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Developing Strategy to Reduce the Mortality of Native Chicken using Qualitative Modeling

Ismoyowati[1]*, Elly Tugiyanti[1], Diana Indrasanti[2], Novie Andri Setianto[3], and Vony Armelia[4]

[1]Department of Animal Production, Faculty of Animal Science, Jenderal Soedirman University, Purwokerto, 53123, Indonesia
[2]Department of Animal Science, Faculty of Animal Science, Jenderal Soedirman University, Purwokerto, 53123, Indonesia
[3]Department of Livestock Socio-economic, Faculty of Animal Science, Jenderal Soedirman University, Purwokerto, 53123, Indonesia
[4]Postgraduate, Faculty of Animal Science, Jenderal Soedirman University, Purwokerto, 53123, Indonesia

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* Corresponding author:
E-mail: ismoyowati@unsoed.ac.id

ABSTRACT

Smallholder native chicken farming continues to face challenges that include simple farming management as well as ND and AI diseases that lead to decreased productivity and increased mortality rate. The aim of the study was to develop a strategy to reduce the mortality rate of native chickens in extensive and semi-intensive rearing systems. This study uses survey method with 78 extensive and 88 semi-intensive native chicken farmers as respondent. This study explores the disease incidence, illness treatment, mortality rate, as well as AI and ND antibody titers which then analyzed descriptively. System dynamic model using Ventana software (VENSIM) was used to identify the contributing factors to the mortality rate of native chicken in smallholder farming. The results showed that the common diseases among native chickens reared in semi-intensive and extensive farming are AI, ND, CRD, and pullorum, with a high rate of disease-specific mortality (>5%). Compared to native chickens in semi-intensive farming, those of in extensive farming showed a higher natural immunity against AI and ND. The qualitative modeling produced seven reinforcing loops and five balancing loops. Some challenges in developing native chicken farming were disease incidence due to lack of proper land and cage, the occurrence of selling unhealthy chickens, farmers opting out for poultry vaccination, high operational cost, lack of business motivation, limited knowledge on poultry management and health, lack of extension programs, and traditional management. We concluded that the rate of disease-specific mortality (ND and AI) remained high in native chickens reared both in extensive and semi-intensive farming. It takes an effort to improve farming management, vaccination, and the government's contribution through extension programs to decrease disease incidence and mortality rate of native chickens.

Key words: Causal loop diagram, Disease**,** Mortality, Native chickens

Introduction

Indonesia has the potential germplasm of native chickens to produce meat and eggs to meet food demand, particularly animal-based protein. Native chickens are commonly reared in rural areas. The national population of native chickens increased by 1.22% to 305.4 million between 2019 and 2020. However, Central Java province saw a declining population by 5.36% from 41,554,574 (2019) to 39,328,326 (2020). Data showed that the 2021's population of native chickens in Central Java is 40,018,923 – a 1.76% increase from the previous year (Director-General of Livestock and Animal Health Services, 2021). Banyumas and Kebumen are two districts with a relatively high population of native chickens, i.e., 1,071,350 and 3,927,820, respectively. The population of native chicken in Banyumas district has increased by 11%, but in the Kebumen district, it has decreased by 19% (Agency of Livestock and Animal Health Service Central Java Province, 2020).

The current challenges to smallholder native chicken farming include simple farming management (extensive and semi-intensive) and incidence of Newcastle Disease (ND) Avian Influenza (AI) diseases that contribute to declining productivity and increased mortality rate among native chickens. Likewise, Newcastle disease (ND) and Avian Influenza (AI) are reported as the most detrimental poultry disease around the world (Alexander, 1995). Newcastle disease is caused by type 1 Avian Paramyxovirus in the family of Paramyxoviridae, while AI comes from influenza virus type A in the family of Orthomyxoviridae (Alexander, 2000; Swayne and Suarez, 2000; Suarez and Schultz-Cherry, 2000). The most virulent types of ND and AI are listed in the Office International des Epizooties (Swayne and King, 2003). Vaccination to poultry is a successful intervention strategy to control ND and AI (Capua and Marangon, 2004; Veits *et al.*, 2006; Ismoyowati *et al.*, 2013) because it can reduce mortality risk by five times compared to the non-vaccinated poultry reared in household farming or scavenge (Harrison and Alders, 2010).

Native chicken farming belongs to agribusiness that risks contracting disease incidence and mortality. Poultry production is a complex system that is influenced by factors, such as management, disease agents, and environment. on an industrial scale, poultry faces more complicated challenges and high costs. A complex disease-related challenge is attributed to the multifactorial etiology, including variance in pathogenic virulence and pathogenicity, pathogenic interactions, environmental factors, farming management, poultry's immunity status, vaccine efficacy, and feeding. The extensive factors have made it challenging to implement disease control (Galarneau *et al.*, 2020).

A thinking system is a feasible measure to solve these issues. A thinking system is a theory to understand and control any changes that occur in the system. Meanwhile, dynamic modeling attempts to study, understand and analyze a complex system due to perpetual change (Forrester, 1971; Ford, 2010). Modeling has been used for years in poultry production for feed management and growth models, risk factor models for poultry disease recognition and mitigation, and impact of disease on production parameters (Emmans, 1981; Sentíes-Cu e *et al.*, 2010; Volkova *et al.*, 2010) and economic models (Williams, 1999). System dynamics can address the complexity of a dynamic production system and combine inherent feedback loop and system delay (Sterman, 2000; Homer and Hirsch, 2006). System dynamics consist of qualitative modeling with Causal Loop and quantitative modeling with Stocks and Flows diagram (Sterman, 2000).

This study aimed to evaluate the disease incidence and the mortality rate of native chickens reared in extensive farming and semi-intensive farming, investigating the contributing factors to the mortality rate, and develop a Causal Loop Diagram as the basis for investigating the strategy to decrease the mortality rate of native chicken.

Materials and Methods

This study surveyed native chicken farmers and their farms in a structured, questionnaire-based interview. Data collection also included direct observation of poultry conditions and blood sampling for measuring ND and AI antibody titers. The steps of the survey were as follows: 1)We targeted native chicken farmers in Banyumas and Kebumen area. The number of native chicken farmers running extensive farming and semi-intensive farming was 36 vs. 44 in Banyumas and 42 vs. 44 in Kebumen; 2)To collect the samples (farmers), we applied the Purposive Sampling Technique with criteria: smallholder native chicken farming under traditional (extensive) and semi-intensive management. An extensive rearing system is an uncaged rearing of chickens that are grazed around the backyard. Whereas a semi-intensive system refers to chickens farming that are kept in a limited area, the farmer provides cages and feeds with limited quantity and quality. We collected data through interviews with the farmers, questionnaires, and direct observation and measurement in the field. The data included farming system (extensive vs. semi-intensive), disease prevention, total sick chickens, diseases (e.g., ND, AI, Infectious Bronchitis (IB), Infectious Bursal Disease (IBD), Chronic Respiratory Disease (CRD), Aspergillosis, Coccidiosis, Ornithonyssus bursa, and others), disease treatment, medication, vaccination, sales of sick chicken, culling, time of exposure to disease, and the role of extension agent in preventing and medicating disease among native chickens; 3)We drew blood samples from two chickens aged 16-20 weeks from each farm (n=324 birds) to measure the ND and AI antibody titers. Blood sampling was performed according to animal ethic protocols published by The Centre of Research and Community Service No. 1443/UN23.18/PT.01.01/2021. The antibody titers were examined using the Haemagglutination Inhibition (HI) test; 4)Data of disease incidence, treatment to sick chickens, mortality, AI and ND antibody titers were subjected to descriptive analysis. The System Dynamics was modeled to identify the contributing factors to the mortality rate of native chicken in smallholder farming, the inter-element relationship in native chicken farming, and the qualitative and quantitative modeling of native chicken farming. Additionally, strategies were designed to decrease the mortality rate among native chickens. The steps in system dynamics modeling (SDM) include: 1) Identify problems and limitations; 2) Develop a dynamic hypothesis that explains the causes of the problems; 3) Build causal loop diagram (CLD); 4) Develop stock and stream models; and 5) Perform model simulations (Galarneau *et al.*, 2020). The System Dynamic model used a thinking system using Ventana software (VENSIM).

Results and Discussion

Diseases incident and mortality

Disease incidence in Banyumas and Kebumen districts included AI, ND, CRD, and pullorum (Figure 1). In the interview, most farmers mentioned that native chickens often contracted diseases that led to sudden death. Farmers' ignorance of the types of disease contributed to poorly managed poultry farming.

Preventing disease among native chickens can be done by vaccination and cage sanitation.

Our observation showed that only 11.11% of extensive farming-breeders in Banyumas and 5% in Kebumen performed ND or AI vaccination to their native chickens. Native chicken farming is crucial to develop, especially in rural areas to supply meat and eggs and provide additional income for the community (Burhanudin *et al.*, 2019). Banyumas district is one of the centers for developing native chickens in Indonesia (Iswanto *et al.*, 2018), and the Kebumen district has a high population of native chickens (BPS, 2021). Some common diseases contracting poultry in these two districts are AI, ND, CRD, and Pullorum (Figure 1). Avian Influenza (AI) records the highest disease incidence in extensive farming in Banyumas (61,11%) and Kebumen (70%), exceeding the incidence in semi-intensive farming in Banyumas (40,91%) and Kebumen (50%). Avian Influenza is also reported to have the highest incidence among poultry (Sub-Directorate for Observing Animal Diseases, 2014).

Figure 1 shows that AI disease incidence is the highest of other diseases. AI incidence is caused by a seasonal infectious disease that originated from an outbreak in 2012. Extensive or free-range farming would moderate the spread of disease more rapidly and extensively. According to most farmers interviewed in our study, native chickens often contracted diseases that cause sudden death. Farmers' ignorance about the type of diseases that contracted their poultry has led to poor poultry management. The second prevalent disease after AI, Newcastle Disease records a low percentage of incidence probably due to routine ND vaccination among poultry farms that help curb the disease. A survey study of ND vaccination rollout in 11 villages of Chibuto, Mozambique reported that the farms had more chickens reared in the semi-intensive system (15.0) than in extensive farming (8.7). Compared to the non-vaccinated chickens, the vaccinated chickens had a bigger population size (16.9 vs. 10.0), higher average hatchability (80% vs. 70%), and five-time less risking death due to ND. The efficacy of ND 1-2 vaccination is reflected in the average increase of flock size and decreased mortality rate due to ND (Harrison and Alders, 2010). Meanwhile, CRD and Pollurum were of low incidence in Banyumas and Kebumen district, but predators remained prevalent in the semi-intensive farming in Banyumas.

Delabouglise *et al.* (2020) reported the impact of AI outbreak on smallholder chicken farming in south Vietnam. In small broiler flocks (≤16 chicken/flock) the estimated probability of harvest was 56% higher when an outbreak occurred, and 214% higher if an outbreak with sudden deaths occurred in the same month. Vaccination and disinfection combined have a strong and positive correlation with flock size. The majority of poultry producers in the low-income country are smallholder farmers who rely on quick sales of their poultry to compensate for the loss due to disease. AI-infected chickens are distributed to markets or trade networks, thus potentially increasing the spread of AI.

Prevalent diseases to native chickens include ND, gumboro, fowl pox, snot, CRD, AI and paralysis. The common challenges to native chicken farmers include lacking knowledge on the standard practice of commercial farming and biosecurity, and the under optimum sanitation and animal health treatment which may expose the native chickens to many diseases. Diseased livestock would lead to low productivity even death (Libriani *et al.*, 2020). These challenges are also found in Banyumas and Kebumen districts.

Vaccination rollout to chickens reared in different farming systems in Banyumas and Kebumen has reached 40-70%. ND and AI antibody titers are crucial to identify the vaccine potentials to stimulate protective immunity in chickens, especially after the vaccination. This effort is taken to prevent AI or ND outbreaks (Kencana *et al.*, 2016). The percentage of the use of chemical and herbal medicine, the sales of sick chickens, and culling were low, except in semi-intensive farming in Banyumas.

Disease treatment to native chicken may include offering medicine and vitamin or herbal medicine. In Banyumas, 11.11% of the extensive farmers offered herbal medicine for their sick livestock, 9.09% semi-intensive farmers offered vitamins and medicine, and 36.36% used herbal medicine. In Kebumen, 30% of extensive farmers and 15% of semi-intensive farmers preferred medicine and vitamin, 35% of extensive farmers and semi-intensive farmers provided herbal medicine to treat poultry disease (Figure 2).

Native chicken farmers treated their sick chickens in different manners. In Banyumas, 5.56% of extensive farmers sold their sick chickens, while 22.22% opted for culling the sick chickens. In semi-intensive farming, 9.09% of farmers chose to sell sick chickens, while 27.27% preferred culling. In Kebumen, 15% of the extensive farmers sold the sick chickens, and 30% culled them. In semi-intensive farming, 10% of the farmers sold sick chickens, and the rest 30% preferred to cull them for family consumption (Figure 2).

The present study showed that native chicken farms in Banyumas and Kebumen districts tend to use herbal remedies to treat disease in poultry (Figure 2). Herbal remedies are an alternative solution for chemical medicine as a supplement to improve native chicken's body immune against stress and common disease (Mahfuuzhoh *et al.*, 2019) as well as an appetite booster for livestock to improve health less susceptible to disease (Yuliani *et al.*, 2020).

Vaccination refers to an act of injecting antigen (weakened virus or disease agent) into a healthy body to improve antibody or body immune. Vaccination is the most effective measure to give protection to native chickens from disease incidence. The low vaccination rates among native chickens are probably due to farmers' lack of awareness of the importance of

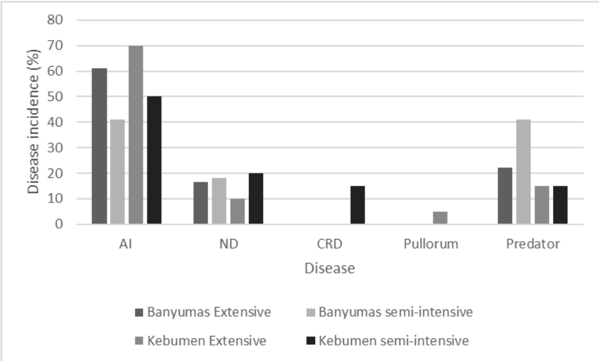

Figure 1. Disease record of Native chicken.

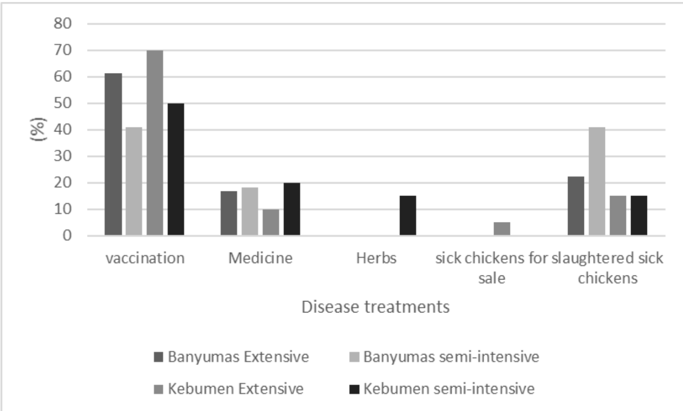

Figure 2. Disease treatment among poultry.

maintaining poultry health through vaccination and performing the vaccination by themselves. To the best of our knowledge, there are no or limited extension programs on poultry health targeting native chicken farmers in Banyumas and Kebumen. Therefore, animal health issue remains an obstacle in the development of native chicken farming.

Rosyidi (2018) stated that many disease incidences and feed poisoning are due to farmers' partial knowledge and consumers' lack of awareness of the safety and halal status of animal-based food remain unreported or unidentified. Sick chickens for sale or culling illustrate such an alarming food safety among Banyumas and Kebumen community; therefore, the government should educate the people regarding the best practice of disease treatment for native chickens.

Some disease incidence and predators are behind the mortality of native chickens. Mortality rate refers to the average death among native chickens in one-year maintenance. The mortality rate of native chicken in Kebumen and Banyumas was relatively high compared to the 5% threshold (Sofjan, 2012). Native chicken mortality in the farms observed in this study ranged from one to three chickens per year (Table 1). Kebumen has a smaller flock size but a higher mortality rate than Banyumas (Table 1), so it is crucial to investigate what has caused the phenomena from a maintenance perspective. Hidayat and Asmarasari (2015) stated that the challenges in native chicken farming are slow growth, high mortality, and low production of eggs. In addition, farmers' low level of knowledge on disease and disease prevention, disease incidence, and environmental factors contribute to the increased mortality rate among native chickens in the location of the study.

The mortality rate of native chicken is generally affected by an extreme environmental condition, disease, antinutritional substances in feed, and competition for feed (Kestaria *et al.*, 2016). Traditional farming systems contribute to 70% of the mortality rate of native chickens (Rajab and Papilaya, 2012). It was in line with Nurmi *et al.* (2018) that the environment contributes 70% to the success of a farming business. The factors influencing mortality rate include body weight, chicken breeds and strains, climate conditions, environmental hygiene, sanitation, equipment, cage, and environmental temperature. Fluctuating weather conditions would cause a decrease in feed intake, which leads to declining body weight, and eventually, death.

Since ND and AI are viral diseases, poultry's health status should be subjected to a serology test to observe the antibody titers in the chickens. Table 2 illustrates the result of the Haemagglutination Inhibition test (HI test) of native chicken.

Table 1. The mortality rate of native chicken in semi-intensive and extensive farming

Area	System	Average number of chickens/farmer (bird)	Mortality/year (%)
Banyumas	Extensive	14.89	6.72
	Semi-intensive	18.59	7.79
Kebumen	Extensive	12.9	14.34
	Semi-intensive	18.15	16.53

Table 2. The Percentage of ND and AI antibody titres in native chicken reared in extensive and semi-intensive system

Antibody titres	Extensive (%)	Semi-intensive (%)	Antibody titres	Extensive (%)	Semi-intensive (%)
	ND			AI	
0	50.00	57.14	0	50.00	54.76
<2^6	39.47	30.95	<2^4	47.37	42.86
≥2^6	10.53	9.52	≥2^4	2.63	2.38

Based on the recommended HI test by the World Organisation for Animal Health (Office International des Epizooties, 2012), AI and ND protective antibody titers are $\geq 2^4$ and $\geq 2^6$, respectively, reflecting a high level of antibody against the diseases. The protective antibody titers against ND of native chickens reared in extensive and semi-intensive farmings in Banyumas and Kebumen were 2,38% and 10,53%, respectively (Table 2). This result confirmed a study about local chicken raised under a traditional management system in three selected agricultural-climatic zones in Central Ethiopia. The study reported that the hemagglutination inhibition (HI) test for ND antibody titers produced an overall seropositive rate of 32,22%, which varied between farming in highland (28,57%), medium-altitude area (29,69%), and lowland (38,33%). ND is reportedly the main contagious disease that threatens the sustainability and productivity of traditionally-reared native chickens (Tadesse *et al.*, 2005). In Nigeria, the high prevalence of ND antibody among native chickens (17%) which may be due to virulent infections such as mesogenic strain, which is a virus that causes respiratory and neurological symptoms that leads to low mortality, or lentogenic strains (mild respiratory infection without apparent morbidity and mortality) (Oyiguh *et al.*, 2014).

Protective antibody titers of AI in extensive farming and semi-intensive farming are 2,63% and 2,38%, respectively (Table 2). It shows partial efficacy of vaccination rate among native chicken in Banyumas and Kebumen regardless of the farming system. The percentage of protective antibody titers of ND and AI is lower than the non-protective ones, which is probably because the chicken samples in the research location are never naturally infected by AI or ND. Also, it indicates a failed vaccination which may be attributed to different factors, including the chicken conditions, vaccinator, and vaccine equipment.

A previous study reported that AI and ND vaccination records of native chickens reared under an extensive system were non-existent. The Haemagglutination inhibition (HI) test showed that the antibody prevalence against AI and ND was 31,6% and 38,8%, respectively, and the average antibody titers of AI were 0,32 ± 0,1 Log 2 and BD were 0,39±0,2 Log 2. The result showed that 70,4% of serum contained HI antibodies against AI and ND antigens. It was suspected that native chickens reared under an extensive system play a crucial role in spreading ND and AI diseases (Wakawa *et al.*, 2009). Yuliantari *et al.* (2018) reported that AI prevalence is considered relatively high if it is produced from 2.5% of the total blood serum. Sutrisna (2014) stated that antibody titers are not consistently protective; the efficacy will decrease with time, and the declining rate is affected by the disease virulent or animal condition. Therefore, vaccination is the prerequisite for an optimum formation of antibody titers.

Strategy to reduce mortality rate

Factors that were allegedly influencing the mortality rate of native chicken in family poultry farming can be explored and strategies for development can be designed using a model developed in Causal Loop Diagram (CLD). Modeling in the current study found seven reinforcing loops and five balancing loops. Loops of Smallholder native chicken farming (Family poultry production).

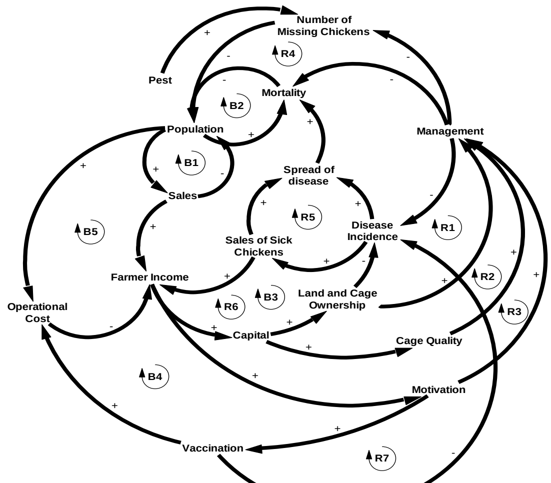

Figure 3. Loops of smallholder native chicken farming.

Figure 4 illustrates three balancing loops (B), namely B1, B2, and B3, and three reinforcing loops (R): R5, R6, and R7. Loop B1 shows that population increases sales, and the higher the sales, the smaller the population. Loop B2 indicates that population increases mortality rate, which then decreases the population. Based on loops B1 and B2, an effort to maintain the population of native chicken is crucial to curb mortality and sales rate.

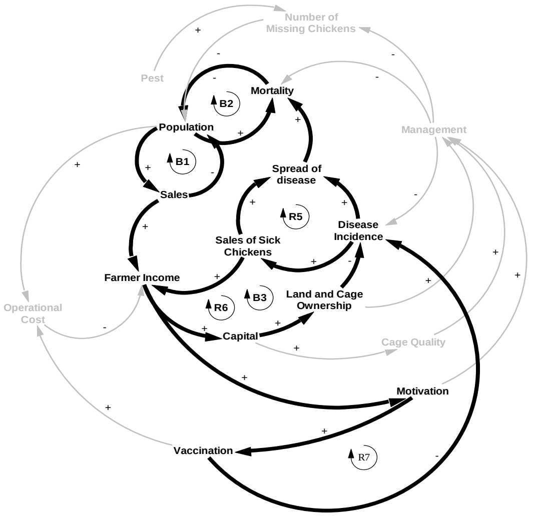

Figure 4. Loop disease incidence.

Figure 4 illustrates three balancing loops (B), namely B1, B2, and B3, and three reinforcing loops (R): R5, R6, and R7. Loop B1 shows that population increases sales, and the higher the sales, the smaller the population. Loop B2 indicates that population increases mortality rate, which then decreases the population. Based on loops B1 and B2, an effort to maintain the population of native chicken is crucial to curb mortality and sales rate.

Loop B3 shows that farmer income increase capital. Capital improves land and cage ownership, reduces disease incidence, thus lowering the total sales of sick chickens. Loop R5 shows that income increases capital, capital improves land and cage ownership, which decreases disease incidence and sales of sick chickens, and eventually, reduces the spread of disease, resulting in an increased population, sales, then income. Loop R6 shows that income increases capital, capital improves land and cage ownership and reduces disease incidence, thus curbing the spread of disease and mortality rate and eventually increasing population, sale, and income. Loop R7 shows that income increases business motivation, motivation improves vaccination rates and reduces disease incidence, the spread of disease, and mortality, and eventually increases poultry population, sales, and farmer income. The sales of sick chicken increase farmers' income and their business capital. The analysis shows that disease prevalence is positively correlated with mortality, so the increased prevalence of the disease will raise the mortality rate. Mortality is negatively correlated with farmer income because a high mortality rate would decrease farmer income. When farmer receives less profit, it is assumed that disease prevention has been improved, thus reducing disease prevalence. These correlations collectively impose a balancing effect on the system and result in declining disease prevalence and mortality (Galarneau *et al.*, 2020).

Based on loops R5, R6, and R7, we suggest farmers allocate their income for vaccination and improve their land and cage ownership so that they can curb the spread of disease and mortality. We found that most farmers in Banyumas and Kebumen districts did not vaccinate their native chickens, which may have caused high susceptibility to disease outbreaks and high mortality rates. Farmer's ignorance of the harmful consequences of consuming sick chickens made them sell the sick chicken for half price. Poultry reared in an extensive farming system does not pose as a serious threat as those in an intensive system that have homogeneity of genetic stock and poor biosecurity. AI pandemic has impacted native poultry, farmers, and traders of native poultry. The impacts include cultural issues, village poultry value chains, approaches to biosecurity, marketing, poultry disease prevention, and control compensation, genetic diversity, poultry as part of livelihood strategies, and effective communication. The first step towards HPAI prevention and control is increasing awareness that poultry health and welfare is vital (Alders *et al.*, 2014). Accordingly, it takes a collaborative measure from multiple stakeholders and the government to increase farmers' level of knowledge on animal health and welfare.

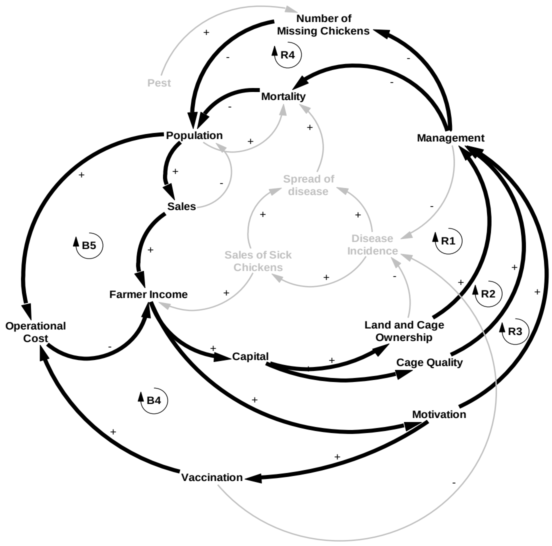

Figure 5. Loop Management.

Figure 5 consists of two balancing loops (B), i.e., loop B4 and B5, and four reinforcing loops, i.e., loop R1, R2, R3, and R4. Loop B4 shows that farmer income increases motivation, improves vaccination rates, increases operational cost, and decreases farmer income. Loop B5 indicates that population increases the operational cost, then decreases farmer income. Income increases management that will increase the population. Poultry vaccination reduces disease risk among native chickens, but vaccination rollouts will add to operational costs. This monetary factor is crucial in farmers' decision to perform vaccination whereas their knowledge of the importance of vaccination is low. Farmers tend to limit their flock size to curb operational costs because the high maintenance cost is not equal to the low selling price that ranges from Rp20,000,00 to 150,000,00, depending on the chicken's age and sex.

Loop R1 shows that a positive rate is attributed to population – sale – farmer income – capital – land and cage ownership – farming management – mortality – population. The high population would increase farmer income, and then increases capital reinvestment, improve land and cage ownership, and increase management, which then decreases mortality, and eventually increases population. Loop R2 shows that population increases sales, sales increase farmer income, and their capital, then increases cage quality and improves management, reduces mortality rate, and eventually, increases the population. Loop R3 shows that population increases sales, sales increase farmer income, business motivation, and management, then reduces mortality rate, and eventually, increases population. Loop R4 shows that management decreases the number of missing chickens, which means an increased population that gives rise to sales and income, and eventually, increases capital and improves management. The result showed that native chickens reared under extensive farming tend to go missing more often than in a semi-intensive system where farmers invest in more treatment and care for their animals. In extensive farming, chickens roam free in the natural environment, thus more susceptible to going missing. Based on loops R1, R2, R3, and R4, it takes an allocated income for improving land and quality cage to reduce the mortality rate among native chickens.

Conclusions

Disease incidence among native chicken reared in semi-intensive and extensive farming includes AI, ND, CRD and pullorum. Disease-causing mortality remains high (>5%). Native chickens reared under extensive farming shows a higher body immune against AI and ND than those in semi-intensve system. CLD qualitative model produces seven reinforcing loops and five balancing loops. The challenges to developing native chicken farming include disease incidence due to lack of appropriate land and cage, sales of sick chicken, zero vaccination rates, high operational cost, low business motivation, low level of knowledge on farming management and animal welfare, non-existent extension programs by the government related to traditional farming management. Strategy to reduce mortality includes preventing the incidence of diseases by providing land and cage for breeding, prohibiting sales of sick chickens, introducing vaccination, improving management through extension program and campaign, and mentoring by medical personnel to native chicken farmers.

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