultry as main occupation (%)	85.0	85.0	80.0	70.0
Household head – working on farm (%) :				
Full time	75.6	74.6	73.3	71.9
Not full time	24.4	25.4	26.7	28.1
Poultry management (%) :				
Independent	4.9	74.6	3.3	82.5
Contract	95.1	25.4	96.7	17.5
Farm ownership type (%) :				
Owner	31.7	19.4	50.0	35.1
Manager	43.9	28.4	13.3	15.8
Owner and manager	14.6	40.3	30.0	7.0
Others	9.8	11.9	6.7	42.1
Non-poultry income per household (%) :				
None	0	1.5	0	1.7
< Rp 6 million	42.5	84.9	100.0	96.6
≥ Rp 6 million	57.5	13.6	0	1.7
Experience in HPAI (%) :				
On farm	17.5	3.0	26.7	0

Item	West Java		Bali	
	Layer	Broiler	Layer	Broiler
Within village	27.5	7.6	45.0	3.4
Within sub- district	32.5	12.1	50.0	11.9

4.1. Farmer characteristics

4.1.1. Age of the household head

The age of the decision maker may be an important factor influencing the adoption of biosecurity activities. The household head is generally responsible for the decisions made on NICPS poultry farms. Older farmers may be more set in their ways and less prepared to change or invest in new activities. The age of household heads surveyed ranged from 40 to 44 years of age; the oldest was 65 years old while the youngest was 19 years old. There were no significant age differences between household heads in West Java and Bali, and between the household heads of layer and broiler farms.

4.1.2. Education

Education may be an important influence on farmer adoption of biosecurity. Given its relationship with the ability of farmers to analyze and understand biosecurity measures, it is expected that the higher the educational level of farmers, the greater their biosecurity adoption. The average educational background of household heads of layer and broiler farms in both West Java and Bali was at the senior high school level. Some were university graduates while others had not graduated from elementary school. There were no illiterate household heads.

4.1.3. Household size

Household size or number of family members may also influence biosecurity adoption. It may be that the larger the size of the family the more people that may have access to the farm and farm sheds, therefore, increasing the potential for disease movement both onto and within the farm. On average, the number of family members of layer and broiler respondents in both West Java and in Bali households was four persons.

4.1.4. Poultry farming experience

Poultry farming experience may also be an important influence on biosecurity adoption. As with educational level, it is expected that the greater the experience in poultry farming, the greater the likelihood that farmers will implement biosecurity measures. The length of farm experience can potentially provide an opportunity for farmers to manage their poultry farm through the process of 'learning by doing', either individually, by observing the experiences of other farmers, or from training given by relevant institutions. On average, layer farmer respondents in Bali and West Java had greater farm experience than broiler farmer respondents, 14.2 years for layer farmers and 6.3 years for broiler farmers in Bali, compared to 9.7 years and 6.7 years respectively for layer and broiler farmers in West Java. Respondents in Bali generally had more experience as poultry farmers compared to respondents in West Java. In Bali experience ranged from 3 to 44 years for layers and 0.7 to 33 years for broiler farmers. In West Java, the farming experience of broiler and layer respondents ranged from 0.5 to 30 years and 1 to 27 years, respectively.

4.1.5. Poultry as main occupation for household head

If poultry is the main source of income, it may be that production and efficiency may be important to these households, hence, they may have higher levels of biosecurity. About 70 to 85 per cent of household heads worked predominantly as layer and broiler farmers. The importance of poultry farming as a source of income for household heads in West Java was greater than that of Bali household heads. Moreover the number of household heads working on layer farms as main occupation in Bali was higher than those working on broiler farms.

4.1.6. Working on the farm

Similarly, active involvement of household members in poultry farm operations can also be categorised as one of risk factors that may influence the implementation of biosecurity. It may be that the larger the number of household heads working fulltime on their farms, the higher the adoption of biosecurity measures. The percentage of household heads who work fulltime on their farm ranged between 72 to 76 percent, the remainder worked on the farm part-time. The number of household heads working fulltime on layer farms was greater than in broiler farms.

However, similar to the actual size of the household the higher the number of family members working on the farm, the higher the potential biosecurity risk since their movement between other farm and house may increase the potential for disease movement onto and around the poultry farm.

4.1.7. Poultry management

Egg and broiler products are produced under two management systems; independent and contract. Independent farmers make their own input purchase and product sale decisions, while contract farmers tend to have these decisions made by large poultry companies. Contract farmers rely on the company to supple all inputs and sell their product at an agreed price.

The majority of layer farms both in Bali and West Java are contract farmers. About 95 per cent of surveyed farmers in West Java and 97 per cent in Bali were contract farmers, the remainder are independently managed. On the other hand, about 75 per cent and 83 per cent of broiler farms in West Java and Bali was under independent management, respectively.

4.1.8. Farm ownership type

Farm ownership type may influence biosecurity adoption. The survey respondents all had an important role in making decisions relating to biosecurity implementation. It was found that the farm ownership status of respondents could be defined as; owner; manager; owner and manager; and other (e.g. rent a shed). It may be that an owner/manager, will be more likely to implement biosecurity activities as they have more incentive to improve production and work directly on the farm. The majority of layer farms in West Java are large-scale and operated by managers. However, broiler farms were predominantly run by smallholder owners and varied in size from small to large-scale. In West Java, broiler farms were generally managed by owner/managers.

4.1.9. Non-poultry income

The importance of family income derived from non-poultry sources (or/and from livestock) may influence the priority to invest in poultry farm infrastructure and management changes. If non-poultry income is high there may be less priority for farmers to be concerned about poultry income and hence less investment in poultry activities. Households were divided into three groups based on the level of non-poultry income, these were; no non-poultry income; less than Rp. 6 million; and greater than Rp. 6 million. Most farmers in Bali earned less than Rp. 6 million from non-poultry sources while in West Java, about 85 per cent or broiler households and 43 per cent of layer households earned less than Rp. 6 million from non-poultry sources.

4.1.8. Experience in HPAI

Poultry farmers who had experience in HPAI may implement higher levels of biosecurity. Surveyed farmers was classified into three categories; those who had experience of HPAI on their own farm, those who had heard of outbreaks within their village, and those who had only heard of it occurring at the sub-district level. It is expected that farmers' experience in HPAI in their own farms will generate a greater response compared to those who only hear about HPAI outbreaks at the village or district levels.

The experience of layer farmers in HPAI was greater compared to broiler farmers in both Bali and in West Java. This is because the production cycle of layer farms is longer than that of broiler farms (two years for layers and only 30 days for broilers) and thus the layer farms have a greater chance of experiencing HPAI. About 27 per cent of layer farmers had experience of an HPAI outbreak on their own farm. In Bali, there were only three per cent of broiler farmers who had this experience.

4.2. Asset ownership

Ownership of assets may influence the level of biosecurity adoption. Agricultural assets that may increase the potential risk include type of land (irrigated and dryland) ownership, and ownership of native chickens and ducks (Table 2). The higher the level of asset ownership potentially the greater the biosecurity risk. The average area of land owned was less than one hectare, the range being 0.1 to 0.5 hectare.

About 22 layer (37 percent) and 25 broiler farm respondents (42 percent) in Bali had native chickens. Over all respondents this was an average of 12 native chickens and 6 native chickens per layer and broiler farmer respectively. In West Java only 5 layer (12 percent) and 13 broiler respondents (19 percent) owned native chickens, an average of 2 native chickens per household. Duck ownership was lower than native chicken ownership. There were only seven households (two layer and five broiler) in West Java that owned ducks. In Bali, there were two layer respondents and five broiler respondents who had, respectively, 5 ducks, and 16 ducks per household.

Apart from agricultural assets, other assets owned by farmers include motorbikes and televisions. The extent of asset ownership and the level of savings can reflect the level of farmers' wealth and may affect their ability to implement biosecurity. It was noted that not all respondents had motorbikes and televisions. The average ownership of motorbikes and televisions was less than one unit per household and 1 to 2 units per household respectively. About 28 per cent to 58 percent of farmers did not have saving. The level of savings ranged from Rp.1 to Rp.10 million.

Table 2: Asset ownership on broiler and layer farms in West Java and Bali, 2009

Item	West Java		Bali	
	Layer	Broiler	Layer	Broiler
Dry land (ha)	0.1	0.1	0.5	0.4
Irrigated land (ha)	0.0	0.2	0.1	0.1
Native chicken (bird)	2	2	12	6
Duck (bird)	0.4	1.3	0.2	1.3
Motorbike (unit)	0.4	0.0	1.8	1.0
Television (unit)	1.3	1.4	1.6	1.1
Total value of loans (Rp million)	13,418	22,227	167,694	27,937
Saving (%) :				
None	34	39	28	58
< Rp 1 million	22	19	22	13
Rp 1 million to Rp 10 million	37	21	23	18
≥ Rp 10 million	22	18	27	10

4.3. Farm characteristics

4.3.1. <u>Farm size and capacity</u>

The level of biosecurity may also be influenced by poultry farm size and capacity. This may include the number of farms and sheds, total land area of farms, total and average shed capacity. These variables may have a negative influence on the level of biosecurity. For example, the larger the number of poultry sheds the higher the level of intrinsic risk due to the need for more labour, more transport etc. In both West Java and Bali, the size of layer farms was generally higher than broiler farms (Table 3). On average, the number of poultry farms owned ranged from two to six farms per household. The number of layer farms owned in Bali was higher than in West Java. The capacity of layer sheds was higher than the capacity of broiler sheds. This is a consequence of the structure of layer sheds, which generally include a battery hen facility.

Table 3: Farm size of broiler and layer farms in West Java and Bali

Item	West Java		Bali	
	Layer	Broiler	Layer	Broiler
Number of farms (unit)	1.3	1.7	1.9	1.2
Number of sheds (unit)	17.0	6.8	9.6	1.6
Land area of farm (m^2)	19,778	2,600	1,600	1,298
Capacity of farm (bird)	49,204	8,766	8,930	4,875
Total capacity of all farms (bird)	59.996	20,640	21,982	5,767
Average capacity of all sheds (bird)	2,925	2.226	2,403	4,294
Number of farm entrances farm	1.3	1.9	1.3	1.2
Birds in staff housing (%) :				
All	15.0	16.7	13.3	28.8
Some of them	22.5	27.3	38.3	13.6
None	47.5	56.1	41.7	57.6
others	15.0	0	6.7	0
Source of water for shed (%) :				
PDAM	0	0	40.0	61.0
Well, spring	97.5	98.5	36.7	35.6
River /dam/others	2.5	1.5	23.3	3.4

4.3.2. Farm location

Shed location may also influence biosecurity adoption. Shed location includes factors such as; the distance to other commercial poultry producers, elevation of sheds, and the distance of sheds from main roads, residential places (housings), live bird markets, wetlands, neighbouring sheds, feed shed, offices, parking areas, and boundary fences. For example, the further that poultry sheds are from high-risk areas, the higher the intrinsic safety of the shed and farm.

Table 4: Farm location broiler and layer farms in West Java and Bali

Item	West Java		Bali	
	Layer	Broiler	Layer	Broiler
Number of other commercial farms within 1 km	4	10	11	6
Elevation of sheds (%) :				
Higher than surroundings	29	19	12	13
Same high	61	54	68	75
Lower	9	27	20	12
Distance to main road (m)	206	181	80	71

Distance to nearest house (m)	90	88	69	123
Distance to nearest paddy (m)	339	163	394	340
Distance to nearest live bird market (km)	5	6	16	6
Distance to nearest neighbour's shed (m)	292	194	102	294
Distance to nearest boundary fence (m)	7	2	4	3
Distance to nearest parking area (m)	53	83	12	17
Distance to nearest feed shed (m)	49	21	191	22

4.3. Social capital

Social capital may play important role in determining biosecurity adoption. Social capital is embedded in social interaction and attitudes among communities, and may affect a community's response to disease-related risks. For example, people who are unwilling to trust other people may respond differently to a village outbreak of HPAI compared to those who are prepared to work with the community. Similarly, the perception of the community and their attitude towards HPAI outbreaks can be categorized as a positive or negative response to biosecurity risks and adoption of biosecurity measures.

This study uses a similar methodology for measuring social capital as described in Patrick et al (2010). Respondents were asked questions concerning their attitudes to community and leadership and their expected responses to issues and problems that may arise in their community. Two variables were constructed from these responses. The first was 'social capital', the second 'agency'. Social capital was a measure of the strength of community ties and community interaction while agency is the ability to actually utilise this social capital to benefit the community.

Initial analysis indicates that both social capital and agency tend to be higher in Bali than in West Java but there is no difference between broiler and layer respondents. There is also a significant positive relationship between social capital and agency i.e. the higher the level of social capital the greater the utilisation of social capital. It is expected that both social capital and agency may have a positive influence on the level of biosecurity adoption as smallholders may realise that strong community level biosecurity adoption will have greater individual farm benefits than individual and isolated farmer adoption.

5. Dependent variable – Biosecurity Control Score

5.1 Farm biosecurity model

A large number of biosecurity control measures have been identified and combined into seven stages, representing different stages of the production cycle and farm management cycle. It is within these stages that farmer's can implement particular activities that reduce the possibility of pathogens entering a farm and shed. The seven stages are summarised as follows:

Stage 1. Vector/fomite status of farm inputs. Sources of pathogens may be other farms, markets, villages, feed manufacturers or homes where farm staff have pet birds. Some will be high-risk sources, and others low, depending on the microbiological load of the vectors and fomites they generate.

Stage 2. Traffic onto farm. Pathogens enter farms via people, animals or things (items that have come into contact with contaminated sources). Higher volumes of people, animals and things (organic things like feed, water and manure, and inorganic things like vehicles and farm equipment) entering the farm carries a higher risk of dangerous levels of pathogens entering the farm.

Stage 3. Biosecurity at farm boundary. Physical and functional barriers at the farm boundary are bio-exclusion measures. Physical barriers include fences, gates, wash down bays, and so on.

Functional barriers include policies or behaviours preventing entry of people, animals and things considered higher risk, or that lower the risk associated with entry, such as changing clothes or using footbaths.

Stage 4. Biosecurity between farm boundary and shed. Scavenging birds, rodents, pets, flies, dust, aerosols, and uncontrolled movement of visitors are the sorts of biosecurity hazards that are present inside the farm boundary that may bring potential pathogens closer to the poultry in the sheds. Farms that control these hazards have a biosecurity advantage.

Stage 5. Biosecurity at the shed door. Restricting access of higher risk people, animals and things to sheds, or implementing measures to lower their risk, reduces the likelihood of dangerous levels of pathogens entering the poultry shed and infecting the chickens. Signs, locks, footbaths and bird proof netting are examples of some *shed door* biosecurity measures.

Stage 6. Traffic into the shed. Pathogens can enter the poultry shed via people and the animals and things they carry. Introducing systems to reduce the amount of such traffic into sheds offers a biosecurity advantage.

Stage 7. Susceptibility of the layer and broiler flock. Disease will only establish in a flock if their resistance to disease is sufficiently low, or their exposure to pathogens is sufficiently high, or both. Resistance to disease is supported by proper vaccination, adequate nutrition, shelter and stocking rates. Exposure to pathogens is limited by taking precautions in the preceding stages 1 to 8, but also by implementing age segregation, all-in-all-out systems, and by compartmenting the flock in a number of sheds.

5.2. Constructing the biosecurity control score

The dependent variable in this analysis is the biosecurity control score (BCS) derived from the 44 farmer responses to the disease risks that they as individuals face.

The first step in generating a BCS is to score each individual biosecurity control indicator (Appendix 1). A biosecurity indicator will be, for example, the source of poultry feed, the actions taken to minimise pest and rodent entry, or the number and type of signs installed around the farm.

Most of the indicators have been allocated scores ranging from 1 to 3 (1 being low biosecurity, and 3 being high biosecurity). For example it is more biosecure to purchase farm inputs (indicators 1B to 1E) direct from the contractor or feed company (a score of 3) rather than from a poultry shop (score 2) or from another farmer (score 1). There are several indicators that have a broader range of responses, and therefore a broader range of scores. One of these is *3C: Parking and vehicle washing*. Low biosecurity with regard to this indicator (a score of 1) means there is no designated parking area, no car wash area and no high pressure pump available to clean vehicles as they enter. High biosecurity (a score of 7), indicates that a car park, car wash area and pressure pump are present. Scores of 2 to 6 indicate the presence of some but not all of these facilities.

These individual biosecurity indicators can be grouped into the eight biosecurity stages (as defined in the model above). Each can be scored in two ways. The first is to aggregate the scores of the individual indicators in each stage. For example, for *Stage 1: farm input*, the indicator scores from 1A to 1G would be summed, while for *Stage 3: Biosecurity at the farm gate,* it would be summing the indicator scores from 3A to 3L. The total score at each Stage will be influenced by the number of indicators in the stage. For example, Stage 3, with 12 indicators will have potentially a higher score than Stage 6 with only two. This measure gives every indicator an equal value, and therefore, the stages with more indicators are intrinsically more important.

The BCS is calculated by summing the biosecurity stage scores. This is a simple method and makes no judgment with regard to the importance of each indicator in influencing on-farm biosecurity. It values each of the biosecurity indicators equally. It is this variable that is used as the dependent variable in the analysis

5.3. Using the biosecurity control score

The results are divided into two sections. The first section discusses the potential differences between respondents in Bali and in West Java. The second compares broiler and layer smallholders, evaluating the differences between the two smallholder types.

5.3.1. Biosecurity in Bali and West Java

The BCS suggests that in Bali broiler smallholders have a significantly higher adoption of biosecurity activities than do layer smallholders (Table 5). This result may be surprising as it is sometimes expected that layer smallholders, given the longer life span of their chickens and greater difficulty in finding replacement chickens, may have more to lose from a disease outbreak than do broiler smallholders. However, it may be that broiler smallholders, who are mostly contracted to produce birds by larger companies, receive better technical and biosecurity advice than the layer smallholders who are more likely to be independent producers.

Table 5: Testing for differences in biosecurity adoption between Bali and West Java farms

Item	Bali			West Java		
	Layer (n=60)	Broiler (n=60)	t-test	Layer (n=41)	Broiler (n=67)	t-test
BCS	122.5	132.4	-5.48***	138.0	133.5	1.95**

**significant at the 95 per cent level ***significant at the 99 per cent level

In West Java the result is quite different. Layer farms have significantly higher BCS scores than broiler smallholders. In Bali, broiler smallholders have a higher biosecurity score for all control stages except *traffic onto farm* (Table 6). In West Java broiler smallholders tend to purchase their inputs from more biosecure sources, however, layer smallholders had significantly higher biosecurity scores for the risk stages; *biosecurity at farm gate* and *susceptibility of flock*. Layer farms tend to be laid out or structured in a more biosecure manner with a higher likelihood of having poultry sheds further from potential sources of disease. They also have better biosecurity at the farm gate (Stage 3).

Table 6: Testing for differences in biosecurity scores at the stage level; Bali and West Java

Stage	Bali			West Java		
	Layer (n=60)	Broiler (n=60)	t-test	Layer (n=41)	Broiler (n=67)	t-test
Farm inputs	12.4	14.8	-6.57 ***	14.5	15.9	-2.96 **
Traffic onto farm	7.9	7.1	2.33 **	7.4	7.2	0.59
Biosecurity at farm gate	13.9	13.8	0.03	20.7	15.4	4.22 ***
Biosecurity farm gate to shed	8.9	10.7	-5.49 ***	9.7	10.3	-1.30
Biosecurity at shed	6.9	8.4	-5.68 ***	8.2	8.7	-0.56
Traffic into sheds	3.9	4.5	-3.74 ***	4.2	4.2	-0.10
Susceptibility of flock	11.5	10.3	3.72 ***	12.5	11.8	2.33 **

**significant at the 95 per cent level ***significant at the 99 per cent level

5.3.2. Biosecurity in broiler and layer farms

Rearranging the data by farm type allows comparison of layer farms in Bali and West Java and broiler farms in Bali and West Java. When comparing farms within the provinces, there are two noteworthy results (Table 7). ***Firstly***, layer smallholders implement significantly more biosecurity measures in West Java than they do in Bali. ***Secondly***, there is no real difference in biosecurity status on broiler farms between the two provinces.

The reason for this may be that most broiler smallholders in the NICPS are contracted to large companies who have uniform contracts and expectations across Indonesia. Each contract has agreed activities to be performed and agreed biosecurity measures that should be implemented. The layer industry is not beholden to large multinational companies to the same extent and, therefore, layer smallholders are able to make more independent decisions when it comes to biosecurity adoption. There may well be many other significant variables influencing adoption, an area that can be explored in greater depth in future work.

Table 7: Testing for differences in biosecurity status; broiler and layer smallholders

Item	Layer			Broiler		
	Bali	West Java	t-test	Bali	West Java	t-test
BCS	123.5	138.0	-6.29**	132.4	133.5	-0.66

**significant at the 95 per cent level ***significant at the 99 per cent level

Table 8 compares, at the risk stage level, layer farms between the provinces and broiler farms between the provinces. It considers, for example, the particular risk stages where Bali smallholders may be different to smallholders in West Java. There are significant differences between the broiler smallholders in Bali and in West Java. Broiler smallholders in Bali have better biosecurity between the farm gate and the shed.

Table 8: Testing for differences in biosecurity control level; broiler and layer smallholders

Item	Layer			Broiler		
	Bali	West Java	t-test	Bali	West Java	t-test
Farm inputs	13.0	14.5	-3.43***	15.3	15.9	-1.50
Traffic onto farm	6.3	7.5	2.14**	7.6	7.2	1.04
Biosecurity at farm gate	14.9	20.8	-4.75***	14.9	15.4	-0.62
Biosecurity farm gate to shed	9.4	9.8	-0.79	11.1	10.3	2.37**
Biosecurity at shed	7.2	8.2	-3.13**	8.9	8.7	0.71
Traffic into sheds	4.1	4.2	-0.39	4.6	4.2	-3.65***
Susceptibility of flock	11.9	12.5	-2.02**	10.8	11.8	-3.87***

**significant at the 95 per cent level ***significant at the 99 per cent level

Amongst layer smallholders, there are also significant differences. Generally, layer smallholders in West Java have higher biosecurity scores than those in Bali. There are significant differences in five of the seven control stages. Layer smallholders in West Java source their farm inputs from more biosecure sources, and have better-structured farms than the smallholders in Bali. Their sheds are positioned further away from potential sources of pest and disease; have more biosecure infrastructure and management practices at the farm gate, and; have more biosecurity measures at the entrances to poultry sheds.

6. Correlation between biosecurity and farm and farmer characteristics

This section discusses the correlation between farm biosecurity level and farmer and farm characteristics for layer and broiler farms in West Java and Bali. The purpose of this correlation analysis is to identify potential factors that may influence farmer adoption of biosecurity. The results will be used to select the independent variables that will be included in the following regression analysis .

6.1. Layer farm

Education, age, and the farming experience of layer farmers are significantly correlated to biosecurity adoption (Table 9). These characteristics may influence the perception and decision-making of broiler farmers to implement biosecurity activities. Farm area is also highly correlated to biosecurity adoption. Larger-scale layer smallholders tend to adopt high levels of biosecurity than do smaller-scale producers. Ownership status of broiler farm is significantly correlated to biosecurity adoption.

Table 9: Correlation between farmer and farm characteristics and biosecurity adoption on layer farms in Bali and Java

Characteristics	Biosecurity adoption measure		
	BCS		
	Correlation coefficient	Prob > r	
Age	-0.18288	0.0715	*
Education	0.24033	0.016	**
Household size	-0.10009	0.3193	
Farm experience	-0.19108	0.0569	*
Non-poultry income per household	-0.04073	0.6859	
Farm member working on farm	0.0031	0.9755	
Dryland	0.00316	0.975	
Irrigated land	-0.07732	0.4421	
Native chicken	0.1331	0.1845	
Duck	0.14304	0.1536	
Number of farms	-0.05693	0.5718	
Number of sheds	0.32843	0.0008	***
Land area of farm	0.4656	<.0001	***
Capacity of farm	0.24069	0.0153	**
Total capacity of all farms	0.22817	0.0217	**
Average capacity of all sheds	0.11114	0.2685	
Social capacity	-0.11122	0.2682	
Agency	-0.04069	0.6862	
Experience on HPAI	-0.04238	0.6739	
Dummy ownership	-0.28744	0.0036	***
Dummy management	0.16254	0.1044	*
Dummy poultry as main occupation	0.01555	0.8773	

Note: *significant at 90 per cent level **significant at the 95 per cent level, ***significant at the 99 per cent level

6.2. Broiler farm

It was found that only one farmer variable, *dryland land ownership*, was significantly correlated to biosecurity adoption on broiler farmers (Table 10). In terms of farm characteristics, the variables *number of sheds* and *capacity of farm* were significantly correlated to biosecurity adoption. It was noted that *agency* and *management* were also significantly correlated to biosecurity adoption probably due to the fact that broiler farms are predominantly managed under contract.

Table 10: Correlation between farmer and farm characteristics and biosecurity adoption of broiler farm in Bali and West Java

Characteristics	Biosecurity adoption measure BCS		
	Correlation coefficient	Prob > r	
Age	0.06075	0.5009	
Education	-0.01878	0.836	
Household size	0.01598	0.8585	
Farm experience	0.09586	0.2856	
Non-poultry income per household	0.07362	0.4107	
Farm member working on farm	-0.04181	0.6448	
Dryland	0.15728	0.0774	*
Irrigated land	-0.02532	0.7775	
Native chicken	0.08023	0.3699	
Duck	0.06087	0.4966	
Number of farms	0.00424	0.9623	
Number of sheds	0.24786	0.005	***
Land area of farm	0.07203	0.4247	
Capacity of farm	0.38219	<.0001	***
Total capacity of all farms	0.35956	<.0001	***
Average capacity of all sheds	0.15276	0.0864	*
Social capacity	0.10464	0.2417	
Agency	-0.08767	0.327	
Experience on HPAI	0.08417	0.3468	
Dummy ownership	-0.02117	0.8132	
Dummy management	-0.15806	0.0759	*
Dummy poultry as main occupation	-0.02934	0.7434	

Note: *significant at 90% level, **significant at the 95% level , ***significant at the 99% level

7. Factors influencing the adoption of biosecurity

There are two methods of calculating the dependent variable in this paper. The first is the use of the BCS which simply ranks and aggregates farmers' adoption of the 44 biosecurity control indicators (BCIs). The second method is to construct a modified BCS using Principle Components Analysis (PCA).

A potential problem with the simple aggregation method of constructing the BCS is that it gives equal weighting to all variables and does not take into account the potential correlations between variables. To overcome the possibility of over emphasising the importance of particular variables, this study uses PCA, which converts a set of variables into a set of values of uncorrelated variables called principal components and constructs a modified BCS.

7.1 Analysis using the BCS

This section discusses the results of a multiple regression model (Table 11), using the total poultry farm BCS as the dependent variable. The selection of independent variables included in the analysis was based on the results of the correlation analysis outlined in the previous section. The analysis employed the SAS (Statistical Analysis Software) program.

The previous analysis showed that BCS for layer farmers differed significantly from the broiler farmers in both Bali and West Java (Table 5). It also showed that the BCS for layers differed between the two locations while for broiler farmers there was no significant difference (Table 7). Therefore, in this analysis respondents were divided into groups of layer and broiler in order to identify factors influencing the adoption of biosecurity. Separate analysis is undertaken for each group.

The results of analysis show a robust estimation. Not all farmer and farm characteristic variables discussed earlier in the paper (Tables 1 to 4) significantly influence the adoption of biosecurity measures. Some important variables, especially those significantly correlated to BCS (Tables 9 and 10) do influence the adoption of biosecurity.

Table 11: Factors influencing biosecurity adoption of layer and broiler farm

Variable	Layer (R^2 = 0.9670)	Broiler (R^2 = 0.9581)
Characteristics of farmers :		
Age	0.97336 ***	0.79781 ***
Education	1.73117 ***	0.84161 ***
Non-poultry income	-0.000017 *	0.0000923
Household size	0.40936	2.85157 ***
Characteristics of farm :		
Land area of farm	0.000225 **	0.000618 **
Distance to neighbour poultry	0.0107 **	0.00665 **
Distance to road	0.00537	0.00911 **
Dummy farm management	12.52574	2.46004
Number of farm	1.74017	3.78263 **
Average capacity	0.000374	0.00172 ***

Note: *significant at 90 per cent level, **significant at the 95 per cent level, ***significant at the 99 per cent level

7.1.1 Characteristics of farmers

For layer and broiler farm respondents, the regression model indicated that the farmer characteristics that significantly influence the adoption of farm biosecurity measures were age and education level of the household head. The older and the more educated the farmer the higher the adoption of biosecurity activities. Older farmers may have more control over their decision making and more confidence to make improved managerial decisions. More educated farmers may be more able to understand the biosecurity concept and see the potential importance of implementing these management changes.

Non-poultry income had a negative effect on the adoption of biosecurity activities on layer farms but not on broiler farms. That is the higher the level of non-poultry income on layer farms the lower the adoption of biosecurity. Layer farmers who were more dependent on the income from egg production were more likely to attempt to protect their assets and maybe improve efficiency than were farmers who had other priorities.

The number of household members had a positive significant influence on biosecurity control in broiler farms. Conversely, there was no significant influence of the number of household members on biosecurity adoption in layer farms. While it was expected that the higher the number of family members may lead to a lower level of biosecurity adoption, this analysis showed that, in fact, the higher the number of household members, the higher the adoption of biosecurity activities. It may be that farmers understand the risks posed by many people having access to their farm and find it easier to insist on good biosecurity adoption with their family members as opposed to hired labour. Broiler farms tend to be smaller than layer farms and hence can rely on family labour rather than hired labour. Broiler farms are also probably less labour intensive than layer farms.

7.1.2 Characteristics of farms

There are two variables, 'land area of farm' and 'distance of farm to neighbour's poultry', that had a positive influence on biosecurity adoption in layer and broiler farms. As expected the larger the farm (in land area, maybe not capacity) the higher the adoption of biosecurity activities. It may be that the respondents with larger farms understand the increased risk of disease entry and have the resources to do something about it.

The distance to a neighbour's poultry influences a farmer's decision to implement biosecurity but probably not in the way that was expected. It was expected that the closer the farm is to a source of disease, in this case a neighbour's farm, the greater the attempt to minimise the ability of the disease to spread. However, this analysis has shown that the further the poultry farm from the source of risk, the higher the adoption of biosecurity measures. Another factor influencing the biosecurity control adoption was the distance from the farm to the nearest road. This factor had the same positive significance as did distance from neighbours, but this was only on broiler farms. It appears that smallholders who are close to important sources of risk such as neighbouring farms and roads may believe that it is a waste of time trying to reduce the risk while smallholders who have a natural advantage believe that the risk is manageable and worth investing in.

Whether the farm was independent or contract had no significant influence on the adoption of biosecurity both on broiler and layer farms. It may be that there weren't enough broiler farms that were independently managed and layer farms that were under contract to provide a clear enough difference between the farms.

Broiler farmers who had more, and larger, farms adopted higher levels of biosecurity. This was because larger-scale broiler farms need to avoid the potential large losses caused by disease outbreaks. They are prepared to invest more time and money to minimise the risk of loss. The layer farmers surveyed were mostly larger-scale anyway with more uniform investment and implementation of biosecurity measures.

7.2 Analysis using a modified BCS

7.2.1 Constructing and interpreting the modified BCS

Commonly there are two objectives using PCA. Firstly, to construct an uncorrelated linear combination of variables and secondly, to reduce the number of variables in the dataset and to derive the principle components that are linear combinations of the original variables. PCA can be used if data can be represented by a fewer number of principle components without substantial loss of information (Sharma, 1996). If variables are perfectly correlated then the first principle component will account for all of the variance of the data. The greater the correlation among the variables the greater the data reduction can be achieved.

In this analysis the 44 biosecurity control indicators have been grouped into seven biosecurity stage variables. These were then aggregated into the BCS dependent variable. Using PCA the seven biosecurity stage variables are converted in to seven new variables which are a linear combination of the original variables. The PCA analysis reduces the risk of placing too much emphasis on variables which are providing the same information. The number of principle component variables that need to be retained depends on the objective of the research and how much information is able to be sacrifice without influencing the robustness of the analysis. For this analysis, we need only one variable (principle component) to be retained so that it can be used as the dependent variable in a regression analysis.

The *eigenvalues* in PCA is the variance of the new variable (principle component). The proportion of variance of the new variable (PRIN) to total variance of the original variable is presented in Table 12. The description of the *eigenvalue* from the covariance matrix is: (1) each new variable is linear combination of the original variables, (2) the first new variable (PRIN1) accounts for the maximum variance in the data, (3) the second new variable accounts for the maximum variance that has not be accounted for by first variable, (4) the 7th new variable accounts for the maximum variance that has not been accounted for by 6th variable, hence the 7 new variables are uncorrelated.

Table 12: The proportion of *eigenvalue* in the principle component analysis of BCS; layer and broiler farms in Bali and Java

Principle Component	Proportion Eigenvalue of the Covariance			
	Bali		Java	
	Layer	Broiler	Layer	Broiler
PRIN1	0.5270	0.5473	0.7210	0.5403
PRIN2	0.1730	0.1433	0.1079	0.1899
PRIN3	0.0969	0.1238	0.0815	0.1219
PRIN4	0.0738	0.0833	0.0445	0.0777
PRIN5	0.0646	0.0591	0.0225	0.0388
PRIN6	0.0434	0.0360	0.0164	0.0215
PRIN7	0.0213	0.0074	0.0062	0.0098

The total variance of the seven new variables (PRIN) in Bali Layer farms is 32.2, which is the same as original variables. The variance of the first new variable, PRIN1, is 17.0, accounting for 52.7 % of the total variance of original data, and PRIN2 is 19.2 %, PRIN3 9.6%, PRIN4 is 7.4%, PRIN5 is 6.5%, PRIN6 is 4.3% and PRIN7 is 2.1%.

If only one variable; PRIN1, is needed to be retained, then for Bali layer farms, the proportion variance of new variable PRIN1 to total variance was only 52.7%. This means that variable PRIN1 captures 52.7% of the total variance from the original variable, while PRIN1 for Bali-Broiler, Java-Layer and Java-Broiler was 54.7%, 72.1%, and 54.0 % respectively. In other words, we lose 47.3% of the information from original variable BCS of Bali-Layer, 45.3% for Bali-Broiler, 27.9% for Java-Layer and 45.0% for Java-Broiler.

The simple correlation between the original variable (TOTAL) and a new variables (loading) provides an indication of which of the original variables are influential or important in forming the new variables. The higher the loading, the more influential the variable is in forming the principle component score. There are no guidelines as to how high this loading should be when constructing the PCA score, but a loading of 0.5 or above is generally an appropriate cutoff point. From the eigenvector, the first Principle Component equation, PRIN1 for Bali-Layer, Bali-Broiler, Java-Layer and Java-Broiler, is given by:

PRIN1(Bali-Layer): 0.024 TOTAL1 + 0.068 TOTAL2 + **0.958 TOTAL3** + 0.246 TOTAL4 + 0.116 TOTAL5 – 0.033 TOTAL6 – 0.046 TOTAL7

PRIN1(Bali - Broiler): 0.155 TOTAL1 + 0.080 TOTAL2 + **0.965 TOTAL3** + 0.096 TOTAL4 + 0.154 TOTAL5 – 0.0001 TOTAL6 – 0.075 TOTAL7/8

PRIN1(Java-Layer): 0.160 TOTAL1 + 0.078TOTAL2 + **0.973 TOTAL3** + 0.075 TOTAL4 + 0.112TOTAL5 – 0.015 TOTAL6 + 0.057 TOTAL7

PRIN1(Bali - Broiler): 0.155 TOTAL1 + 0.080 TOTAL2 + **0.965 TOTAL3** + 0.096 TOTAL4 + 0.154 TOTAL5 – 0.0001 TOTAL6 – 0.075 TOTAL7

The above equations indicate that the value of PRIN1 is significantly affected by the variable TOTAL3, for all poultry systems. The loading for all equations is above 0.9. TOTAL3 represents 'Biosecurity at Farm Gate', is an aggregation of biosecurity indicators such as fence and locks, number of entrances to the farm, parking and vehicle washing, presence and use of footbath at farm gate, shower and change room availability for visitors and employees, etc. The main reason why the TOTAL3 stage variable dominates in the formation of PRIN1 is that there is a wide variation in the adoption of the activities included in this stage.

7.2.2: Factors influencing the adoption of biosecurity using PCA

This section discusses the results of a multiple regression model (Table 13), using Variable of PRINT1 as modified of BCS variable as a dependent variable to identify factors influencing biosecurity adoption of Layer and Broiler Farmer in Bali and Java. The analysis employed the SAS (Statistical Analysis Software) program.

The results of using principle component as dependent variable with same independent variable used in the previous model (using BCS as dependent variable in Table 11), shows not as a robust estimation as previous model. The adjusted R^2 is 0.2, and only few variable significantly difference influencing biosecurity adoption.

For layer farm respondents, the regression model indicated that the only variable that significantly influencing biosecurity adoption is Dummy farm management which has a positive coefficient parameter. It seems that the farms independently managed have a clear enough difference between the farms with under contract in influencing biosecurity adoption. For broiler farm, the farm characteristic that were significantly influencing biosecurity adoption was age of the household head, while the farm characteristic that influencing level of biosecurity adoption was distance to neighbour poultry.

Table 13: Factors influencing biosecurity adoption of layer and broiler farm in Java and Bali

Variable	Layer (R^2 = 0.223)	Broiler (R^2 = 0.207)
Characteristics of farmers :		
Age	- 0. 04848	0.08732 **
Education	0.10165	-0.06666
Non-poultry income	-0.0000017	0.00002083
Household size	-0.56890	-0. 13625
Characteristics of farm :		
Land area of farm	0.0000474	-0.00006634
Distance to neighbour poultry	0.00265	0.00167 *
Distance to road	0.0005720	0.00003390
Dummy farm management	6.69017 **	-0.87628
Number of farm	0.35739	0.47259
Average capacity	0.0004588	0.0001881

Note: *significant at 90% level, **significant at the 95% level

Since the previous analysis indicated that level of biosecurity adoption by layer farmers differed significantly from the broiler farmers in both Bali and West Java (Table 5), in this analysis respondents also were divided into these groups layer and broiler farm for each Bali and West

Java respectively. The independent variables included in the model were selected based on the same hypotheses as variables in the previous analysis.

For the layer farms in Java, there are no characteristics of farmers that significantly influence the adoption of biosecurity. The characteristics of farms which were significant include 'number of farms' and 'land area of farm'. The more sheds, the higher the level of biosecurity. Conversely, the more farms the lower the biosecurity adoption. For broiler farms in Java, farm characteristics which significantly influencing the adoption of biosecurity were 'numbers of farms', which has negatively significant influence, and 'number of sheds' which has a positive influence (Table14).

Table 14: Factors influencing biosecurity adoption of layer and broiler farm in Java

Variable	Layer (R^2 = 0.5119)		Broiler (R^2 = 0.3543)	
Characteristics of farmers :				
Age	0.06919		0.03933	
Experience on HPAI	0.17033		0.53595	
Characteristics of farm :				
Number of farm	-5.16133	**	-1.66434	***
Number of shed	0.30913	***	0.37115	***
Land area of farm	-0.0000078		-0.00025826	**
Average capacity	0.000875		0.00013242	
Other farms within 1 km2	-0.38467		0.02810	
Agency	1.03592	**	0.28223	

Note: *significant at 90% level, **significant at the 95% level, ***significant at the 99% level,

The result of regression analysis for Bali farms is presented in Table 15. The characteristics of layer farmers that significantly influence the adoption of biosecurity were 'age of head of household' and 'experience with HPAI'. The younger the head of the household, the higher the adoption of biosecurity. While it was expected that household head experience with HPAI would lead to a higher level of biosecurity, this was not the case, with experience in HPAI having a negative influence on biosecurity. This may well be due to the fact that poor biosecurity may lead directly to greater HPAI prevalence and farmers are still unsure how to minimise the risk.

For broiler farms in Bali, there were no characteristics of farmers that significantly influence biosecurity adoption, while the only farm characteristic that had a significant influence was the 'number other farms within 1 km^2' which had a negative influence. That is, the higher the number of other farms within 1 km^2 radius, the higher the level of biosecurity adoption. Broiler farms which are located near other farms tend to increase their biosecurity to minimize the risk of disease spread.

Table 15: Factors influencing biosecurity adoption of layer and broiler farm in Bali

Variable	Layer (R^2 = 0.2852)		Broiler (R^2 = 0.1794)	
Characteristics of farmers :				
Age	-0.12029	**	0.05976	
Experience on HPAI	-0.34301	***	-0.10105	
Characteristics of farm :				
Number of farm	0.62623		0.02786	

Number of shed	-0.09027		0.23790	
Land area of farm	-0.00063	*	-0.000061	
Average capacity	0.000073		0.00014	
Other farms within 1 km2	0.06691	*	-0.27793	**
Agency	-0.52285	*	-0.51471	

Note: *significant at 90% level, **significant at the 95% level, ***significant at the 99% level,

8. Summary and conclusions

This study has developed a useful method of measuring the adoption of biosecurity on poultry farms in Indonesia. The Biosecurity Control Score consists of 44 biosecurity control indicators that are grouped into seven stages from the sourcing and type of farm inputs, through to the activities undertaken to reduce the susceptibility of the flock to disease incursion. Every farm is, therefore, allocated a measure of biosecurity adoption which is an individual response to the social, economic, environmental and institutional factors influencing them.

Using the BCS to compare farmer adoption showed that in Bali, broiler farmers had higher adoption levels than layer farmers. In West Java, on the other hand, the biosecurity adoption in layer farms was higher than in broiler farms. In West Java, the implementation of biosecurity measures in layer farms was better than in broiler farms particularly at farm gate stage. In Bali, almost at every stage the implementation of biosecurity measures in broiler farms was better than in layer farms.

There was significant correlation between biosecurity implementation and farmer and farm characteristics in layer farms. Farm characteristics that were significantly correlated with adoption were age, education, and farming experience. There was also significant correlation between the level of adoption and farm characteristics such as number of sheds, land area of farm, capacity of farms, ownership type, and management type. In broiler farms, variables that were significantly correlated to biosecurity control were the number of sheds, total capacity of all farms, average capacity of all sheds and management type.

Using the BCS as the dependent variable, this study then identified the potential factors that influence the adoption of biosecurity activities. It was noted that not all variables that are correlated to biosecurity adoption will necessarily have a causal effect. The regression analysis identified that older more educated farmers with larger families of are more likely to adopt better biosecurity in layer and broiler farms. On layer farms, farmers with fewer non-poultry sources of income will have better biosecurity.

The farm characteristic that may influence biosecurity adoption in both layer and broiler farms is land area of the farm. In broiler farms the number and average capacity of farms are also important. The analysis suggested that variables related to farm size had a positive impact on biosecurity control; the larger the farm the better the biosecurity. The distance of layer and broiler farms from neighbour's poultry and nearest road was also important; the greater the distance the better the biosecurity.

Using PCA and a modified BCS as the dependent variable, although not providing as robust an estimation as the previous model, still identifies similar farm and farmer characteristics that influence the adoption of biosecurity activities. The analysis identified that the farm characteristics (i.e. number of farm and sheds) in West Java are more important in influencing biosecurity adoption than farm characteristics, for both layer and broiler farms. Farmers with fewer farms and more sheds will have higher biosecurity. The younger layer farmers in Bali with less experience of HPAI will also have higher biosecurity. Also, the higher the number of other farms within a 1 km^2 radius, the higher the level of biosecurity adoption.

With the above results, consequently, either method of constructing the BCS is useful. It is suggested that the unique characteristics of farmers and farms should be considered during the process of encouraging the improvement of poultry farm biosecurity. This is because each farmer has a different and unique set of characteristics and, therefore, a different appropriate response. Therefore, policy on increasing the adoption of biosecurity requires an understanding of three aspects. *Firstly*, the level of farmer adoption of biosecurity as a response to their unique set of influences. *Secondly*, identification of the significant factors that influence biosecurity adoption. *Thirdly*, identification of cost effective activities that minimize the risk of disease spread and benefit all stakeholders in the market chain. Overall, government policy needs to facilitate the improvement of biosecurity adoption among poultry farmers. Dissemination of poultry farm biosecurity techniques together with the cost-effective biosecurity implementation proposed by ACIAR and other institutions needs to be promoted.

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Appendix 1: Individual farm biosecurity control indicators

Stage	*Level of biosecurity*		
	Low	*Medium*	*High*
1. Vector/fomite status of farm inputs			
1AType of poultry feed	Home produced feed, home produced feed & commercial pellets, mixture of all feed types	Purchased grain, purchased grain & commercial pellets	Commercial feed (pellets only)
1B Source of concentrate	Spot market, other smallholder	Poultry shop	Contract company, direct from feed company
1C Source of grain and other ingredients	Other smallholder	Poultry shop	Contract company, direct from feed company, spot market
1D Source of supplements	Spot market, other smallholder, don't know	Poultry shop Don't purchase	Contract company, direct from feed or drug company
1E Source of litter	Spot market, other smallholder, don't know	Poultry shop, rice mill, don't purchase	Contract company
1F Assurance that DOC were healthy and safe	Own knowledge, don't know	Trust supplier	Government certificate, supplier certificate
1G Poultry drinking water chlorinated	No, don't know	Sometimes	Yes
2. Traffic onto the farm			
2A Permission for collector to enter farm 2B Permission for Dinas to enter farm 2C Permission for relative of labourer to enter farm	Contract company, technical support, Dinas, poultry shop, collectors, no decision		Owner, manager, owner + manager, manager suggests owner decides
3. Level of biosecurity at farm boundary			
3A Fences and locks	No secure boundary fence, no locks	2 rankings between these	Secure boundary fences, locks on

Stage	***Level of biosecurity***		
	Low	***Medium***	***High***
	on gates	low and high options	all gates, gates locked at all times
3B Number of entrances	>3	2	1
3C Parking and vehicle washing	No parking area, car wash area or high pressure pump	5 rankings between these low and high options	Dedicated parking area, car wash for all vehicles entering farm, high pressure pump spray
3D Signs around perimeter	No signs	2 rankings between these low and high options	High number of signs per farm area, sign instructing report to office
3E Footbaths at farm gates	No footbath at farm entry	2 rankings between these low and high options	All entries have footbaths, water and detergent regularly changed
3F Unsold eggs return to farm	Yes, sometimes, don't know		No
3G Family living off farm; requirements when entering farm	Nothing, some of these things, don't know		Register at office, visitor log book, use protective clothing, enter through shower, park outside farm, answer about previous farm visits that day, scrub/change boots, wash hands, vehicle, equipment
3H non-family employees living off farm; requirements when entering farm			
3I Visitors, non-employees living off farm; requirements when entering farm			
3J Shower and change room for visitors and employees	Yes, but not used, no		Yes and used
3K Use of own cages when selling live chickens	Yes, sometimes, don't know	No	
3L Clean cages and equipment returning from market	No, sometimes, don't know		Yes, no equipment comes back to the farm
4. Level of biosecurity between farm boundary and shed			
4A Feed shed sealed against rodents and birds	No, sometimes, don't know		Fully sealed

Stage	*Level of biosecurity*		
	Low	***Medium***	***High***
4B Water overflow management	Water lying, no action taken	2 rankings between these low and high options	No water lying around, action taken
4C Spilt feed management	Yes, sometimes, don't know		No
4D Village chickens and ducks management	Yes, always around shed	Sometimes	No
5. Level of biosecurity at the shed door			
5A Construction of shed walls	Other	Plastic	Concrete, netting
5B Shed locked at all times	No, sometimes, don't know		Yes
5C Signs at the shed doors	No, don't know	Some	Yes, all
5D Concrete footbath at shed entrances + disinfectant	No, don't know	Some	Yes, all
5E Wild birds and rodents entering the shed	Yes, sometimes, don't know		No
5F Action to prevent entry of wild birds and rodents	Nothing	Built off ground, rat baits, scarecrows, fence around shed, cut trees	Bird proof netting
6. Traffic into sheds			
6A Number of employees working in shed	>2	0-2	0
6B Number of people entering sheds	>2	0-2	0
7(i). Susceptibility of layer flock			
7(i)A Decision on layer vaccination program	Other	Manager suggest, owner decides, contract company	Owner, manager, owner + manager
7(i)B Vaccinate layer chickens	No		Yes
7(i)C Source of vaccines for layers	Spot market, poultry shop, other smallholders, direct from feed	Contract company	Government, direct from drug company

Stage	*Level of biosecurity*		
	Low	*Medium*	*High*
	company		
7(i)D Same age of layers in shed	No		Yes
7(i)E Layers quarantined before mixing with others	No		Yes
7(ii). Susceptibility of broiler flock			
7(ii)A Decision on broiler vaccination program	Other	Manager suggest, owner decides, contract company	Owner, manager, owner + manager
7(ii)B Vaccinate broilers for ND	No		Yes
7(ii)C Vaccinate broilers for Gumboro	No		Yes
7(ii)D Vaccinate broilers for HPAI	No		Yes
7(ii)E Source of vaccines for broilers	Spot market, poultry shop, other smallholder, don't purchase	Contract company	Government, direct from drug company