Economic analysis of farmers' behavior and incentive towards African swine fever control in Madagascar

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AHPD : animal health and phytosanitary directorate
ASF : African swine fever
ASFV : African swine fever virus
CP : compensation Program
CSF : classical swine fever
CV : contingent valuation
DQ : direct questioning
EAD : emergency animal diseases
FAO : Food and Agriculture Organization
FMD : foot and mouth disease
GDP : gross domestic product
GPS : global positioning system
HPAI : highly pathogenic avian influenza
ICT : item count technique
LSU : livestock standard unit
MAEP : Ministry of agriculture livestock and fisheries
(Ministère de l'Agriculture de l'Elevage et de la Pêche)
MGA : Madagascar Ariary
OIE : office international des epizooties (World organization for Animal health)
RVF : rift valley fever
SD : system dynamics
SE : standard error
SS : sensitive statement
StdD : standard deviation
TAD : transboundary animal disease
WTA : willingness to accept
WTP : willingness to pay

CHAPTER 1

Introduction

1.1 Background and challenges

Agriculture is the main support of Africa's rural livelihoods; two-thirds of rural African's household income is from on-farm agriculture (World Bank, 2015). Agriculture in Africa accounts for 32% of gross domestic product (GDP) and employs 65% of the workforce (World Bank, 2013a). It indicates Africans' livelihood high dependence on agriculture. Unfortunately, about 80% of the farms operate in a land smaller than 2ha and the average farm size decreased between 1970 to 1990 in sub-Saharan Africa (Lowder et al., 2016). As for livestock particularly, significant number of rural African farmers depend on them (World Bank, 2013b).

Besides, animal diseases pose major threats to livestock sectors in Africa. For example, in 2014, 83 animal diseases have been reported from 41 member states of the African Union and have caused a total direct loss (death, slaughter, and destruction) of about 1.3 million of animals (AU-IBAR, 2014). In addition to the economic impacts of the diseases, the measures to be taken to mitigate the risk of disease introduction or spread constitute a burden for farmers and the governments.

In Africa, pigs are kept to be a main source of income or cash emergency. For examples in Kenya, 98% of farmers have pigs as the main source of income (Kagira et al., 2010); in Namibia, Tanzania, and Benin, pigs represent a significant source of livelihood (Youssao et al., 2009, Kagira et al., 2010; Petrus et al., 2011;). However, like most case in developing countries; the average pig herd size per household in the above mentioned countries is very small such as 3.6 in Kenya (Kagira et al., 2010) and 2.3 in Tanzania (Petrus et al., 2011). In addition, pigs are also a source of protein for farmers (Petrus et al., 2011, Mashatise et al., 2005). Even if pigs are the farmers' main source of income, they hold few numbers which is a sign of poverty.

Pigs can be a viable and profitable enterprise that can be easily implemented and adopted by small-scale farmers. Moreover, pigs require little initial investment and they are productive (Dietze, 2012). Therefore, development of pig production can be one of the means to be considered to fight against poverty in Africa.

The most serious limiting factor for pig production in sub-Saharan Africa that have been identified were scarcity or high cost of feed (Halimani et al., 2007; Adesehinwa, 2008; Ironkwe and Amefule, 2008; Kagira et al., 2010), inadequate animal health (Karimuribo et al, 2011), poor housing facilities (Mashatise et al., 2005) inadequate supply of breeding stock (Moreki and Mphinyane, 2011; Muhanguzi et al., 2012), and lack of knowledge in terms of husbandry skills (Petrus et al., 2011).

In Madagascar, a significant proportion of households (20%) owns at least one pig, and pig farming constitutes a significant source of income or saving for Malagasy pig producers (INSTAT, 2011). However, like in many other African countries, African swine fever (ASF) is endemic in Madagascar. ASF is considered the most serious infectious disease in pigs in Africa (AU-IBAR, 2014). Additionally, though ASF is not among the major constraints, it is recognized to be a significant limitation of pig production (Mutua et al., 2011; Muhanguzi et al., 2012).

ASF is a transboundary animal disease (TAD) that can have a significant negative impact on a nation’s economy. It causes major economic losses because of its high mortality rate which results in the reduction of pig production. Consequently, it constitutes a threat for a significant proportion of Malagasy population who depend heavily on pig farming and who risk, as a result of ASF, to lose their livelihoods.

As mentioned previously, ASF is a pig disease of high economic impact. Therefore, social studies related to ASF are focused on 1) measuring the economic impact of ASF, such as the studies of Mlangwa and Samui (1996) and Babalobi et al. (2007); 2) determining the cost implication to the farmers of ASF prevention (Fasina et al., 2012) and 3) estimating the cost of prevention of ASF such as that of Bech-Nielsen et al. (1993). Study that tries to propose a way of controlling ASF spread that takes into account farmers’ point of view is lacking.

Most of the previous studies conducted which are related to ASF were on veterinary studies such as development of vaccine (King et al., 2011; Correia et al., 2013;

O'Donnell et al., 2015) or treatment (Powell et al., 1996; Alonso et al., 2001; Andrés et al., 2002; Freitas et al., 2016), surveillance (Fasina et al., 2010), and epidemiology (Penrith and Vosloo, 2009; Jori et al., 2013; Oganesyan et al., 2013; Okoth et al., 2013; Sánchez-Vizcaíno et al., 2015).

Unfortunately, all the attempts to develop ASF vaccine have failed (Rock, 2016) and to date, there is no effective vaccine available against ASF (OIE, 2013). Moreover, so far there is no effective treatment for ASF (OIE, 2013).

Factors that have been identified to constitute a risk for ASF spread are direct contact between pigs (Wieland et al., 2011), movement of pigs (Penrith and Vosloo, 2009), lack of compensation (Fasina et al., 2010; Nantima et al., 2015) and feeding of pigs with swill (Penrith, 2013; Nantima et al., 2015). Those factors, especially the last three, depend on the farmers' behavior. In other words, farmers' behavior plays an important role in the spread of ASF. To our knowledge, study that considers farmers behavior in the spread of animal disease is lacking. Therefore, the general purpose of this study is to draw policy implications for a successful control of ASF by focusing on farmers' behavior.

To avoid pig movements, the Malagasy government made a law (Ministerial Decree N^{o} 396/99) in which the Article 4 stipulates that selling ASF-infected pigs is prohibited. However, as mentioned previously, pig is the main source of income for farmers. Thus, the behavior of selling the ASF infected pigs illegally might happen and it will lead to ASF spread, and farmers' knowledge about ASF might affect that behavior. That is the first assumption in this study.

Along with movement restriction, pig slaughter is the only effective way to control ASF (OIE, 2013). It requires government's intervention and farmers' cooperation by reporting ASF suspicion in order that government can slaughter the ASF infected pigs. That explains why lack of compensation is one of the factors that spread ASF, in the sense that farmers will not cooperate in slaughtering their animal without receiving economic incentive such as compensation. Therefore, the second assumption in this study is that financial compensation might be an incentive for farmers to report ASF.

Swill feeding also is previously mentioned as factors of ASF spread. It is particularly of principal concern for the case of Madagascar because farmers might buy the ASF contaminated meat; and contaminated swill results in ASF infection in the farm. The behavior of buying contaminated meat is encouraged by a social norm called *fihavanana* for a mutual support among farmers which is an informal custom that has been developed in Malagasy society. Moreover, pig slaughter is currently not conducted during ASF outbreak due to unavailability of compensation because of government's budget limitation. Consequently, if a compensation program is adopted, it should be cost effective. Therefore, the third and last assumption of this study was that ASF can be controlled cost effectively by considering social norm.

1.2 Literature review

1.2.1 African swine fever in Africa

ASF is one of the most feared pig diseases in the world. The disease originated from Africa but it is present in other continents as shown in Figure 1.1.

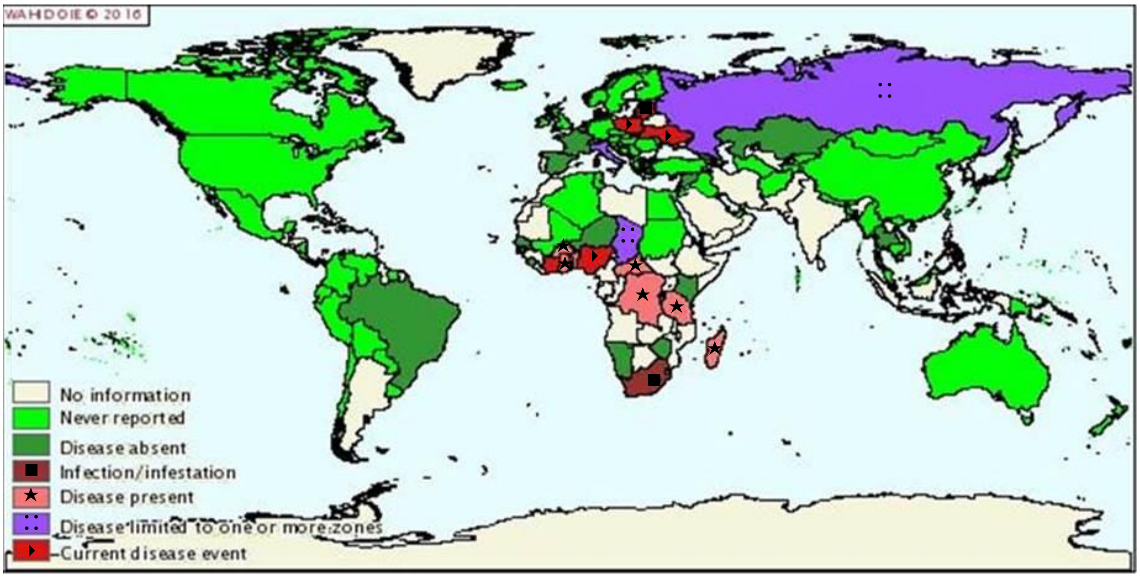

Figure 1.1 Distribution of ASF in the world

Source: OIE, 2016

The ASFV infects domestic pigs and wild pigs (bush pigs and warthogs[1]). Bush pigs are hunted for their meat in many African countries, and leftovers fed to domestic pigs could lead to infection (Jori and Bastos, 2009). The ASFV also infects different species of soft ticks, in which it can survive more than 5 years (Oleaga-Perez et al., 1990).

The first recorded outbreaks of ASF were reported in pigs in Kenya in 1914. Because ASF has similar symptoms to Classical Swine Fever (CSF), a later study Montgomery (1921) confirmed that the disease is different from CSF. Regarding its spread, ASF occurred in a large number of countries in southern and eastern Africa by the late 1960s (Plowright et al., 1994). In West Africa, Senegal was the first to report it in 1978 (Penrith et al., 2013), Cameroon suffered its first introduction in 1982

[1] Wild pig found in sub-Saharan Africa

(Plowright et al., 1994), and Cote d'Ivoire in 1996 which spread all over West Africa (Penrith et al., 2013). Figure 1.2 shows the distribution of ASF in Africa in 2011. It can be seen that 28 African countries are affected by ASF, of which 26 countries have reported the presence of ASF in domestic pigs and two countries have infected warthog (Penrith et al., 2013).

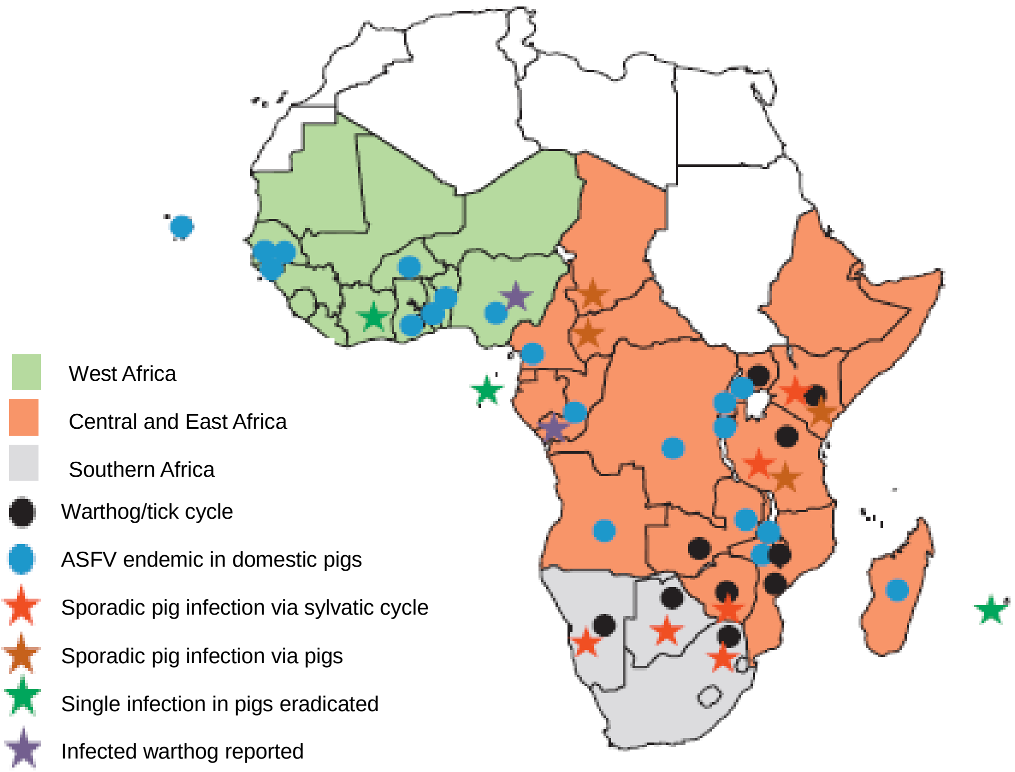

Figure 1.2 ASF distribution in Africa in 2011

Source: Penrith et al., 2013

In 2014, only 14 African countries reported having experienced ASF cases with Democratic Republic of Congo experiencing the highest number of outbreaks (71) followed by Cameroon (31). Namibia experienced the less number of outbreaks (1). In addition, 11 countries did not submit a report which does not guarantee the absence of outbreak on 2014. The pig mortality rate caused by ASF of the 183 outbreaks reported was estimated to be 54.2% (AU-IBAR, 2014).

Only São Tomé e Principe and Mauritius are the African countries that have succeeded in eradicating ASF (Penrith, 2013). Cote d'Ivoire could eradicate the case in 1996 (Penrith, 2013) but ASF has been apparently reintroduced according to Figure 1.3.

Apart from most sub-Saharan Africa, Western Europe, the Caribbean, Brazil, and most recently, the Caucasus have experienced ASF (Penrith and Vosloo, 2009).

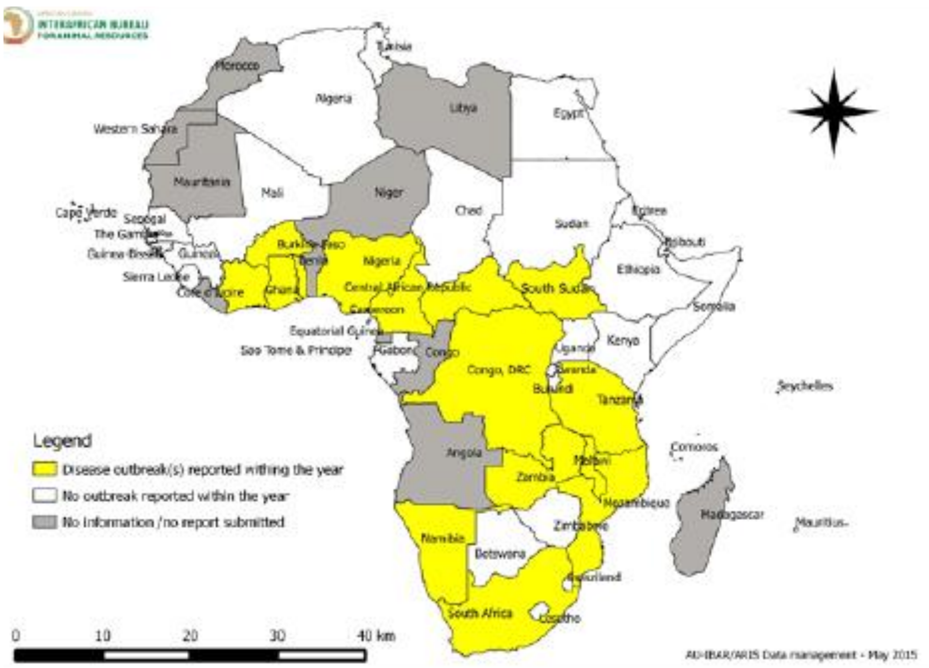

Figure 1.3 ASF distribution in Africa in 2014

Source: AU-IBAR, 2014

1.2.2 Farmer's knowledge, behavior and attitude on animal disease control

When a farmer suspects a case of ASF in his farm, he has the choices between to slaughter the suspicious pig and sell the meat or do nothing and wait for the pig to recover or die. As mentioned previously, selling of ASF-infected pig is illegal in Madagascar; hence it is assumed that selling of ASF infected pig is a sensitive behavior. However, it is the most rational behavior that a farmer can adopt in order to get remaining value of the infected pig to prevent income shock.

In addition to the economic factor, that behavior can be influenced by other different factors such as knowledge, opinions, values, beliefs and so on (Ajzen and Fishbein, 2005). Several studies (Salameh et al., 2004; Recena, 2006; and Brown et al., 2008) showed that farmers' knowledge affects their behavior or attitude. For instance, Recena (2006) showed that farmers' well knowledge about pesticides results in low level of exposure. Similarly, farmers who have low knowledge about pesticides applied low preventive measures (Salameh et al., 2004).

According to Penrith et al., (2013), successful eradication of ASF in Côte d'Ivoire in 1996 was partly due to an awareness campaign that helped limit farmers' risky behavior that causes the spread ASF. Therefore, one aspect of this study (Chapter 3 and 4) is to consider farmers' knowledge about ASF in order to explain their attitude and behavior towards ASF control. To our knowledge, few studies (Jansen et al., 2010; and Arif et al., 2017) have been conducted to explain animal disease incidence or management in a farm by farmers' knowledge, attitude or behavior. The study of Jansen et al. (2010) recommended that animal health promotion programs should consider farmers' behavior and farmers' attitudes. In that study, farmers' self-reported[2] behavior and attitudes together explain 31% of the variation within the clinical mastitis incidence in one farm. There are two limitations of that study. First, the attitudes and behavior are self-reported, indicating that it is possible that socially desirable answers were reported by the farmers, and this could have led to a bias in the results. Second, farmers' knowledge about mastitis which might have influenced their behavior was not considered. The findings of Arif et al. (2017) indicate that farmers have low knowledge about the roles and responsibilities of stakeholders involved in biosecurity and emergency animal diseases (EAD)[3] management. In addition, the low knowledge is assumed to create confusion about EAD management and impact upon producers' willingness to report animal disease but the relationship between farmers' knowledge and willingness to report is not clearly shown.

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[2] Behavior that is individually reported by farmers without being verified.

[3] an exotic disease; or a variant form of an endemic disease, which is not endemic and would have a national impact: or, a serious infectious disease of unknown cause; or, a known endemic disease occurring in a very significant outbreak form that would cause national impact or serious market access loss

As part of ASF control, selling of ASF-infected pig or ASF-contaminated meat[4] is illegal in Madagascar. In this study (Chapter 3), we would like to directly assess farmers' knowledge about ASF and then, identify that there is a relationship between farmers' knowledge and the possible illegal behavior of selling ASF-infected pig.

1.2.3 Economic incentive and animal disease reporting

Farmers always have more information about their animal's risk exposure to a disease, and their effort to mitigate risk, than any other person. This is called information asymmetry. Gramig et al. (2006) discussed about the effect of asymmetric information in the case of animal insurance. Insurers are unable to have the correct information about the risk of exposure of the animals, meaning there is hidden information. Consequently, farmers who have animal with high risk of contracting disease will buy the insurance. This is called adverse selection. After contracting the insurance, farmers may also increase the risk of exposure to animal disease in order to benefit from the insurance. Again, farmers are the only one who has that information. This situation is called hidden action or moral hazard.

Information asymmetry also poses problem in animal disease control conducted by government (Gramig et al., 2009; Hennessy and Wolf, 2015). Pig slaughtering is only possible if the government has information about the health status of the pigs. Only pig farmers possess that correct information, and the decision to reveal the information to the government is up to him. Therefore, government should create incentive for the farmers to report any suspicion in their farm.

Compensation encourages reporting of infectious disease. In another words, it can be used as incentive in order to get the right information from farmers. Compensation also provides a safety net to farmers to avoid a huge loss (OECD, 2012). Following are some examples of various compensation schemes in developed and developing countries.

In Australia, there is a compensation scheme already implemented prior to the outbreak. For any emergency animal disease such as CSF, Foot and mouth disease

[4] From now on, selling of ASF-infected pig or ASF-contaminated meat will be referred to selling of ASF-infected pig.

(FMD), Rift Valley fever (RVF), etc, it is already planned by the government that farmers will be compensated. Animals that are being reported and confirmed to be infected are being destroyed. The amount of compensation given to the farmer can be as high as the market value of the herd (OECD, 2012). Australia could eradicate CSF and there is no outbreak since 1961 (NAQS, 2016). Unlike the case of Australia, in Botswana, the maximum amount of compensation to be given to farmers in case of FMD represents only one-third of the animal's market value depending on the government's budget (OECD, 2012). Botswana could not eradicate FMD from the whole country; however, its status is FMD free zone where vaccination is not practiced (OIE, 2017). Brazil has another kind of compensation scheme. For the case of FMD, a compensation of 100% of the value of the animal is given to farmers where 50% is from the government and the other 50% is given by private sector (OECD, 2012). Like Botswana, Brazil is an "FMD free zone where vaccine is not practiced".

Two instances where compensation program were present but ASF could not be eradicated are that of Togo and Benin. In Togo, the budget for compensation was not enough because of the large pig population. In Benin, compensation was available only some time after the beginning of the outbreak, meaning, ASF could not be controlled and became endemic (Penrith et al., 2013).

Some studies show that stamping out for animal disease control is economically worthwhile. Examples are that of McInerney and Kooij (1997) for Aujeszky's disease, the study of Smith et al. (2007) for bovine tuberculosis control, and that of Bech-Nielsen et al. (1993), which analyzed the cost and benefit of ASF eradication in Spain. However, farmers' cooperation is needed for a feasible stamping out, therefore developing an economic incentive system for farmers to report is needed, especially if government's budget limitation poses a problem. To the best of our knowledge, few studies (Gramig et al., 2009; Hennessy and Wolf, 2015) have focused on designing compensation for animal disease control. Moreover, such studies are mainly theoretical in nature. For instance, the theoretical study of Gramig et al. (2009) suggested compensation to incentivize farmers to invest in biosecurity. However, as pig farms in Madagascar are mainly small scale, pig farmers are unable to invest in biosecurity (Costard et al., 2009a). Hence, this study (Chapter 4) considers compensation as an incentive to report infection case. As for the study of Hennessy and Wolf (2015), it concludes on the need to provide sufficient compensation to ensure reporting, but not so large as to decrease the appropriate levels of biosecurity. However, the cited study does not specify the amount of compensation to be given to farmers. As such, our study also measures farmers' willingness to accept (WTA) compensation for a successful stamping out in order to control ASF appropriately. Additionally, Penrith et al. (2013) showed that the successful eradication of ASF in Côte d'Ivoire in 1996 was partly due to an awareness campaign that helped limit the risky behavior of pig farmers that spread ASF. Moreover, Hennessy and Wolf (2015) consider compensation to mainly induce reporting, but our study also identifies if, in addition to the unavailability of compensation, lack of knowledge might also be a barrier for reporting.

1.2.4 Epidemiology and animal health economics

Epidemiological modeling allows investigating the dynamics, frequency, and aspects of diseases in animal populations. Different studies have been conducted to measure the transmission of ASF under different circumstances. The study of de Carvalho Ferreira et al. (2013) found that, under experimental condition, the basic reproduction ratio (R_0) of ASF under experimental conditions is to be 18. Following the definition of Anderson and May (1979), it means, one infected pig can in average causes the infection of 18 pigs in a fully susceptible population during its entire infectious period. The study of Barongo et al. (2015) used three methods[5] to determine the basic reproduction ratio. First, there is the method of nearest infectious neighbor. Basically, GPS[6] coordinates of affected herds and the month when the first death was reported are needed. Second is the epidemic doubling time method and the third is the Susceptible Infected model. Both methods need epidemiological data such as the date of the infection and the number of infected pigs. The study area of Barongo et al. (2015) is characterized by the predominance of free ranging and tethering[7].

The limitation of those two studies is that they do not consider the case where pigs are kept permanently in the pen but still ASF spreads. According to Penrith and Vosloo

[5] Details can be found in Barongo et al., 2015
[6] Global positioning system
[7] Tie pig with rope so as to restrict its movement

(2009), the introductions of ASF in an infection-free area have almost all been associated with movement of domestic pigs and pork products rather than contact with the wild pigs. Nantima et al. (2015) identified that farmers who practice free range are the most vulnerable while those who had the least number of pig purchases, minimal swill feeding, and less treatment for parasites are the least vulnerable to ASF. In addition, infected pigs or swill feed contaminated with ASFV are often the causes of ASFV introduction into pig populations. In Madagascar, there are some areas where free range is not practiced, but a large proportion of farmers use swill feeding. Swill feeding is a major concern because some farmers in Madagascar buy ASF contaminated meat due to a social norm called *fihavanana*. Therefore, the epidemiological model in Chapter 5 will consider *fihavanana* as a cause of ASF spread.

Economics analyses allocation of scarce resources in the realm of competing human demands. Animal health economics is a decision making support tool on animal health interventions at various levels (individual animal, national herd or international) (Otte and Chilonda, 2000). The mission is either to analyze the consequences of a change (for instance introducing a new vaccine or policy) or to make judgment on how desirable such a change would be. Animal health economics has recently become a growing discipline because of the importance of animal disease. Economics of animal health literature has covered different areas such as 1) the possibility of financing of veterinary delivery services in sub-Saharan Africa from livestock-related revenue and livestock services revenue (Anteneh, 1991) and 2) the roles of the state and the private sector in the provision of veterinary services (Mlangwa and Kisauzi 1994) which concluded that privatization of veterinary services in sub-Saharan Africa will lower than currently available, the general level of animal health care provided to certain types of producers.

In addition, there is the most frequent analysis in the area of losses due to diseases and cost-benefit analysis of control strategies. Examples are that of Bech-Nielsen et al. (1993), Rendleman and Spinelli (1999) and Zhang et al. (2014). Those studies apply epidemiology and economic analyses. Actually, economics and epidemiology play an important integrative role in understanding the options available for decision makers with related costs and benefits (Perry et al., 2001). However, the existing animal health economics literature does not generally address human behavior in the analysis of disease impact (Rich and Perry, 2010). This study (Chapter 5) contributes to fill this gap by integrating the farmers' behavior of buying and selling ASF-contaminated meat in the epidemiological model, and determining the economic impact of stopping those behaviors.

1.3 Objectives of the study

The general purpose of this study is to draw policy implications for a successful control of ASF by focusing on farmers' behavior.

There are three specific objectives corresponding to three main analyses in this study:

1- To derive policy implications for ASF control from farmers' sensitive behavior that spreads ASF.

2- To determine suitable incentive for farmers for an effective control of ASF.

3- To draw policy implications from farmers' behavior and incentive for a cost-effective control of ASF.

This thesis comprises of seven chapters:

Chapter 2 describes the situation of pig production and infectious pig diseases in Madagascar. More specifically, this chapter will present the general situation of livestock, particularly pigs in Africa in general and the case of Madagascar. In addition, the infectious pig diseases in Madagascar will be presented, as well as more detailed of government's policy regarding livestock development and animal disease control.

Chapter 3 corresponds to the first specific objective. It is devoted to discuss about farmers' knowledge and sensitive behavior towards ASF. Farmers are assumed to sell ASF-infected pigs but do not admit it directly because of the law which prohibits that behavior. Item count technique (ICT) is used in the analysis.

Chapter 4 corresponds to the second objective in which farmers' WTA compensation will be discussed. As mentioned previously, compensation helps to reduce asymmetric information about the pigs' health status during outbreak. The method used in the analysis is contingent valuation method (CVM).

Chapter 5 is devoted to the third specific objective. It examines the relationship between the social norm of mutual support called *fihavanana*, and the spread of ASF will be discussed. Farmers buy the ASF-contaminated meat because of *fihavanana*, and it causes ASF spread. First, system dynamics (SD) modeling is used to simulate the spread of ASF, and second a cost benefit analysis is done to determine the cost effectiveness of a compensation program.

Chapter 6 is the general discussion. The findings in the Chapters 2 to 5 will be discussed with that of previous literature.

Finally, Chapter 7 is devoted to the conclusion where confirmation or invalidation of the three hypotheses will be mentioned.

The following Figure 1.4 summarizes the main steps of the study.

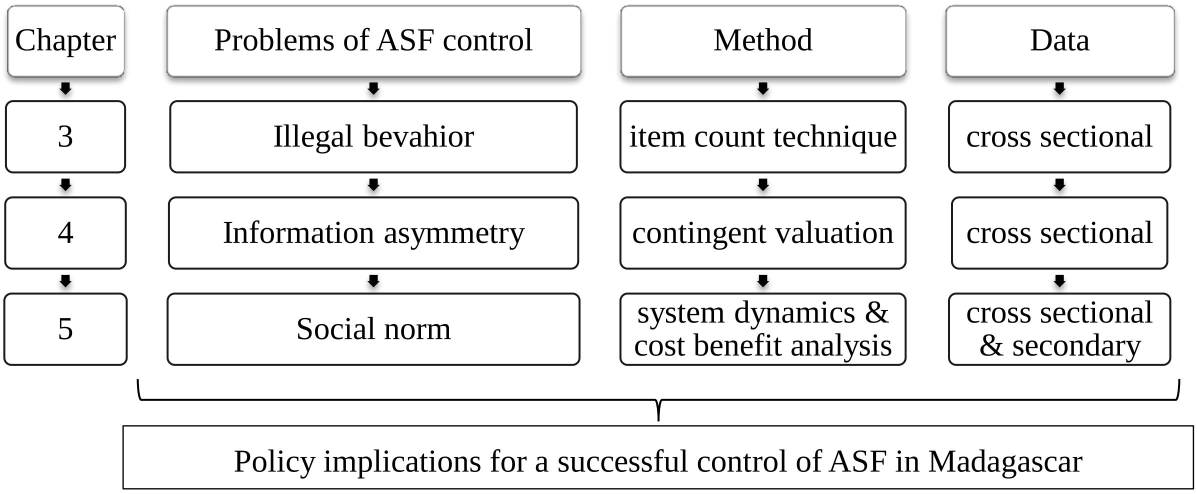

Figure 1.4 Framework of the study

1.4 Data collection and study area

1.4.1 Data collection

For the analysis in Chapter 3 and 4, a cross sectional data was collected in December 2013. Households with pigs in their backyard were approached. Therefore, respondents were individually interviewed face-to-face in Malagasy. A total of 201 pig farmers were interviewed. The data was collected from the Analamanga region, Antananarivo Avaradrano district. Due to unavailability of data about pig numbers at the district level, Ambohimangakely and Sabotsy Namehana Commune were selected for the high probability of finding pig farmers according to a livestock specialist in the district. Based on the communes' map, we selected 12 Fokontany (smallest administrative units) out of a total of 26, including the closest and the farthest from the national route.

A small pre-survey of 20 farmers was conducted in the study area in October 2013 before the main survey in December 2013. The aims of the pre-survey are explained in Chapter 3 and 4.

For the analysis in Chapter 5, a field survey was conducted in June 2016. The sample size is 116 pig farmers, who were randomly selected. Additionally, secondary data was collected from previous literature and Malagasy government's reports.

All of the data were collected from the same study area which is Analamanga region. However, the respondents of the two surveys are different because of the anonymity of the first survey.

1.4.2 Study area

Madagascar comprises of 22 regions. Our study was conducted in the Avaradrano district of the Analamanga region. That region is second in terms of pig number (13%) after the Vakinankaratra region (15%) as shown in Figure 1.5. Antananarivo Avaradrano district had the highest numbers of annual outbreaks of ASF (34 outbreaks) recorded from 1998 to 2004 compared to other districts within the Analamanga region (OIE, 2013). Figure 1.6 shows that those two regions have the highest number of pigs in the country. However, only 18 outbreaks occurred in the Vakinankaratra region between 1998 and 2004 (OIE, 2013).

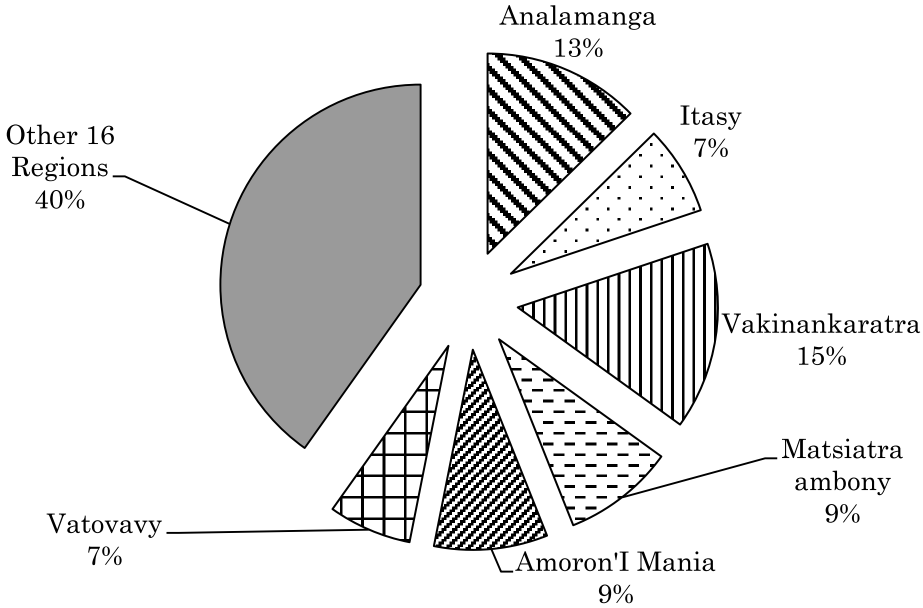

Figure 1.5 Distribution of pig population in Madagascar

Source: MAEP, 2007

Note: percentages are based on the total pig population in the country.

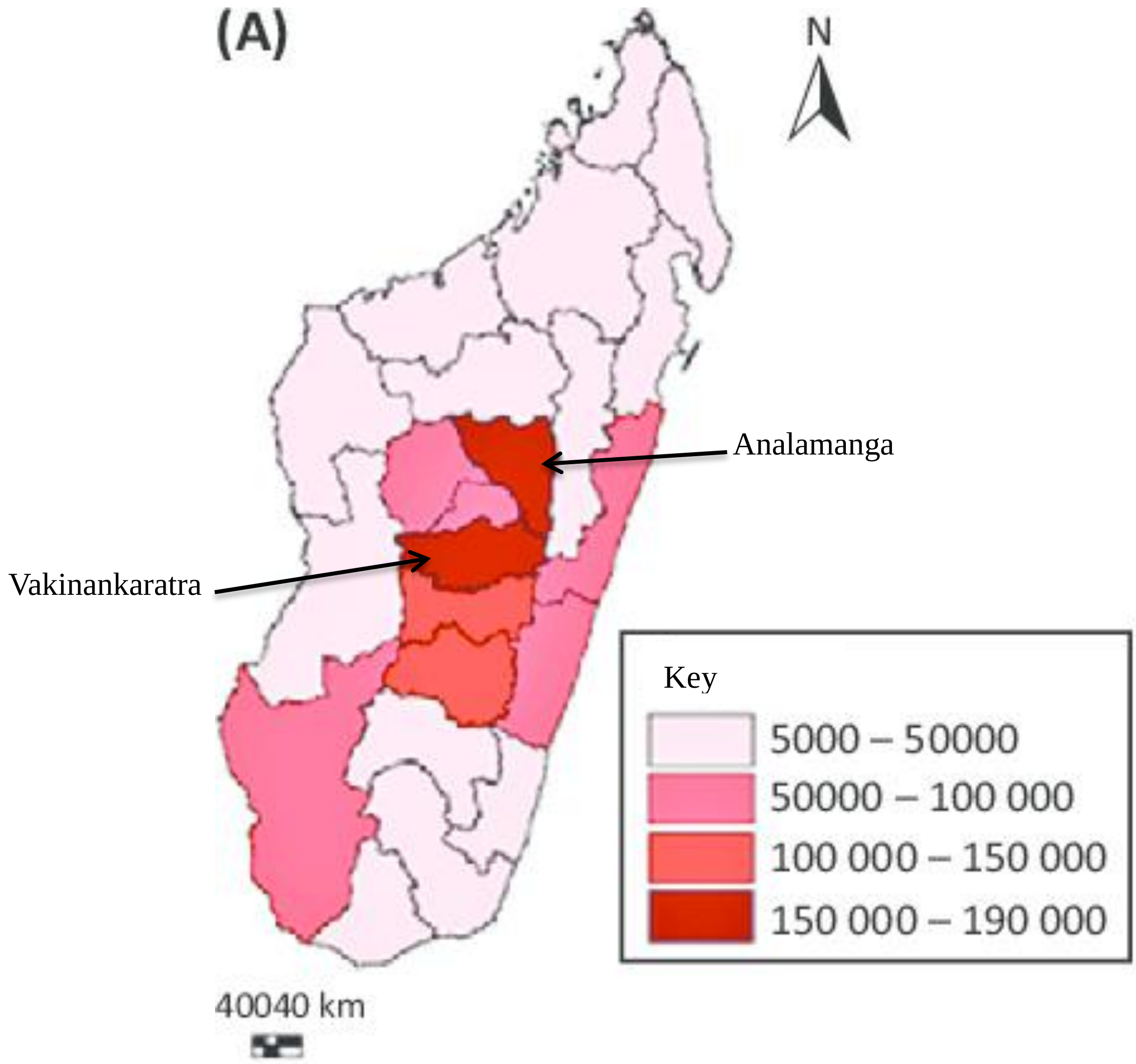

Figure 1.6 Distribution map of pig population by region
Source: Rasamoelina-Andriamanivo et al., 2013

Analamanga region comprises of 8 districts (Figure 1.7). Table 1.1 shows the number of pigs in each district of the Analamanga region. It can be seen that Antananarivo Avaradrano district recorded the highest number of pigs in 2013. There is no data recorded from the district of Antananarivo Renivohitra, which is the capital city of the country.

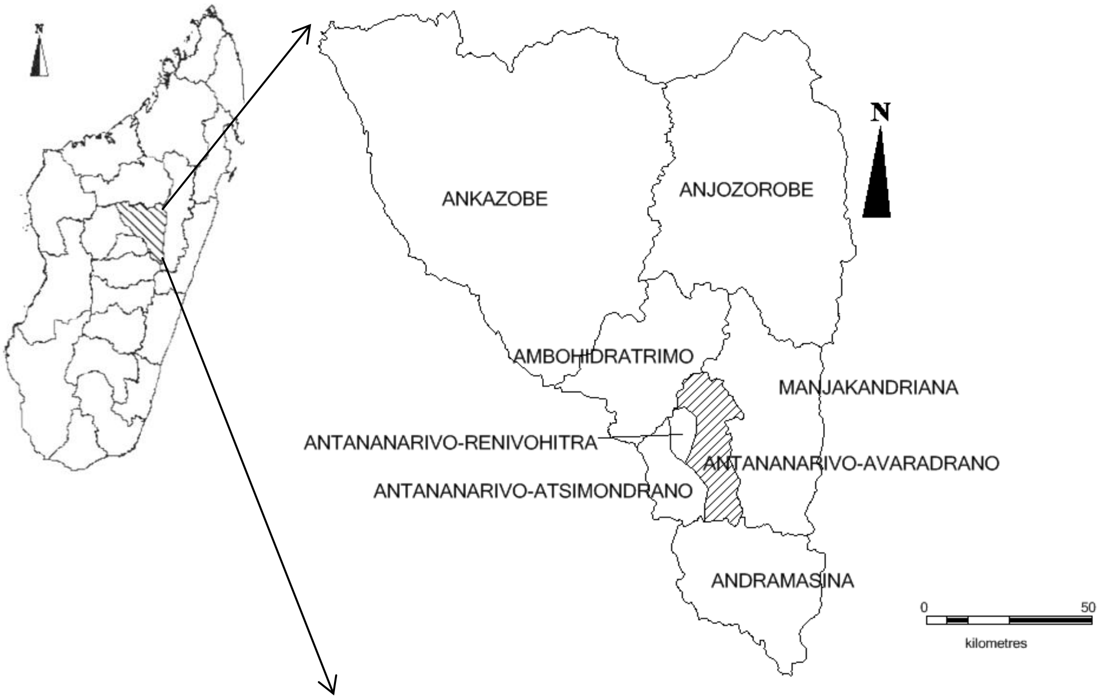

Figure 1.7 Map of the Analamanga region

Source: Author, BD500 database from FTM (Madagascar national institute of geography and hydrography)

Table 1.1 Number of livestock per species per district in the Analamanga region

District	Pig	Cattle	Sheep and Goat
Antananarivo Avaradrano	41,696	34,910	2,259
Antananarivo Atsimondrano	18,129	16,237	4,457
Ambohidratrimo	25,963	51,553	194
Andramasina	9,979	43,840	3,074
Manjakandriana	8,316	41,405	2,306
Anjozorobe	10,212	84,433	2,869
Ankazobe	52,025	133,552	211
Total	166,320	405,930	15,370

Source: Direction interrégional de l'élevage Antananarivo (Antananarivo Inter-regional livestock management), 2011

A total of 34 ASF outbreaks were recorded in Analamanga region. However, only 18 outbreaks occurred in the Vakinankaratra region between 1998 and 2004 (OIE, 2013). The highest numbers of annual outbreaks of ASF (9 outbreaks) were recorded from 1998 to 2004 in the Antananarivo Avaradrano district; compared to other districts within the Analamanga region (Figure 1.8).

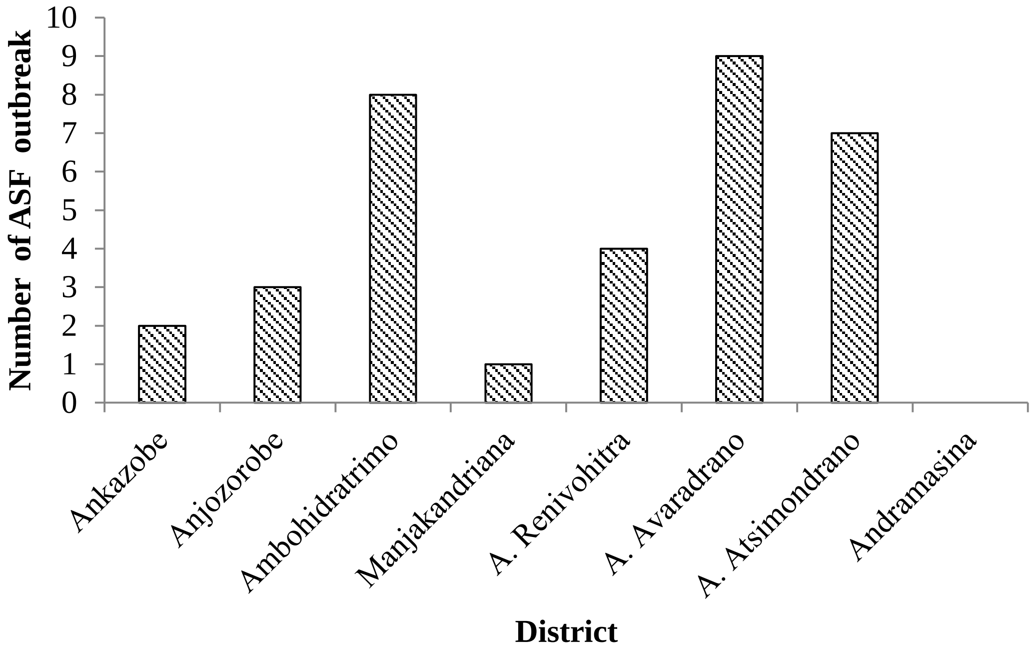

Figure 1.8 ASF outbreak in Analamanga region between 1998 and 2004

Source: OIE data, 2013

2.5.1 Characteristics of the study area

Apart from having the highest number of pig in the region, Antananarivo Avaradrano district is known for potatoes, onion and tomato production. However, rice production is the main farming activity of the majority of the farmers (CREAM, 2013).

The district is fortunate to have a veterinary office available while it is not the case of all districts in Madagascar (Kasprzyk and Ralandison, 2012). There are 34 pig farmers' organization and four slaughterhouses[8]. There is no animal live market in the study area (CREAM, 2013).

2.5.2 Pig farm characteristics in the study area

From Table 1.2 we can see that the farms are small scale with an average herd size of 2.16 pigs which is slightly under the national average of 2.8 (INSTAT, 2011). In addition, farmers do not invest much money on feed and their land area is very small. Figure 1.9 shows a typical pig farms in the study area. The pig pen is very basic and it is located in the backyard.

Table 1.2 Herd size, feed cost and land area

Variable	Unit	Mean (±StdD)	Min	Max
Herd size	Head	2.16 (2.12)	1	30
Feed cost	MGA[9]/day	1,226 (1,181)	0	5,100
Land area	Are	11.4 (21.7)	0	160

Source: Field survey, 2013


Figure 1.9 Pig farm in the study area

Source: Author, 2013

[8] A place to slaughter animals, not necessarily equipped.
[9] MGA: Malagasy Ariary

As for the farmers' dependence on pig farming; it can be seen from Figure 1.10 that most of the spouse (mainly wife) have pig farming as the main job, followed by mix farming (crop production and pig farming). Most of the head of the household have non-agricultural jobs.

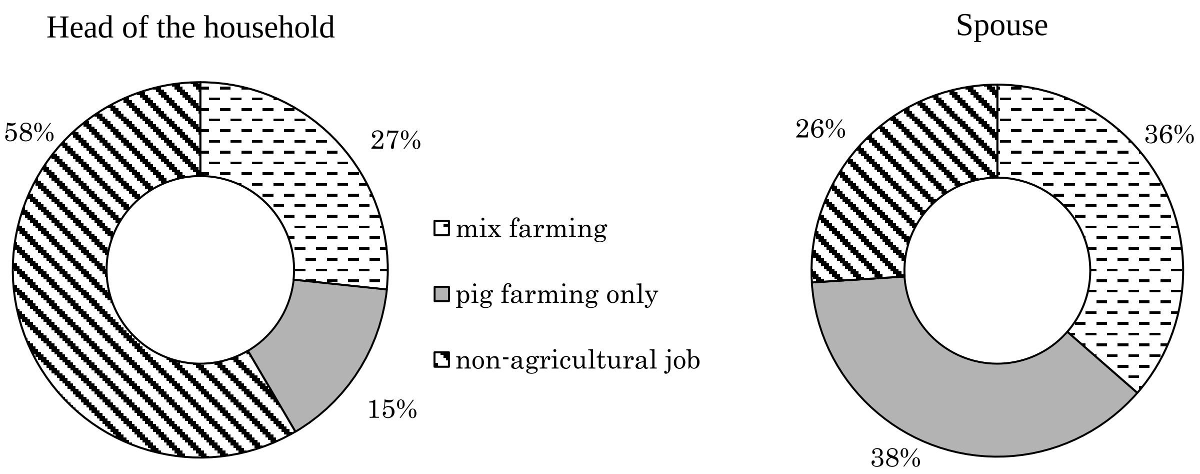

Figure 1.10 Main job in the household

Source: Field survey, 2013

Note: percentages are based on the total sample

Table 1.3 Reasons farmers call veterinarian

Reasons	Number of farmers	Percentage
Vaccination	142	85
Pigs' health	26	16
Anthelminthic administration	114	68
Vitamin and iron administration	96	57

Source: Field survey, 2013

Note: percentages are based on the total sample

Regarding the pig's health, 167 out of 201 farmers have reported to contact veterinarians regularly. It can be seen from Table 1.3 that most of farmers ask veterinarian’s service for pig vaccination such as CSF vaccine. Only 16% of the farmers call veterinarians when their pigs seem to be infected by any kind of disease.

CHAPTER 2

Pig production and infectious diseases in Madagascar

2.1 Background

Madagascar is an African country. Although the origin of Malagasy people is a mix of Indonesia and Africa, Malagasy people shares the culture of cattle pastoralism with Africa (Hurles et al., 2005). Pastoral land in Africa represents about 40% of the total land (African Union, 2010). Cattle in Madagascar are mainly zebu (*Bos indicus*) which is also the predominant cattle in Africa (Hanotte, 2002). In addition, Malagasy pigs has been transported from the mainland of Africa (Blench, 2008). Consequently, even though physically separated from the mainland, the livestock in Madagascar is related to that of Africa.

Livestock production in Africa increases annually. The following Figure 2.1 shows the changes in the number of live animals.

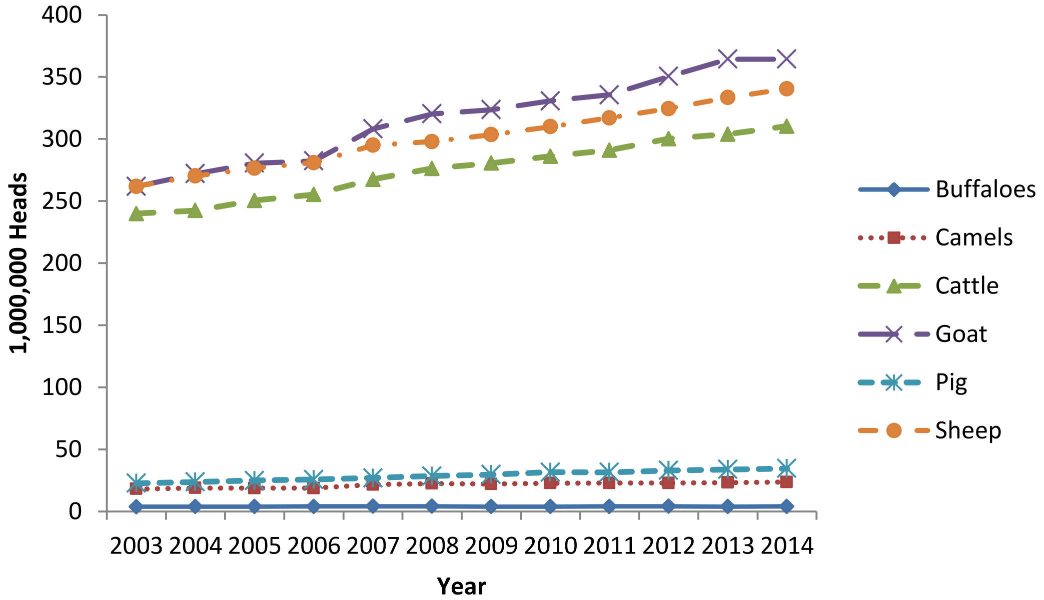

Figure 2.1 Number of livestock in Africa

Source: FAOSTAT, 2016

Compare to the number of goat, sheep, and cattle, pig represents a minority of the livestock. In total there are 35 million pigs in Africa. In 2014, the largest pig population was recorded in Western Africa and Eastern Africa regions which are 14 million and 12 million respectively. The lowest numbers were recorded in Southern (1.8 million) and Northern Africa (29,000) (AU-IBAR, 2014). The following map created by Penrith et al. (2009) based on FAOSTAT data in 2011, shows the pig population per country in Africa. Sudan, Libya, Western Sahara, Mauritania, and Comoros Islands have been reported having no pigs. Those countries have more than 85% of their population as Muslims who do not consume pork or pork products.

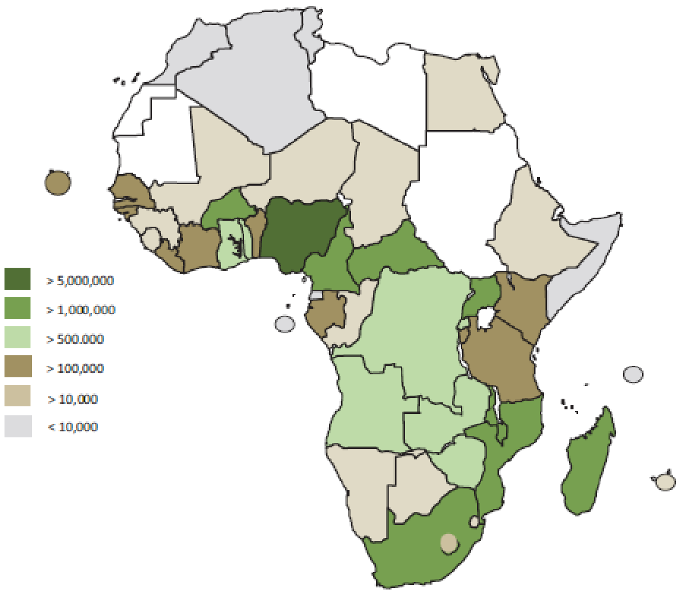

Figure 2.2 Pig population in Africa

Source: Penrith et al., 2013

The annual growth of pig population in Africa is small comparing to that of ruminants, namely goat, sheep, and cattle (Figure 2.1).

The main objective of this chapter is to identify the problems that handicap pig production development in Madagascar. Specific objectives are:

1. To clarify the current situation of the pig production and pig diseases in Madagascar
2. To explain the measures for ASF control in general and in Madagascar

2.2 Poverty and livestock in Madagascar

2.2.1 Poverty in Madagascar

Madagascar is much poorer than any other countries in the sub-Saharan Africa. In fact, if the proportion of poor people that earn less than USD1.9 a day represents about 50% or less of the population in most countries in sub-Saharan Africa; it is almost 80% in Madagascar (Figure 2.3).

Farmers in Madagascar consist of approximately 70% of the population (SSA, 2012). In 2015, agriculture sector accounts for 25.6% of the GDP of the country (World Bank, 2016a). Nearly 70% of the population have raised at least one type of animal. In addition, poor households are characterized by the use of animal as source of income (INSTAT, 2011). Particularly, the smallholder farmers are extremely poor, with an estimated 87.4% of smallholder farmers falling below the national poverty line (INSTAT, 2011).

The most common type of farming is poultry. There is also a significant proportion of households involved in raising zebus (about 30%) and pigs (about 20%).

Figure 2.4 shows the average farm size with regards to the type of animals. Certainly, the size of the livestock is generally small; nevertheless, livestock is an important source of income and a form of saving for households. Indeed, in terms of use, small livestock products are mainly for sales. Self-consumption is usually lower in terms of the number of animals, except for poultry (Table 2.1).

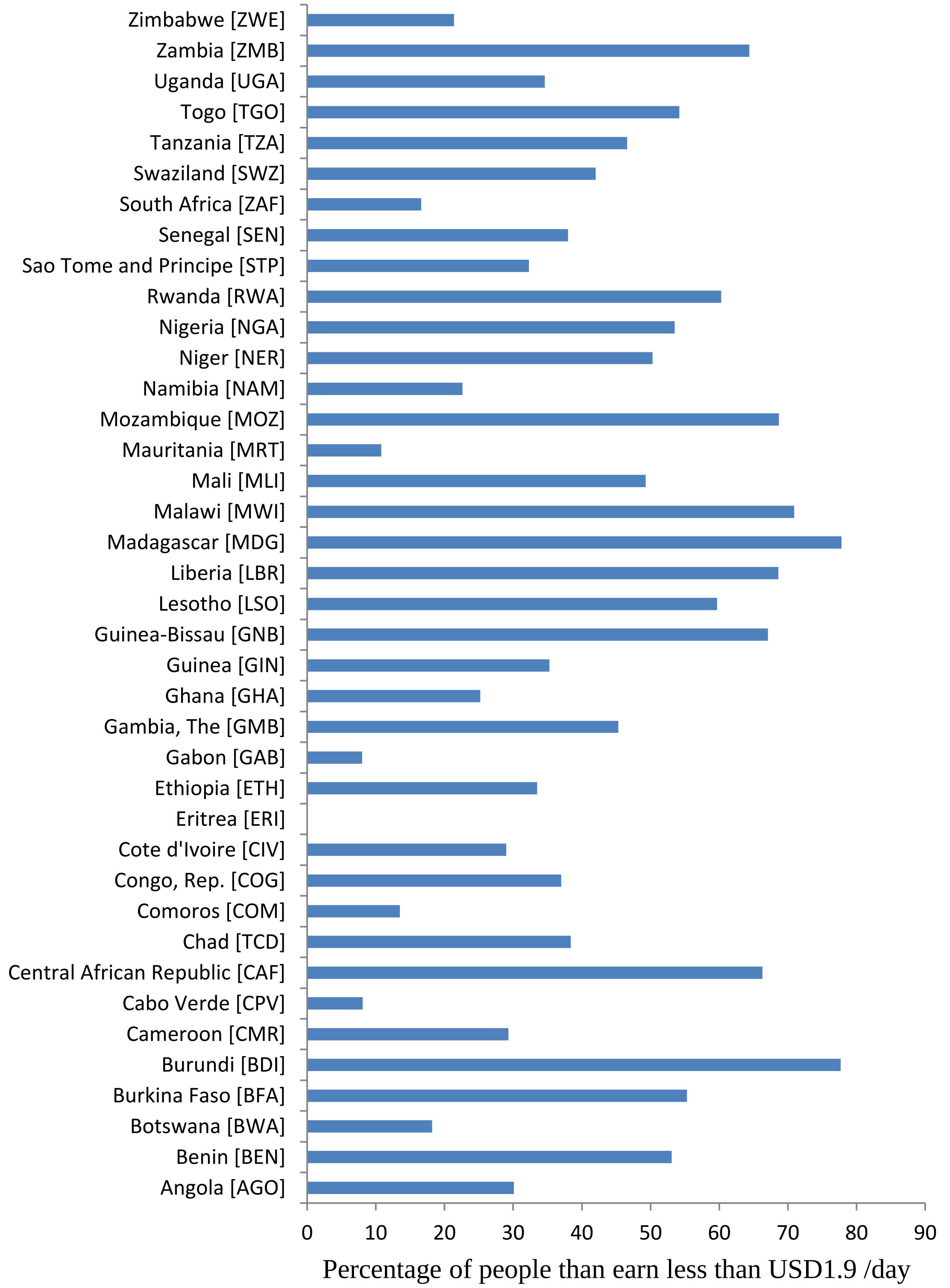

Figure 2. 3 Poverty in sub-Saharan Africa

Source: World Bank , 2016b

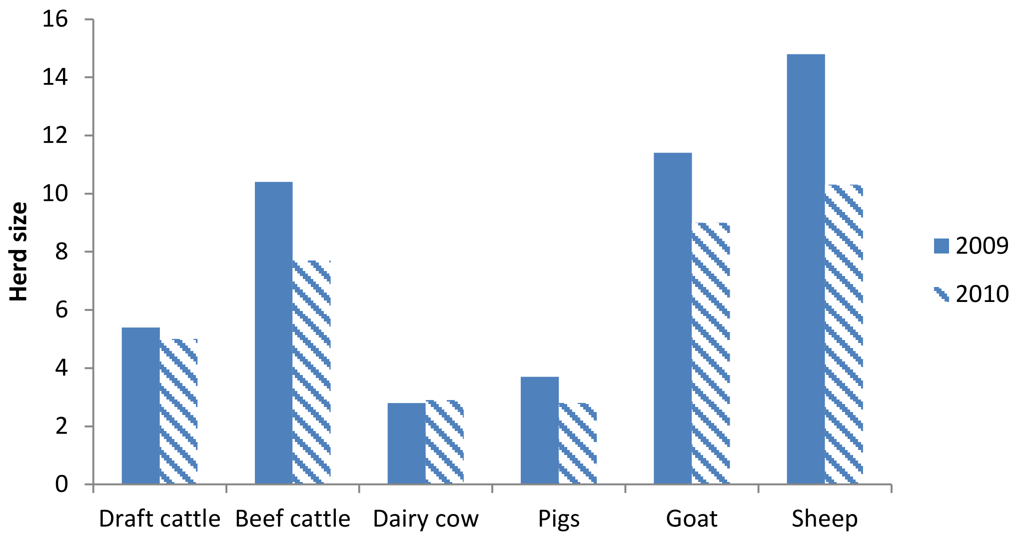

Figure 2.4 Average herd size per farmer household in Madagascar

Source: INSTAT, 2011

Table 2.1 Annual animal utilization in Madagascar

Unit: head/farmer household

Type of animal	Sale	Auto - consumption	Ceremony and others
Pig	1.7	0.1	0.3
Poultry	12.7	6.4	2.7
Goat	3.7	0.3	1.2
Sheep	5.7	0.3	1.9

Source: INSTAT, 2011

2.2.2 Malagasy Government's policy for livestock development

Since the majority of Malagasy household are farmers; the Ministry of agriculture livestock and fisheries (MAEP) considers the development of agriculture as an effective strategy in the fight against poverty and malnutrition. Figure 2.5 shows that budget for livestock development represents only 2% of the MAEP's budget. Despite the fact that large proportion of the population own animals, the budget allocated to the development of livestock production is very tiny. The veterinary service's budget represents 30%

(2,258 billion MGA[10]) of the animal production development budget. This situation indicates that livestock is not really a priority for the government.

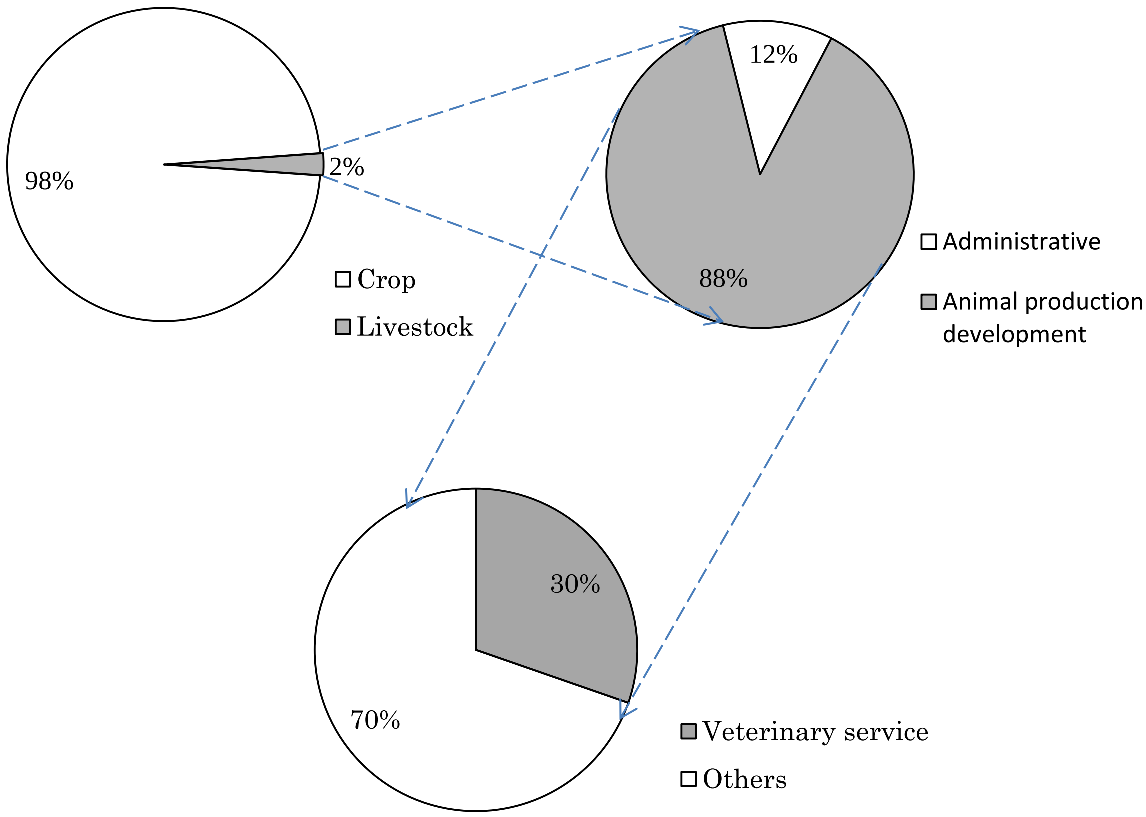

Figure 2.5 Ministry of Agriculture's budget as for 2017

Source: Ministry of finance in Madagascar, 2015

Regarding the government's priorities for the livestock (MAEP, 2016), they are:

- Increase productivity, production animal industry and the marketing of their products;
- Ensure the reopening of export markets for targeted industries and markets;
- Improve governance, services, training and professionalism in the sector.

Animal's health is not regarded as priority despite the numerous endemic animal diseases in the country (Table 2.2).

[10] MGA: Madagascar currency. 1JPY = 30MGA as for April 2017

Table 2.2 OIE listed animal diseases present in Madagascar in 2016

Species	Disease	Zoonosis
Amphibians	Infection with Batrachochytrium dendrobatidis	No
Cattle	Bovine anaplasmosis	No
	Bovine babesiosis	No
	Bovine tuberculosis	Yes
	Lumpy skin disease	No
Cattle, goat and sheep	Heartwater	No
Dog	Rabies	Yes
Honey bees	Varroosis of honey bees	No
Pig	African swine fever	No
	Classical swine fever	No
	Porcine cysticercosis	Yes
Poultry	Infectious bursal disease (Gumboro)	No
	Newcastle disease	Yes (minor)

Source: OIE, 2017

2.2.3 Pig production in Madagascar

Generally, in rural area, pig production contributes to increase farmers' income and saving by using the by-products of their crop. In suburban area, employees and artisans practice pig farming to get additional income (MAEP, 2007a).

In Madagascar, pigs are the second most important livestock after cattle in terms of animal number and farm number. Figure 2.6 and Figure 2.7 show the distribution of livestock and farms per species respectively.

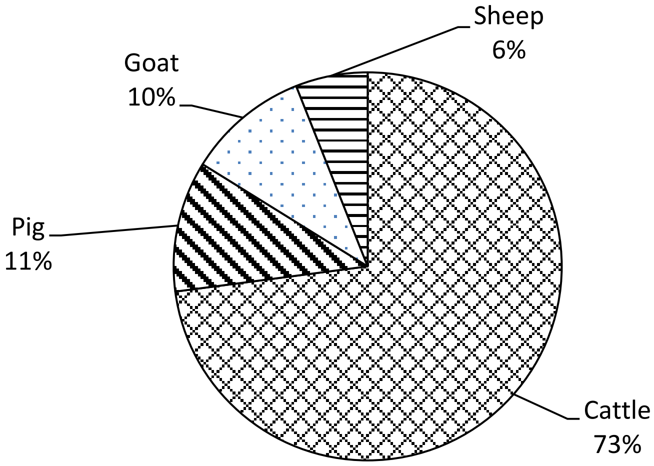

Figure 2.6 Distribution of livestock per species in Madagascar

Source: MAEP, 2007b

Note: percentages are calculated based on the total population per species

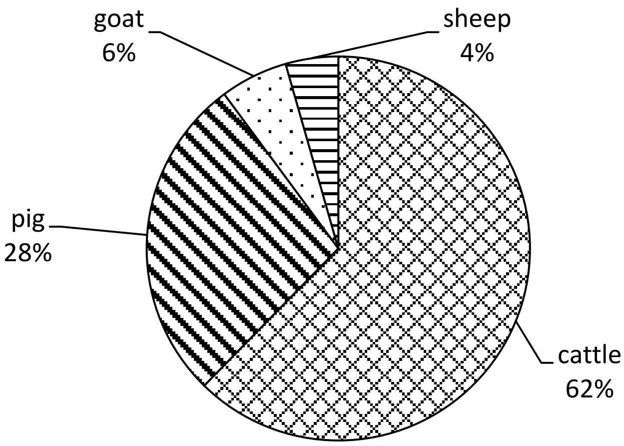

Figure 2.7 Distribution of farms per species in Madagascar

Source: MAEP, 2007b

Note: percentages are calculated based on the total number of farm per species

According to the MAEP (2007b), pigs represent 11% of total livestock and 28% of livestock farmers in 2007. However, Madagascar imports pig meat (Figure 2.8), which implies that domestic production does not meet the demand.

Small-scale farms with 1-10 pigs represent 70% of all pig farms in Madagascar. On the other hand, farms with more than 100 pigs accounted for less than 1% of Malagasy pig farms before the first ASF outbreak in 1998, and have decreased since then (MAEP, 2007a).

Between 1998 and 2000 where ASF outbreak happened for the first time in Madagascar, the import quantity was increasing while the number of pigs was decreasing (Figure 2.8). From 2002, the pig production started to recover but still importation continues. As economic impact of the 2009 political crisis, the GDP of Madagascar decreases from 7% in 2008 to -3.7% in 2009 (Ploch and Cook, 2012). This situation can partly explain the sharp drop of importation of pork in 2009 since Malagasy people normally eat more beef than pork regardless of the income level. As shown in Figure 2.9, individual belonging to the upper class do not eat more pork than in the middle class. The reason probably might be the price difference. Beef has been always cheaper than pork in Madagascar as shown in Figure 2.10.

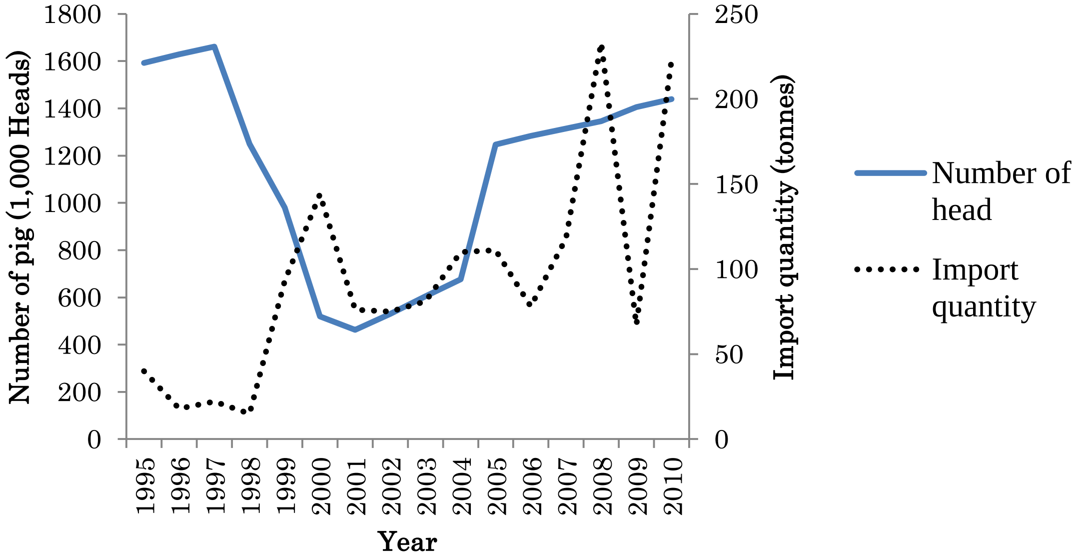

Figure 2.8 Trend of number of domestic pig and import quantity of pork in Madagascar

Source: FAOSTAT, 2016

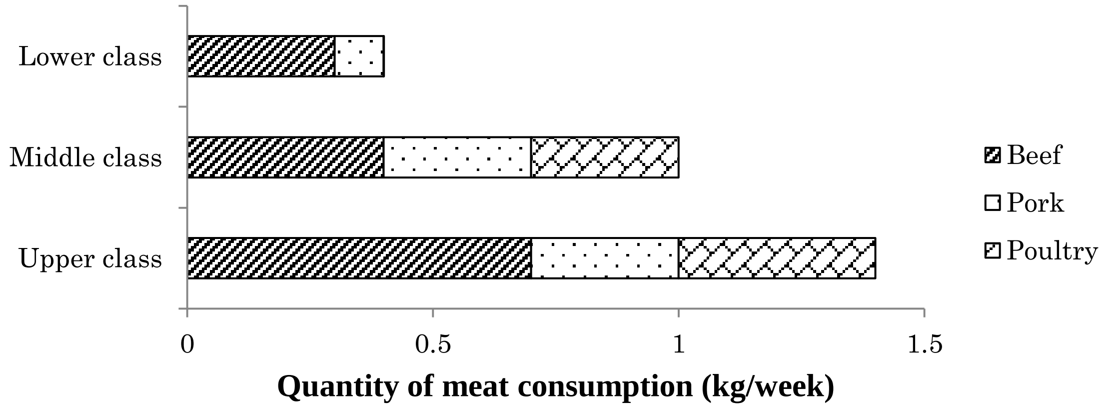

Figure 2.9 Weekly meat consumption per person

Source: Andriamangahasina, 2008

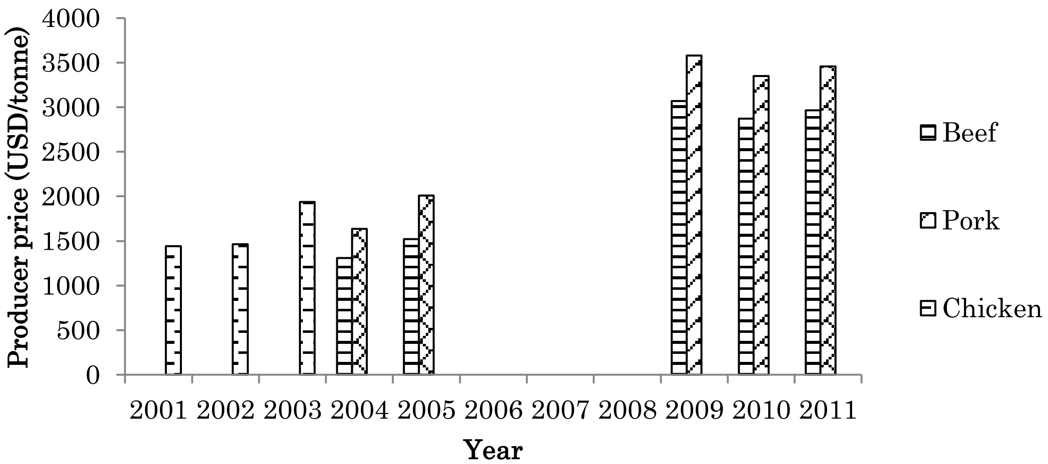

Figure 2.10 Meat producer price in Madagascar

Source: FAOSTAT, 2017

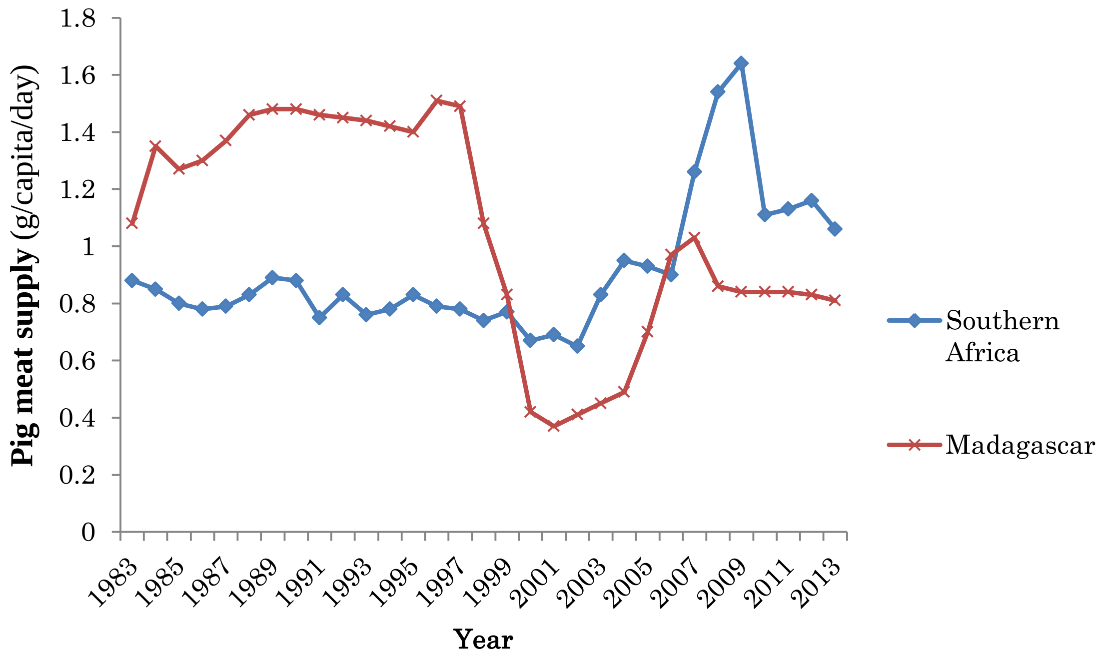

Figure 2.11 Change in pig meat supply in Southern Africa and Madagascar

Source: FAOSTAT, 2017

From Figure 2.11, it can be seen that before the outbreak in 1998, the per capita pig meat supply in Madagascar was almost double of the average in the Southern Africa region. However, after the outbreak, the supply has dropped, and despite the increase of pig number, the per capita supply of pig meat has not been recovered to the situation prior to outbreak.

2.3 Pig diseases in Madagascar

TADs are defined by FAO (n.d.-b) as those epidemic diseases which are highly contagious or transmissible and have the potential for very rapid spread, irrespective of national borders, causing serious socio-economic and possibly public health consequences. Highly pathogenic avian influenza (HPAI) is an example of TADs that has public health issue (zoonosis). Examples of TADs that has serious socio-economic impact are FMD, RVF, CSF and ASF.

CSF, porcine cysticercosis, and ASF are pig diseases listed by the OIE. These three diseases also pose threats to pig production in Madagascar. Figure 2.12 indicates the number of outbreaks of each disease.

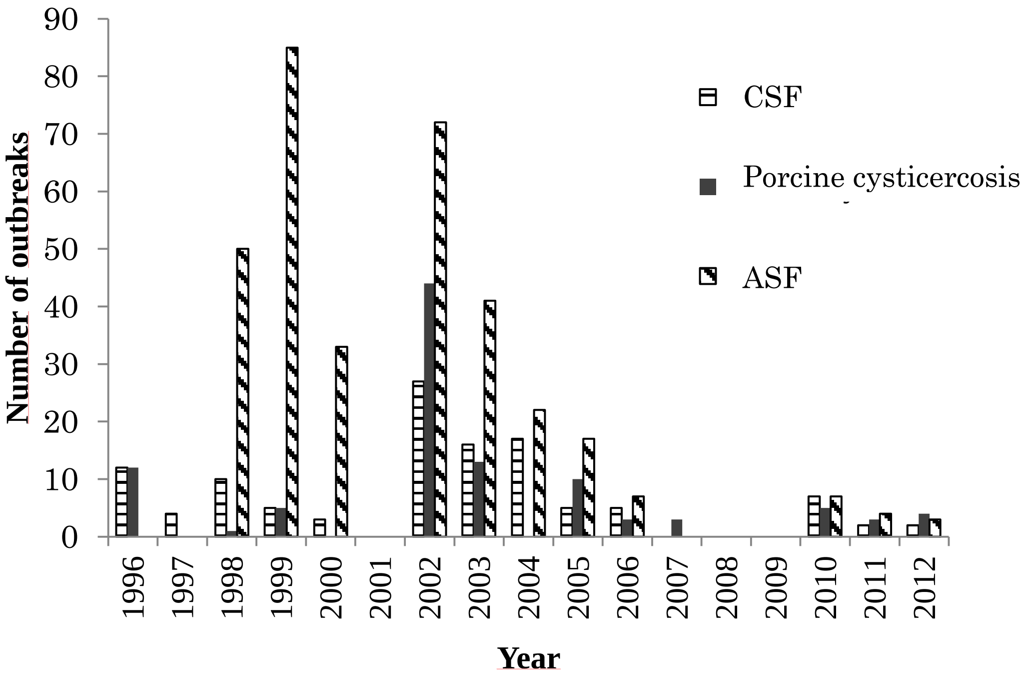

Figure 2.12 OIE-listed pig diseases notifiable in Madagascar

Source: OIE data, 2013

Additionally, pig diseases that are present in the country but not OIE listed diseases are Teschovirus encephalomyelitis, and Atrophic rhinitis (See Appendix 2.1). Farmers are recommended to administer vaccine against those last two diseases in addition to the vaccine against CSF.

2.3.1 CSF

CSF is also known as hog cholera. It is a viral pig disease. The mortality rate can reach 100% in young pigs. In the acute form, CSF symptoms include among others fever, reddening of the skin, anorexia, occasional vomiting and conjunctivitis (OIE, 2009). Mortality in piglets can reach 100%. Under chronic form, CSF causes diarrhea and growth retardation (OIE, 2009).

CSF is present around the world. Most developed countries are ASF free country. Brazil is a CSF free zone.

Madagascar became affected with CSF by the introduction of infected pigs from Europe in 1965 (Roger et al., 2000) and the disease has been endemic ever since (Penrith et al., 2011). In the endemic situation, vaccination with modified live virus strains is effective in preventing losses in countries but it cannot eliminate infection entirely (OIE, 2009). Madagascar produces vaccine against CSF, called "*Ramjivax*" that should be administered once a year (Ministry of Livestock, 2005).

2.3.2 Porcine cysticercosis

It is a zoonotic disease that affects human and pig.

It is highly prevalent in most countries in Africa, Asia, India, and Central and South America (Michelet et al., 2010). The prevalence of cysticercosis in Madagascar ranged from 0.5% to 1% in pork carcasses during the 2008 to 2012 period (DSV, 2012). In human, the prevalence ranges from 7% to 20% (Andriantsimahavandy et al., 2003) with the highest levels in the central highlands and less than 10% in coastal area.

2.3.3 ASF

ASF is a viral disease caused by African swine fever virus (ASFV). Symptoms of ASF are similar to that of CSF such as fever, anorexia, reddening of the skin, and diarrhea. As mentioned previously, there is no vaccine available for ASF.

ASF was selected as the focus of this study, because it is the most important pig disease in terms of the number of outbreaks, as shown in Figure 2.12 (the details of outbreaks are shown in Table 2.3). Moreover, unlike CSF, which can be prevented through vaccination (OIE, 2009), and porcine cysticercosis, which can be treated effectively with oxfendazole (Gonzalez et al., 1995), there is no vaccine or treatment available for ASF (OIE, 2013). Therefore, ASF control needs the intervention of the government more important than the other two diseases.

Table 2.3 Number of annual ASF outbreak from 1998-2012

Year	Number of		
	Outbreaks	Cases	Deaths
1998	50	153,229	107,260
1999	85	12,088	6,156
2000	33	600	577
2001	Disease present but no quantitative data		
2002	72	3,109	2,772
2003	41	1,680	1,576
2004	22	911	746
2005	17	382	337
2006	7	276	211
2007	Unknown	880	874
2008	Disease present but no quantitative data		
2009	Disease present but no quantitative data		
2010	7	144	144
2011	4	156	156
2012	3	36	36

Source: OIE data, 2013

Note: [a)] OIE defines outbreak as an occurrence of the disease in question in an agricultural establishment, breeding establishment or premises where animals are present. In the case of certain parts of Africa, an outbreak means the occurrence of the disease within a sixteenth square degree.

[b)] Case means animals that are infected.

[c)] Death means animals that died from the disease.

Figure 2.13 shows the frequency of ASF outbreak throughout the year. The data was collected between 2001 and 2014. It can be seen that there is no particular month for the outbreak to occur. Additionally, even there is significant increase in the abundance of bushpigs (*Potamochoerus larvatus*)[11] outside forests during the fruiting period (May to August) of *Strychnos spinosa* (Rouillé et al., 2014); the frequency of the outbreak during the same period is not significantly higher. It indicates that bushpigs do not contact domestic pigs or as bushpigs are not carriers of *ASFV* in Madagascar (Ravaomanana et al., 2011).

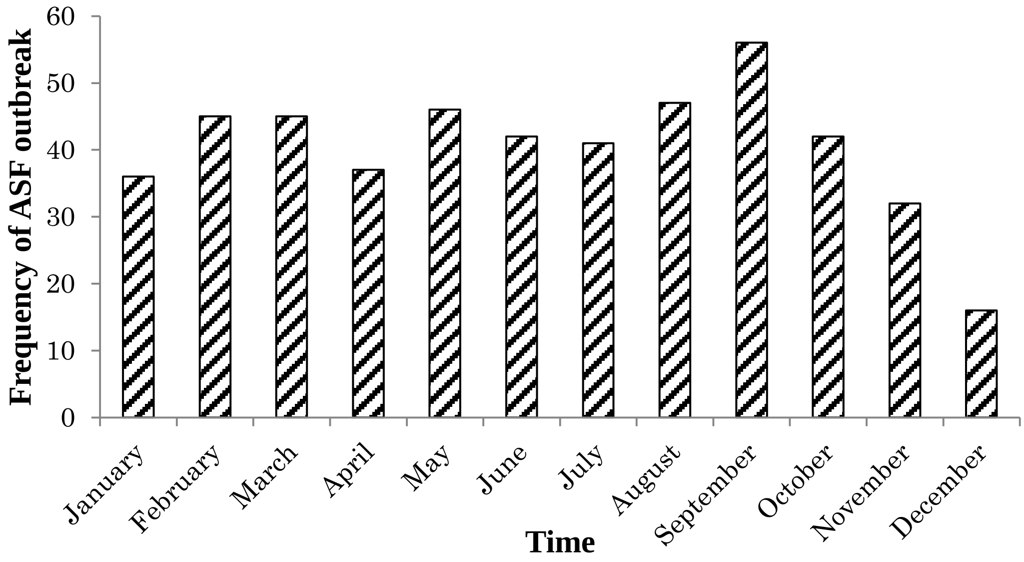

Figure 2.13 Monthly ASF outbreak from 2001 to 2014

Source: MAEP, 2014

[11] The only species of wild pigs that are found in Madagascar

2.4 ASF control

ASF is an infectious viral pig disease with a mortality rate nearly 100% in the case of acute form. A subacute form of ASF causes a lower mortality rate which is between 30 to 70%.

2.4.1 OIE recommendation

To control ASF during an outbreak, the OIE (2013) recommends the following points:

- Stamping out, meaning slaughter of all sick and contaminated animals, destruction of their carcasses, and cleansing and disinfection of premises or modified stamping out (for example, slaughter of sick animals only).
- Zoning, which means designation of infected zone in order to control pig movements.
- Detailed epidemiological investigation, with tracing of possible sources and possible spread of infection.
- Surveillance of infected zone, and surrounding area.
- Avoid contact between pigs and soft tick vectors or their habitats (especially in Africa) – i.e. prevent pigs from wandering.

2.4.2 ASF control in Madagascar

As for Madagascar, ideally, Figure 2.14 shows how pig farmers can report suspected cases of ASF in order to control the spread of ASF. Pig farmers should inform either the local authority or a veterinarian, about any suspicion in his farm. Then, the information will go to the regional department of animal health. Once this information reaches the Animal health and phytosanitary directorate (AHPD), the veterinarian is ordered to take a blood sample and send it to the national laboratory in Analamanga region, which is the only location that tests such cases. While waiting for official confirmation of the presence of ASF, the government may slaughter all pigs within a 1,000-meter radius around the farm suspected of housing the infected animal, to prevent the spread of the disease. If the presence of ASF is confirmed, Article 3 of Ministerial Decree No. 396/99, which stipulates that infected pigs must be slaughtered, is enforced

(MAEP, 2009). Farmers will be informed about the presence of ASF by veterinarian and through media (newspaper, national radio and so on).

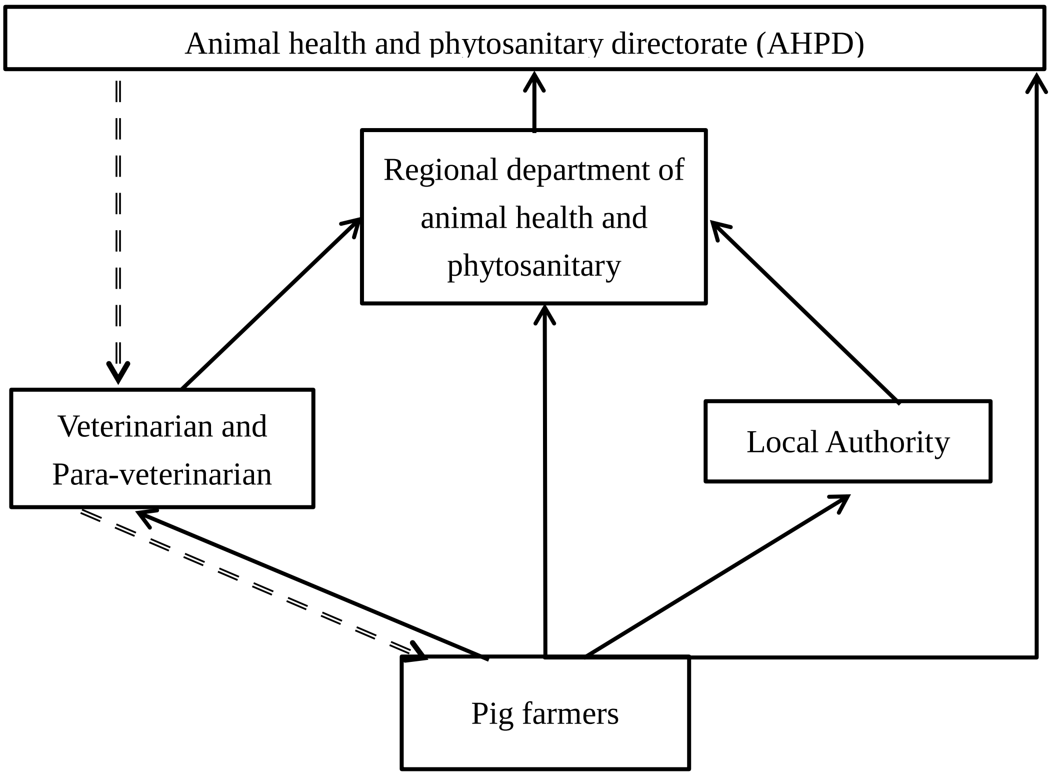

Figure 2.14 Framework for ASF control in Madagascar

Source: modified from MAEP, 2007b

⟶ Information from farmer (report)

═ ═ > Action from government (order to veterinarian and then he will kill and dispose infected pig)

When farmers do not call veterinarians, by visiting pig farms, they can find suspicion of ASF by asking farmers about the current and past disease that affect their pigs if farmers do not call them (MAEP, 2007b). However, the numbers of veterinarians and para-veterinarians (veterinary technicians, veterinary nurses, community-based animal health workers, etc…) in Madagascar which are presented in Table 2.4 are very few compare to other countries. Madagascar is ranked 155th among all the countries in the entire world in terms of number of public veterinarian per livestock standard unit (LSU) (OIE, 2013). Number of veterinarians per LSU is an indicator that allows comparison between countries but it does have little impact on the situation in developing countries (FAO, 1995).

Table 2.4 Veterinarians in Madagascar

	Number of personnel	Number per square kilometer	Number per 10,000 LSU*
Public veterinarian	53	0.0001	0.0175
Private veterinarian	137	0.0002	0.0452
Para-veterinarian	351	0.0006	0.1157

Source: OIE, 2013

Note: *LSU is 250kg livestock standard unit, calculated on the basis of average weights of different species.

Practically, slaughter of pig (susceptible or infected) is not done because of compensation unavailability. When the presence of ASF is confirmed, farmers are encouraged to stop animal movement and isolate infected pigs.

2.5 Conclusion

Madagascar is far poorer than other sub-Saharan African countries and significant proportion of the population depends on pig production. Problems that prevent the development of pig production in Madagascar include the low government's budget allocated to livestock. Moreover, animal diseases such as ASF are present and constitute a threat for the farmers' livelihood. However, animal health is not regarded as a priority of the government. In addition, there are few veterinarians which mean that it is difficult to control the spread of animal diseases, especially ASF. Therefore, it can be recommended that the government should include animal disease control in his priorities for animal production development.

Appendix 2.1 Non-listed OIE pig diseases in Madagascar

Teschovirus encephalomyelitis

Teschovirus encephalomyelitis is caused by *porcine teschovirus serotype 1*. It affects only pigs. The disease's symptoms include high fever, lethargy, anorexia and locomotor disturbances. The disease is highly fatal. The pig may die of suffocation.

The disease was first diagnosed in Czech Republic in 1929. Presently, Teschovirus encephalomyelitis is considered rare. However, some countries have reported cases to the OIE in the last 20 years such as Belarus, Uganda, Romania, Japan and Madagascar (OIE, 2008).

Although the last official report of the disease by Madagascar was in 2005, the disease is still present in the country. Farmers are recommended to vaccinate their pigs against the disease every 8 months (Ministry of Livestock, 2005). The brand name of the vaccine used in Madagascar is "*Sovax Teschen*" which is produced locally.

Atrophic rhinitis of swine

Atrophic rhinitis is a bacterial pig disease, caused by *Pasteurella multocida*. The disease' symptoms are sneezing, snuffling and eye discharge. The disease is rarely fatal but it causes productivity reduction (OIE, 2012).

In Madagascar, vaccine known as "*Pneumoporc*" is produced locally. Pigs are required to be vaccinated every 3 months (Ministry of Livestock, 2005).

CHAPTER 3

Farmers' knowledge and sensitive behavior towards African swine fever

3.1 Background

As shown in the previous chapter, pigs are the second most important livestock in Madagascar in terms of animal number and farm number. Pigs represent 11% of total livestock and 28% of livestock farms are pig farms (MAEP, 2007b). However, the 19 tons and 100 tons of pig meat imported in 2007 and 2010 (FAOSTAT, 2012), respectively, implying that domestic production does not meet demand. Small-scale farms with 1–10 pigs represent 70% of all pig farms in Madagascar. On the other hand, farms with more than 100 pigs accounted for less than 1% of Malagasy pig farms before the first ASF outbreak in 1998, and have decreased since then (MAEP, 2007a).

ASF disease is highly contagious (morbidity rate up to 100%) and highly fatal (mortality rate up to 100%). To the best of our knowledge, the latest vaccine developed for ASF cannot fully protect pigs against ASF (Arguilaguet et al., 2012). Moreover, there is currently no fully effective treatment or vaccine available for ASF (OIE, 2013).

The first case of ASF was detected in Madagascar in 1998, and 60% of total swine had died by 2001 due to outbreaks (Rousset et al., 2001). Following the recommendations of the World Organization for Animal Health (OIE) for the successful eradication of ASF, the Malagasy government controlled the spread of the disease by controlling the movement of pigs inside the country, banning pig reproduction, and slaughtering and disposing all pigs on infected premises. Article 4 of Ministerial Decree No. 396/99 stipulates that selling ASF-infected pigs is prohibited. Unfortunately, ASF remains an endemic disease (Roger et al., 2001) even if the ASFV seems to be present only in domestic pigs (Ravaomanana et al., 2012); meanwhile, wild pigs are also reservoirs of the virus in some African countries (Penrith et al., 2012). Hence, ASF is a constant threat for farmers. To develop pig production in Madagascar, it is important to eradicate ASF.

Although selling of ASF-infected pig is banned by the government, we assume farmers still do it because of the following four reasons:

1) Farmers cannot do something to treat the infected pigs which have high probability to die from ASF, thus they may lose totally their income.
2) The pig value chain in Madagascar.
3) The appearance of the pig meat.
4) Farmers' knowledge about ASF

Figure 3.1 represents the pig value chain in Madagascar. It is generally informal meaning farmers do not pay any tax. There are only four main slaughterhouses in the capital city in Antananarivo. Those four slaughterhouses process 5,600 to 8,500 tons of meat annually. The slaughterhouses are underequipped and of poor hygiene. Most of farmers prefer to slaughter their pig in the village or backyard to avoid local taxes and meat quality inspection in slaughterhouse. Meats sold in supermarket are from slaughterhouses and chilled while meat sold in the wet market are not (Figure 3.2).

The clinical signs of ASF mainly affect the pig's organs (fluids in the chest and abdominal cavities, enlarged spleen, congestion of the intestines, etc…) (Figure 3.3) and the skin (widespread haemorrhages) (Figure 3.4). Although there are red dots in the skin, the pig is burned before removing the internal organ. As a result, the dots on the skin will become less visible for the consumers. In addition, the carcass may appear in good condition (FAO, 2000). It means that farmers do not have many troubles in convincing consumers to buy the ASF contaminated meat. Even though the infected pigs are slaughtered at slaughterhouses, the meat inspection by veterinarian is only visual; therefore, there is a high chance that the contaminated meat goes to the market.

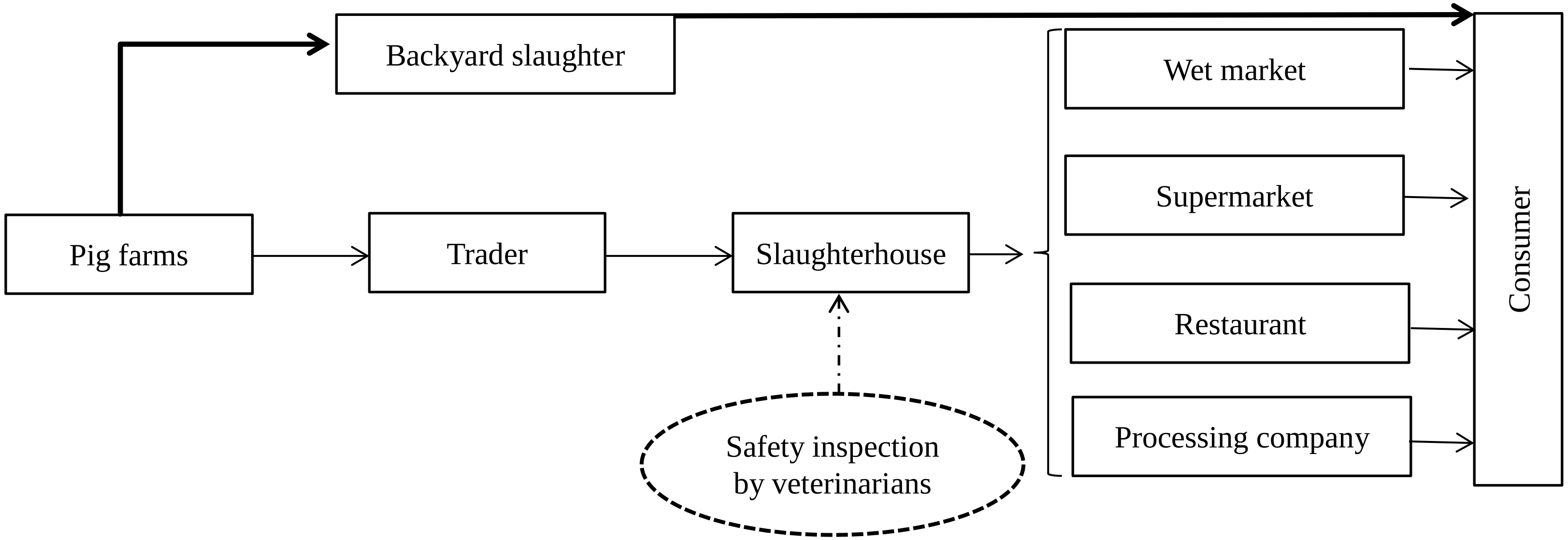

Figure 3.1 Pig value chain in Madagascar
Source: modified from Rasamoelina-Andriamanivo et al., 2013

Figure 3.2 Meat market in Madagascar
Source: Shampion de Nosy Be, 2014

Source :Madascope, 2013

Figure 3.3 Enlarged spleen

Source: FAO, 2000

Figure 3.4 Hemorrhage in the pig's skin

Source: FAO, 2000

Farmers' knowledge about animal disease might affect their behavior. Holt et al. (2011) showed that despite the fact that majority of farmers know that abortion is a symptom of brucellosis; most of the farmers believe that there are some farmers who will sell animal that have aborted to the market. In contrary, lack of knowledge about the transmission of brucellosis through direct contact with infected animal resulted in high-risk practices by farmers (Musallam et al., 2015).

According to Penrith et al. (2012), in ASF endemic areas, farmers are less likely to report ASF, and this situation is an important challenge in the control of the disease. In the present study, we examined whether Malagasy pig farmers sell ASF-infected pigs instead of reporting suspected cases of ASF to the veterinary office or local authority. We hypothesis that selling ASF-infected pigs is a sensitive behavior for farmers since it is prohibited by law.

The general objective of this chapter is to suggest policy measures to limit farmers' sensitive behavior that spread ASF. Specific objectives are:

1. To evaluate farmers' knowledge about ASF.
2. To clarify the factors of ASF spread from farmers' knowledge and sensitive behavior.

The background of this chapter is summarized in Figure 3.5.

The ICT, also known as unmatched count technique or list experiment, is considered as an appropriate method to address the problem of sensitive behavior.

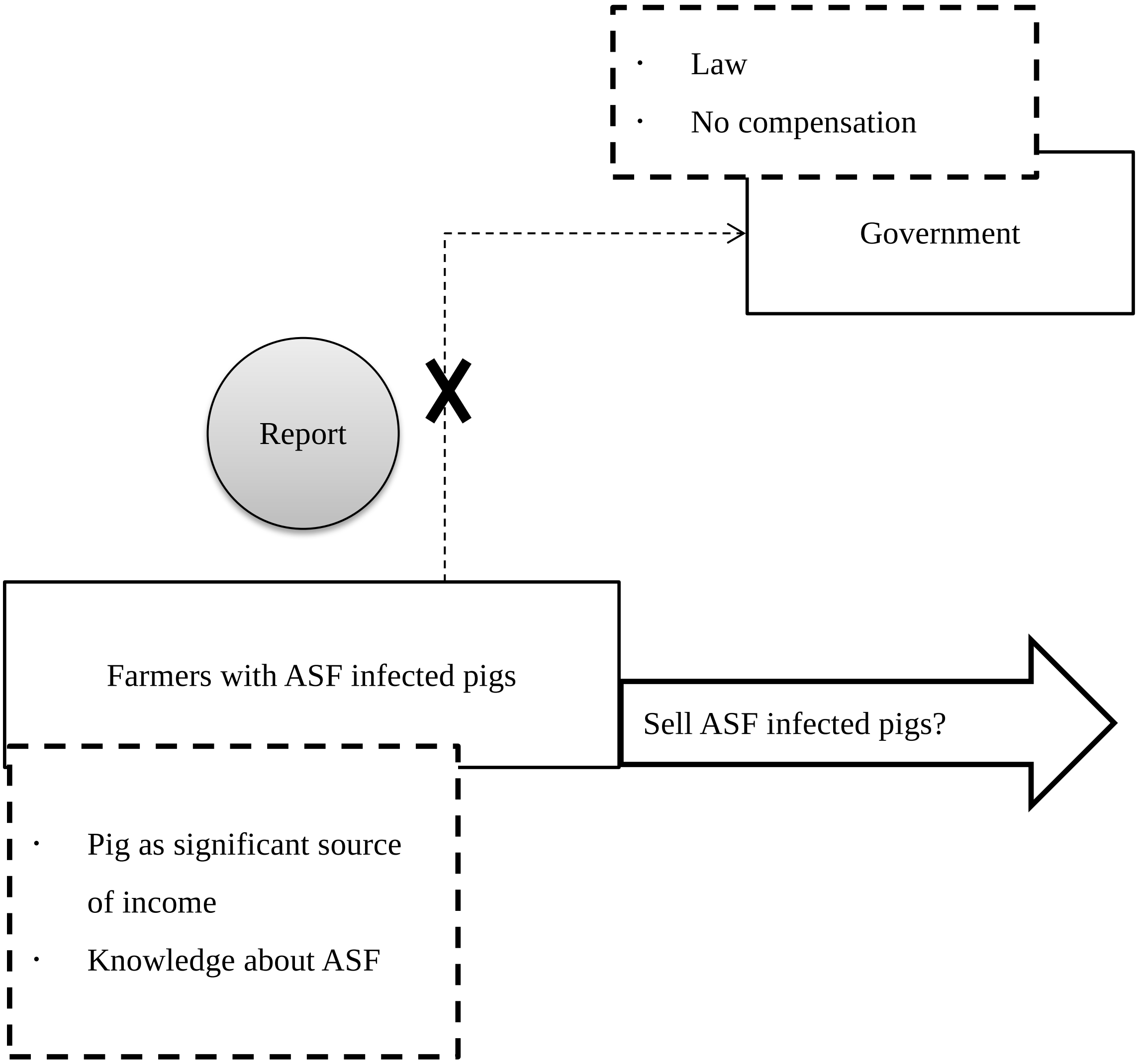

Figure 3.5 Summary of the background of Chapter 3

3.2 Farmers' income from pig farming, resources, and cost of production

3.2.1 Farmers' income from pig farming

During a pre-survey (details will be given in a later part of the text), farmers were reticent to voice even an approximation of the amount of their income. Thus, in the survey, in addition to the question about their yearly amount of income received from pig; they were asked to choose the most accurate definition of their income from pig farming among those three options:

1- income from pig farming is for emergency fund

2- income from pig farming is an additional income

3- income from pig farming is our main income

All of the respondents did not answer to the question "how much do you earn from pig farming?" As for the farmers' definition of their income from pig, the result is shown in Figure 3.6. Most (47%) of the farmers cited income from pig is an additional income. Only 10% of farmers have pig as their main source of income. Nonetheless, it shows that income from pig is significant for the majority of farmers.

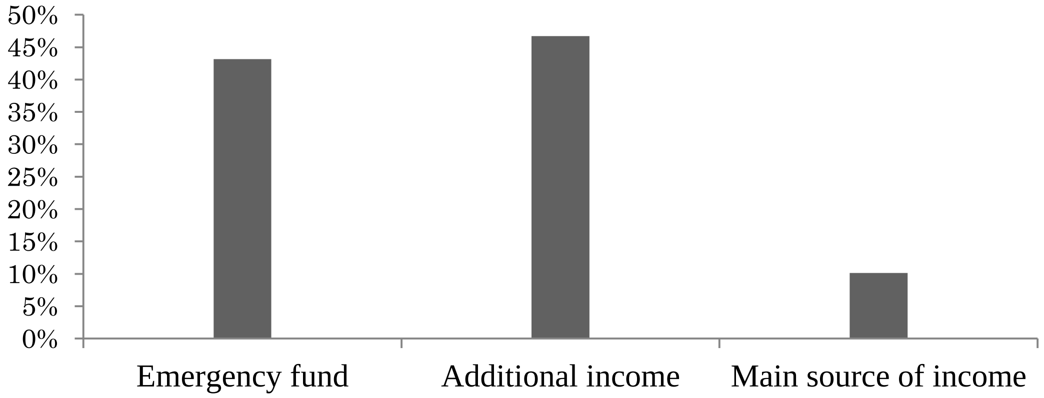

Figure 3.6 Definition of the income from pig

Source: Field survey, 2013

As shown in Chapter 2 (Figure 2.20), the majority of farmers' main source of income is pig farming only or mixed crop and pig production, especially for the women.

3.2.2 Farmers' resources and cost of production

a- Land area

The following Figure 3.7 shows farmers land possession. Forty six percent of farmers are landless, meaning they heavily depend on pig or other activities. The average land area (paddy land and highland) is only 11.37 a (±1.53)[12]. The maximum land area is 60 a. Majority of farmers owns a land of less than 20 a. This situation is similar to the condition of other African countries where farmers own less than 2 ha. It indicates that farmers have small resource for agriculture.

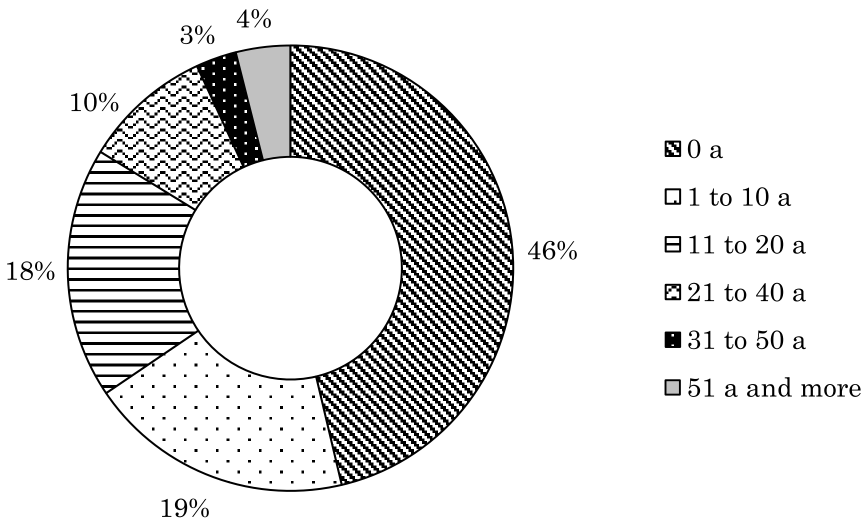

Figure 3.7 Farmers' land area

Source: Field survey, 2013

[12] 1 a = 0.025 acre

b- Pig herd size and type of production

As for other characteristics of the farmers, Table 3.1 shows the pig herd size and the type of production.

Table 3.1 Herd size and type of pig production

Characteristics of the farm		**Total (%)** (n= 201)
Herd size	Less than 4	89
	4 and more	11
Type of production	Breeding and farrow to finish	25
	Farrow to finish only	49
	Breeding only	25
	Boar farm only	1

Note: n= sample size

Source: Field survey, 2013

Eighty nine percent of the farmers own less than 4 pigs, meaning the sample reflects the situation in the country where the average herd size is 2.8 as for 2010 (INSTAT, 2011). Because of the smallness of the herd size, the farmers' income is low.

Most of the farms are farrow to finish only (49%). About 74% of the farms are breeding to finish or farrow to finish. It indicates that majority of the farmers know the meat marketing channel. Therefore, it is relatively easy for them to find meat buyer in case of ASF infection. The proportion of farm which produces fatten pigs is almost the same as the average proportion of farmers selling ASF infected meat.

c- Cost of production and pigs' breed

As a small scale backyard farm, none of the farmers have cited to hire labor. Hence, we assume that the cost of production of the farm is mainly the feed cost.

Figure 3.8 shows the distribution of feed cost per pig per day. It can be seen that the majority of farmers (28%) do no spend money on feed. Their pigs are fed with cut grass, swill from the farmer's kitchen, and by products (mainly rice bran) of their crop production especially rice bran. Again, this situation shows farmers' lack of resources.

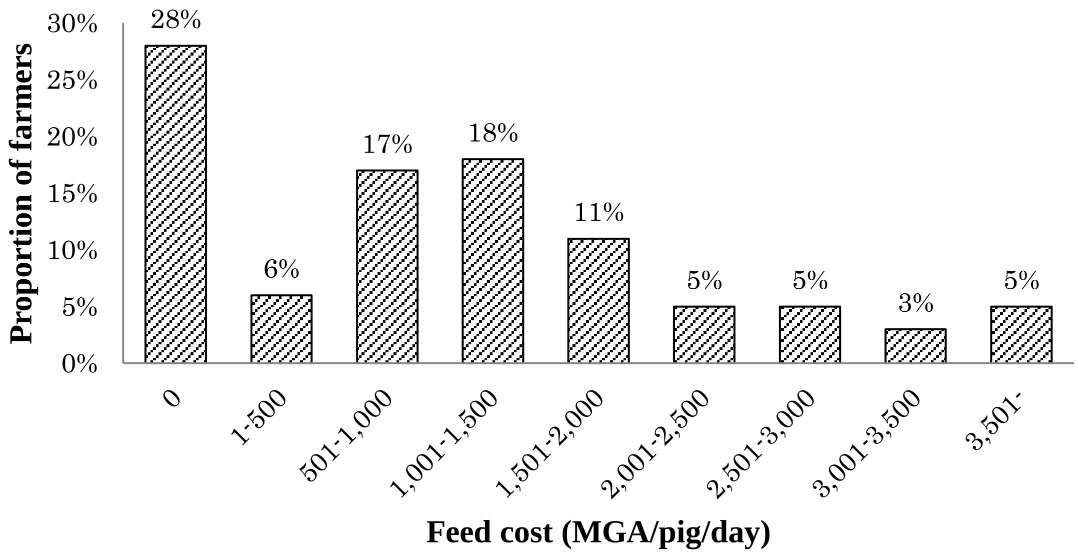

Figure 3.8 Distribution of daily feed cost

Source: Field survey, 2013

For farmers who buy feed, on average, the majority (79%) of the cost is spent on rice bran, as shown in Figure 3.9. Followed by leftover that is bought from local small restaurants. Only 5% of the average feed cost is spent on maize. Other feeds include vegetables, cut grass, cassava, and so on.

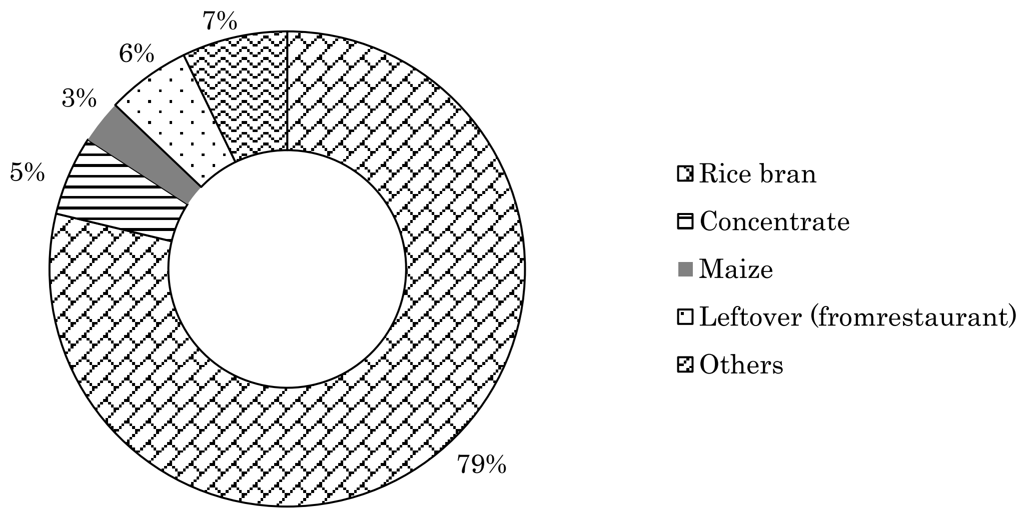

Figure 3.9 Share of cost per feed

Source: Field survey, 2013

Note: percentages are calculated based on the total number of farmers who spend money for pigs' feed

The quality of feed depends on the pig's breed owned by the farmer. As shown in Figure 3.10, the majority of the farms rear exotic breeds (Landrace and Large white). Farmers who raise those breed spend more money on feed (1,375 MGA/pig/day) for a better yield than other farmers with local or cross breed (982 MGA/pig/day). The difference is statistically significant ($p<0.01$). Therefore, there is a possibility that majority of farmers will sell their ASF infected pigs in order to recover, at least their cost of production.

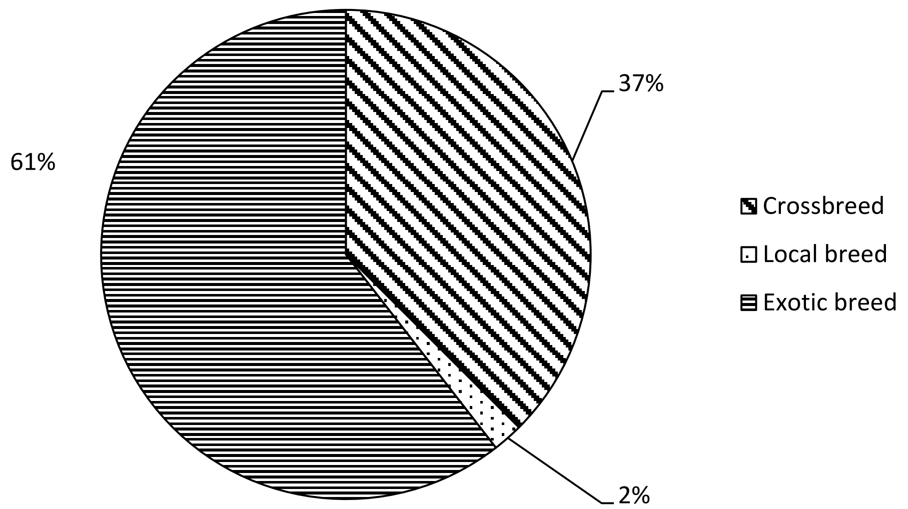

Figure 3.10 Distribution of pigs' breed

Source: Field survey, 2013

Note: Percentages are calculated based on the total number of farms

3.3 Methodology

3.3.1 Questions to elicit farmers' knowledge about ASF

Farmers' knowledge affects their behavior (Bentley 1989; Salameh et al. 2004; Meijer et al. 2014). Therefore, to explain farmers' behavior of selling ASF-infected pig; five true-or-false questions were asked. The questions were related to severity, transmission, and symptoms of ASF. The questions were as follows. The correct answers are provided in parentheses.

Q1. ASF is the same as CSF (False)

Q2. ASF can affect humans (False)

Q3. ASF is transmitted by ticks from pig to pig (True)

Q4. ASF is not transmitted by direct contact between infectious and susceptible pigs (False)

Q5. Blisters on the upper edge of the hoof and in the cleft are symptoms of ASF (False)

To establish a distribution of farmers' level of knowledge, one point was attributed for each given correct answer.

3.3.2 Measuring farmers' sensitive behavior

a- Item count technique

The ICT is an indirect questioning technique that can be used to estimate the proportion of people engaged in a sensitive behavior such as drug use, homophobia or risky sexual behavior. Estimation using the ICT is expected to be higher than that from conventional direct questioning. For example, Rayburn et al. (2003) report that the ICT yielded a higher estimate of the base rate of “people who have had a physical fight with a person because he was gay” than direct questioning. Similarly, LaBrie and Earleywine (2000) report a higher estimated percentage of “people having sex without a condom after drinking” from the ICT than from direct questioning.

There are two types of ICT, the single list and the double list. The procedure is to randomly divide the sample into two subsamples identified as Subsamples A and B.

In the single list technique, one baseline list is needed so that the participants in Subsample A received a baseline list of statements, while those in Subsample B received the baseline list plus the sensitive statement (SS).

The double list technique was used in the present study because it reduces the variance of the estimate to half, thereby giving a more accurate estimate (Droitcour, 1991). Two baseline lists (X and Y) that each contain different items are needed so that the SS can be presented to all respondents. The SS was “sell the meat or the live pig if suspected to be infected or obviously infected by ASF without informing a veterinarian or local authority”. The lists presented to respondents in each subsample are as follow:

For subsample A, the list given to respondents were:

List 1 = Baseline list X+SS:

① use only artificial insemination to obtain ASF-free piglets

② use only boars from ASF-free certified farms to obtain piglets

③ source piglets from ASF-free certified farms only

④ sell the meat or the live pig if suspected to be infected or obviously infected by ASF without informing a veterinarian or local authority

⑤ give manure freely to others because we do not need it

⑥ do not use chemical fertilizer or manure from cattle or poultry for crop farming because the manure from our pigs is enough

List 2 = Baseline list Y:

① spray chemical insecticide to kill ticks in the pigpen at least once every 2 months

② always ask veterinarians' help for farrowing

③ always sell the live non-infected pig, not the meat to meat traders or butchers

④ buy leftovers from small restaurants to feed our pigs

⑤ do not feed the by-products from our crop production to pigs

For subsample B, the lists given to respondents were:

List 1: Baseline list X

① use only artificial insemination to obtain ASF-free piglets

② use only boars from ASF-free certified farms to obtain piglets

③ source piglets from ASF-free certified farms only

④ give manure freely to others because we do not need it

⑤ do not use chemical fertilizer or manure from cattle or poultry for crop farming because the manure from our pigs is enough

List 2: Baseline Y+SS

① spray chemical insecticide to kill ticks in the pigpen at least once every 2 months

② always ask veterinarians' help for farrowing

③ always sell the live non-infected pig, not the meat to meat traders or butchers

④ sell the meat or the live pig if suspected to be infected or obviously infected by ASF without informing a veterinarian or local authority

⑤ buy leftovers from small restaurants to feed our pigs

⑥ do not feed the by-products from our crop production to pigs

The respondents were first told that the questionnaire was anonymous to encourage truthful answers, and then were asked to state the number of items in each list that were true for them without mentioning which ones.

The list given to each subsample is presented in Table 3.2.

Table 3.2 Questionnaire for each subsample

Subsample A	Subsample B	Subsample C
Baseline Y + SS	Baseline Y	Direct question
Baseline X	Baseline X + SS	

Note: Subsample C will be introduced at a later stage in the text

SS: sensitive statement

The optimal number of statements in the baseline list is between three and five (Droitcour et al., 1991). Moreover, the statements on the list were logically consistent with pig farming and ASF (Droitcour et al., 1991). Finally, the statements were designed to obtain a negative correlation between responses to minimize the variance of responses for the baseline list (Glynn, 2013). In addition, baseline list Y was designed to be positively correlated to baseline list X (i.e., each statement in baseline lists X and Y with the same number are positively correlated to each other) to increase the certainty of the estimation (Glynn, 2013).

For example, to illustrate the negative correlation between statements, for the first three statements in baseline list X, if the respondent's farm is a breeding farm, and he uses only artificial insemination to obtain ASF-free piglets, he will count the first statement, but will not count the second or third. Similarly, for the last two statements, if the respondent crop farms and he uses only and all the manure from his own pigs as fertilizer, he will count the fifth statement, but not the fourth. Moreover, to illustrate the positive correlation between baseline lists, farms that practice only artificial insemination are more likely to be able to afford chemical insecticides for the pigpens.

The proportion of farmers engaged in selling ASF-infected pigs[13] as assessed using the ICT is given by the following equation:

$$\hat{p}_1 = 1/2[(\bar{X}_{6B} - \bar{X}_{5A}) + (\bar{Y}_{6A} - \bar{Y}_{5B})] \qquad \text{(Equation 3-1)}$$

where $\hat{p}_1$ is the proportion of farmers who sell ASF-infected pigs, $\bar{X}_{6B}$ is the mean number of statements on "baseline list X plus SS" counted by farmers in Subsample B, $\bar{X}_{5A}$ is the mean number of statements on "baseline list X" counted by farmers in Subsample A, $\bar{Y}_{6A}$ is the mean number of statements on "baseline list Y plus SS" counted by farmers in Subsample A, and $\bar{Y}_{5B}$ is the mean number of statements on "baseline list Y" counted by farmers in Subsample B.

The equation for the variance of Droitcour et al. (1991) was used to calculate the standard errors.

b- Direct questioning

If $\hat{p}_1$ is higher than $\hat{p}_2$, which is the estimate from a direct question (DQ) by the following equation 2, then the behavior of selling ASF-infected pigs can be considered sensitive.

$$\hat{p}_2 = \frac{n_y}{N_{dq}} \qquad \text{(Equation 3-2)}$$

[13] The estimate includes ASF-infected pigs or meat contaminated with ASFV being sold, but for simplification "ASF-infected pigs" will be used throughout the manuscript.

where n_y is the number of yes responses and N_{dq} is the number of DQ respondents.

Therefore, another subsample of respondents, Subsample C, was asked a DQ to estimate the proportion of farmers who admit that “they have sold or will sell the pig if suspected to be infected or obviously infected by ASF without informing the veterinarian or local authority”[14]. That question is slightly different from the SS in the ICT because it includes farmers’ intention in case they have never experienced ASF. Anonymity was guaranteed to evoke truthful answers.

c- Binominal test

The binominal test is suitable for testing the hypothesis that two proportions are equal. As used by LaBrie and Earleywine (2000), the binominal test by Wilcox named *Twobinom* was employed to test the hypothesis that “estimation based on the ICT is equal to estimation based on direct questioning” since it is known to have better statistical properties than Fisher’s exact test. Figure 3.11 summarizes the process of eliciting farmers’ sensitive behavior

A factor score, which is equal to the estimate from the ICT divided by the estimate from a DQ, can be calculated to determine the efficiency of the ICT compared to a DQ.

[14] Farmers’ answer is yes if they have sold or have intention to sell ASF-infected pigs.

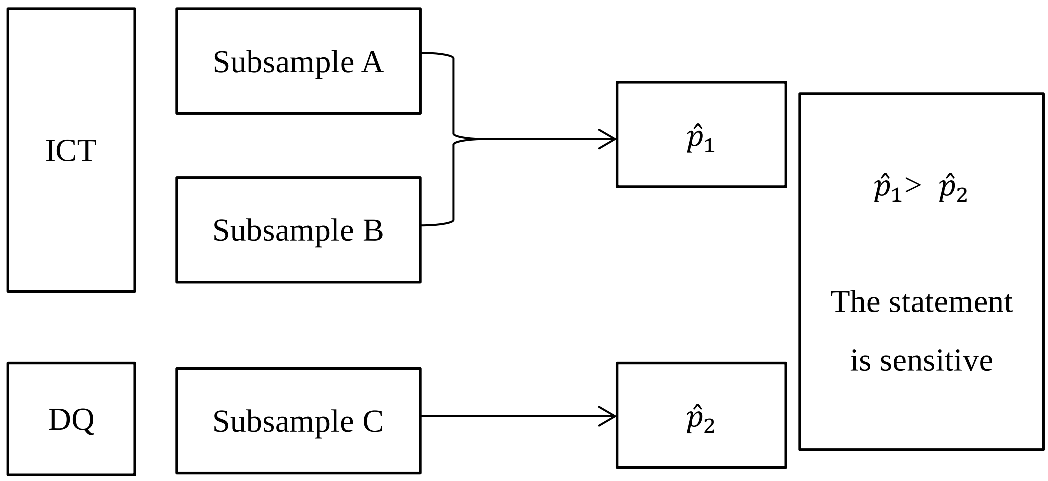

Figure 3.11 Process of eliciting sensitive behavior

3.3.3 Data collection

a- Pre-survey

The aims of the pre-survey are firstly to make certain pig farmers are aware of the existence of ASF, secondly to make sure farmers can answer appropriately to ICT questions since this technique is unusual for them. Finally, the pre survey allowed us to determine farmers' normal farming practices, which are needed for the construction of ICT questionnaire. As mentioned previously, the statements on the list should be logically consistent with pig farming and ASF.

b- Main survey

The targeted sample comprised farmers who have experienced ASF as they were assumed to have more knowledge about ASF than do farmers without experience.

They were asked at the first time whether they have ever experienced ASF outbreaks on their farms. Farmers' responses about ASF experience were not validated because of the unavailability of the list of pig farmers and also the anonymity of the questionnaire.

However, farmers without experience of ASF were included in the sample because it was difficult to find all ASF-infected farms. Only farmers who have ASF experience were given the ICT question to avoid underestimation due to the non-experience of ASF outbreaks. Moreover, according to the MAEP (2007a), all pig farmers are aware that only pigs certified ASF-free can be sold. Therefore, it was assumed that farmers who have not yet experienced ASF would deny when they are directly asked whether they will sell ASF-infected pigs.

The survey was conducted in December 2013 with a total sample size of 201. The sample was divided as shown in Table 3.2. For each subsample of the ICT questionnaire, a minimum of 40 to 50 respondents is needed, although the sample size should be as large as possible to increase the stability and accuracy of the estimate (Dalton and Wimbush, 1994).

Table 3.3 Sample size for each subsample

	ICT		DQ
	Subsample A	Subsample B	Subsample C
Infected farms	81	80	16
Non-infected farms	0	0	24

.

3.4 Results and discussion

3.4.1 Farmers' knowledge about ASF

As for the knowledge questions, the results are shown in Table 3.4. Farmers were expected to respond no to the first question since it was intended to concern severity. But CSF and ASF have the same symptoms; hence, there might be a bias in this estimation of 52.23%. For the second question, "ASF can affect humans", only 27.86% of farmers incorrectly believe that it is true. Awareness about ticks is relatively low (52.24%) despite the fact that ticks are a reservoir of ASF (Ravaomanana et al., 2011). However, most of farmers know the possible transmission of ASF from pig to pig direct contact, which indicates that they can easily understand the need of culling of infected pigs. For the last question, only 49.25% know that blisters are not symptoms of ASF.

Table 3.4 Proportion of farmers in each technique who gave correct answer

Questions	Total (%) (n=201)
①. ASF is same as classical swine fever	52.23
②. ASF can affect humans	72.14
③. ASF is transmitted by ticks from pig to pig	52.24
④. ASF is not transmitted by direct contact between infectious pigs and susceptible ones	95.52
⑤. Blisters on the upper edge of the hoof and in the cleft are symptoms of ASF	49.25

Source: Field survey, 2013

The distribution of the farmers' scores by responding to the 5 true-or-false questions is given in Figure 3.12.

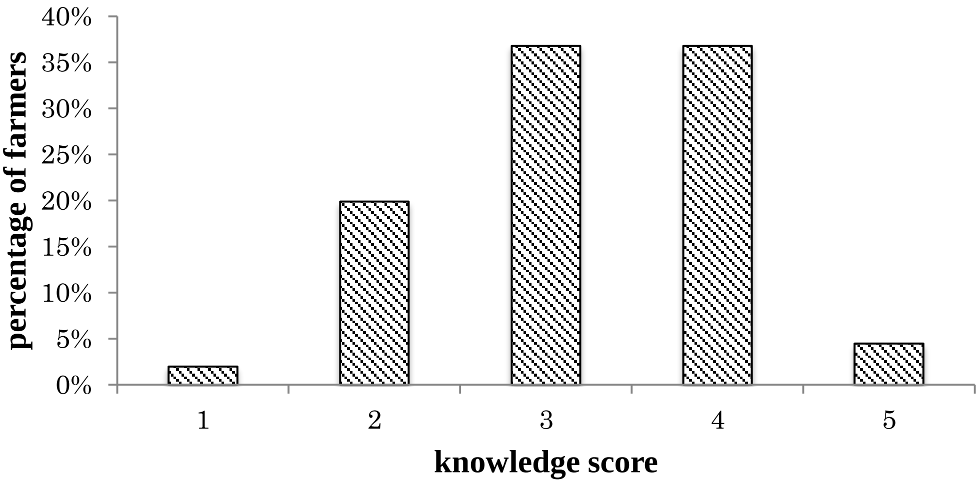

Figure 3.12 Distribution of farmers' knowledge about ASF

Source: Field survey, 2013

Most of farmers got a score of 3 (37%) or 4 (37%) which indicates they have received relatively satisfactory information about ASF. However, only 4% of interviewed pig farmers gave the maximum of 5 correct answers indicating their knowledge about ASF is insufficient.

3.4.2 Farmers' knowledge and sensitive behavior

a- Sample selection bias

As shown in the following Table 3.5, ICT and DQ respondents were comparable in terms of herd size, type of production, since there is no statistical difference between the two respondents of the two techniques (binomial test). In addition, the five true or false questions which were asked to measure farmers' knowledge about ASF because their knowledge might affect their behavior; and the differences between the respondents of each technique were also not significant. Consequently, the characteristics of the sample are homogeneous and indicate that there is no selection bias between ICT and DQ subsamples.

Table 3.5 Comparison of the characteristics of the respondents of the two techniques

Characteristics of the farm		**ICT (%)** (n= 161)	**DQ (%)** (n=40)	**p-value**
Herd size	Less than 4	87	95	0.192
	4 and more	13	5	0.158
Type of production	Breeding and farrow to finish	25	23	0.826
	Farrow to finish only	47	55	0.252
	Breeding only	27	22	0.647
	Boar farm only	1	0	0.631
Farmers' knowledge	ASF is as severe as classical swine fever	52	55	0.690
	ASF can affect humans	74	65	0.251
	ASF is transmitted by ticks from pig to pig	52	55	0.690
	ASF is not transmitted by direct contact between infectious pigs and susceptible ones	94	100	0.133
	Blisters on the upper edge of the hoof and in the cleft are symptoms of ASF	53	45	0.351

b- Proportion of farmers who sell ASF infected pigs

According to the farmers' knowledge about ASF, the estimated proportions of farmers who sell ASF-infected pigs without reporting it are shown in Table 3.6.

For the total sample, about 73% of farmers were found to sell the ASF-infected pigs. That proportion is similar to that of farmers who spend money to buy feed for their pigs (Figure 3.8), which indicates farmers really need to at least recover their cost of production. The estimates based on the ICT are higher than those based on the DQ, but the difference is not statistically significant. This indicates that there is no underestimation from direct questioning. In other words, farmers admit without hesitation that they sell ASF-infected pigs despite the law that prohibits it. In addition, most farmers have sold ASF-infected pigs and those who have not experienced ASF intend to do it. One likely explanation of this situation is that the government does not strictly enforce the law. This idea is supported by the findings of Costard et al. (2009b) who estimated a prevalence of ASF-infected pigs ranging from 1 to 25% from slaughterhouses in different parts of Madagascar.

One possible explanation of the high estimate from DQ is the farmers' lack of experience with ASF. Farmers who have not experienced ASF were included as respondents in DQ. Farmers who have not experienced ASF may not understand how severe ASF is; therefore, they freely say that they intend to sell ASF-infected pigs. In addition, they may not be aware of the existence of the law related to ASF outbreak control that prohibits selling ASF-infected pig. Hence, estimates based on DQ are high and similar to those based on the ICT. From the pre-survey, because all of the interviewed farms, whether or not they have experienced ASF, stated that they know that they have to inform a veterinarian or local authority if they suspect ASF and local veterinarian confirm it. However, we are not sure either they are aware that the government prohibits selling ASF-infected meat.

Considering specifically the second statement of the five true-or-false questions to test farmers' knowledge about ASF, the estimate from the ICT is statistically higher than that from the DQ for farmers who incorrectly understand that ASF can affect humans.

The 1.67 factor score shown in Table 3.6 indicated that the proportion of ICT respondents admitting to selling ASF-infected pigs was 1.67 times higher than the proportion of DQ respondents. This implies that the probability to obtain a truthful answer is higher using the ICT.

Among the five questions, a statistically different estimate between the two techniques was only obtained from the second and third questions. For the question 1, 3, 4, and 5, only the behavior of farmers who gave correct answers to those questions could be considered because the sample size for ICT respondents was not enough (less than 80, meaning the respondent to either list 1 or 2 is less than 40).

Regarding the second question, public health concerns make farmers consider that selling ASF-infected pigs can be a socially unacceptable behavior, and therefore they do not admit it when answering the DQ. In this case, the use of the ICT is favorable for estimating the proportion of farmers who sell ASF-infected pigs. Even the wrong understanding that ASF might affect humans does not stop farmers from selling ASF-infected pigs because reporting entails income loss. In countries where the government's budget is insufficient to compensate farmers, stamping out is condemned to failure (Penrith and Thompson, 2004).

Table 3.6 Estimate of the proportion of farmers selling ASF-infected pigs according to farmers' knowledge

		ICT ($\hat{p}_1$)	DQ ($\hat{p}_2$)	Binominal test	Factor score
Total sample	Estimate (%)	73.20	67.50	p=0.471	-
	Sample size	161	40		
Farmers who think ASF is not as severe as CSF (true)	Estimate	74.08	63.64	p=0.365	-
	Sample size	83	22		
Farmers who think ASF can affect humans (false)	Estimate	83.40	50.00	p=0.0137**	1.67
	Sample size	42	14		
Farmers who think ASF cannot affect humans (true)	Estimate	69.47	76.92	p=0.475	-
	Sample size	119	26		
Farmers who think ASF is transmitted by ticks from pig to pig (true)	Estimate	83.72	50.00	p=0.007***	1.67
	Sample size	83	22		
Farmers who think ASF is transmitted by direct contact between infectious pigs and susceptible ones (true)	Estimate	68.67	67.50	p=0.921	-
	Sample size	152	40		

Farmers who think blisters on the upper edge of the hoof and in the cleft are not symptoms of ASF (true)	Estimate	74.08	92.86	p=0.116	-
	Sample size	86	14		

Notes: ICT: Item count technique (subsamples A and B); DQ: Direct question (subsample C)

The binominal test called *Twobinom* was used to check the statistical significance.

** and *** Significant at 5% and 1% level

For farmers who correctly know that ASF is transmitted by ticks from pig to pig, selling of ASF infected pigs is a sensitive behavior. The probable reason of this behavior is that they know that ticks are present everywhere, hence it is very easy to transfer ASFV. Therefore, they do not want to admit being an additional cause of ASF spread.

When comparing the result of ICT and DQ according to the farmers' knowledge level; the estimates from ICT were higher, but not statistically significant than that from DQ (Table 3.7). It indicates again that selling of ASF infected pig is not a sensitive behavior despite the difference in knowledge. In addition, the prevalence of ASF-infected pigs in slaughterhouses is 14% indicating that many pig owners sell all their pigs as soon as they suspect the presence of ASF (Randriamparany et al., 2005). However, the estimate from ICT is statistically higher (p=0.084) from farmers who get a score of 1 to 3 than that from farmers who get a score of 4 or 5.

Table 3.7 Estimate of the proportion of farmers selling ASF-infected pigs according to farmers' level of knowledge

	ICT	DQ	Binominal test (between the two techniques)
Farmers who get a score of 4 or 5	75.37% (n=69)	57.14% (n=14)	p= 0.169
Farmers who get a score of 1 to 3	86.09% (n=92)	73.07% (n=26)	p= 0.129
Binominal test (between the two knowledge level)	p= 0.084*	p= 0.305	—

Note: n: sample size

* significant at 10% level

It is an indication that there are more farmers with less knowledge who sell ASF-infected pigs than farmers with relatively high knowledge. In another words, knowledge can have a positive effect on farmers' behavior.

3.5 Conclusion

Most of farmers have some minimum cost of production therefore they need to recover that cost by selling the ASF infected pigs. Only low proportion of farmers get the maximum score for the questions about ASF knowledge indicating that there is a need of improving farmers' knowledge for successful control of ASF. Yet, knowledge improvement should be complemented with law enforcement. In addition, selling ASF-infected pigs is not considered as an unacceptable behavior for farmers in Madagascar even though it is prohibited by the government. However, the ICT revealed that farmers who incorrectly believe that ASF can affect humans did not tell the truth even if they have actually sold or will sell ASF-infected pigs. In addition, more farmers with low knowledge sell ASF-infected pig than that with high knowledge. Besides, the significance of the income from pig for the farmers, farmers' small land area and the cost of production mean that farmers have to sell the ASF infected meat. Moreover, most of them know the meat marketing channel, which facilitates the act of selling meat.

The high proportion of farmers who sell ASF-infected pigs contributes to the spread of ASFV and makes the control of outbreaks difficult. Consequently, the Malagasy government should strengthen the current regulations, improve farmers' knowledge about ASF and provide compensation for farmers as incentive for reporting cases.

The next chapter will discuss about farmers' willingness to accept compensation.

CHAPTER 4

Farmers' knowledge and incentive in reporting African swine fever

4.1 Background

Animal disease reduces farm output (Bennett, 2003). Several studies have been conducted to assess the impact of different animal disease outbreaks on farms (Tisdell et al., 1999; Perry and Rich, 2007; Fasina et al., 2012; Rich and Hamza, 2013) Indeed, animal disease is a burden for African countries (Rich and Perry, 2012).

One of the key elements in controlling the spread of ASF is stamping out (culling of all sick and contaminated animals, destruction of their carcasses, and cleansing and disinfection of premises) or modified stamping out (for example, culling of sick animals only) (OIE, 2013). Despite control measures, ASF has been endemic in Madagascar (Penrith et al., 2013). Among the control measures, there is a law (Ministerial Decree No. 960/98, Article 2) that stipulates compulsory and immediate reporting of infectious animal disease suspicion. In developed countries, farmers are given compensation for the slaughtered animals to create incentive to report cases. However, it is not the case in Madagascar due to government's budget limitation. Even though compensation is available, farmers having information about the health status of their animals during an outbreak might be unwilling to report it to the government due to the cost reporting might incur such as very low amount of compensation (Hennessy and Wolf, 2015). This unwillingness to report is considered adverse selection. In fact, farmers in Madagascar illegally sell the ASF infected pigs instead of reporting any ASF suspicion as reported in Chapter 3. According to Penrith et al. (2013), in ASF-endemic areas, farmers are less likely to report ASF, which poses an important challenge for disease control. Additionally, public veterinarians in Madagascar mainly inspect animals in slaughterhouses before slaughter and the meat after slaughter (Meslin, n.d.) rather than monitor farms. Therefore, obtaining information about disease occurrence depends on farmers' willingness to report it. Presumably, one of the reasons for not reporting ASF infections in Madagascar is the lack of incentives, such as a compensation system for infected pigs to be culled. According to Penrith and Thomson (2004), farmers in developing countries accept stamping out as long as market-related compensation is available. Additionally, the Food and Agriculture Organization (FAO n.d.-c) recommends financial compensation as a fair way to deal with the issue of stamping out.

Another fact that cannot be ignored in the control of infectious animal disease is that farmers only possess private information about the level of biosecurity[15] they adopt in the farm before the disease outbreak. If compensation is available, farmers may decrease the level of biosecurity in their farm, resulting in an increased risk of infection, which is a moral hazard[16] issue (Hennessy and Wolf, 2015). Although compensation is currently unavailable, Costard et al. (2009) reported that limited biosecurity measures were applied in smallholder pig farms in Madagascar. However, these might become inexistent if compensation is made available. Consequently, to avoid moral hazard, government should set the compensation lower than 100% of the farm gate price of meat.

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[15] Examples of biosecurity measures are usage of pigpens, absence of pets on the farm, insect control, and feed without kitchen waste.

[16] According to de Janvry and Sadoulet (2016), adverse selection corresponds to hidden information about the characteristics of a person or a product, which gives room for opportunistic behavior. On the other hand, moral hazard corresponds to asymmetrical information allowing opportunism under the form of hidden action. In our context, when compensation is made available, adverse selection is hidden information after the ASF outbreak, while moral hazard is hidden action prior to the ASF outbreak.

Farmers' knowledge about the disease is very important for an effective animal disease control program (Martin et al., 1994). Consequently, the hypothesis in this chapter is that farmers' knowledge about ASF might be a factor that influences their attitude towards reporting and the level of biosecurity they adopt on the farm. That is, we hypothesize that farmers' knowledge along with compensation mitigate adverse selection and moral hazard issues.

Therefore, the general objective of this chapter is to determine economic incentive for farmers for an effective control of ASF. Specific objectives are:

1. To elicit farmers' knowledge about ASF which might affect their WTA compensation
2. To determine farmers' WTA compensation as an incentive for reporting ASF cases

That is, if farmers report ASF cases, the government will cull the infected pigs and provide financial compensation for the farmers' loss.

Figure 4.1 summarizes the background of Chapter 4.

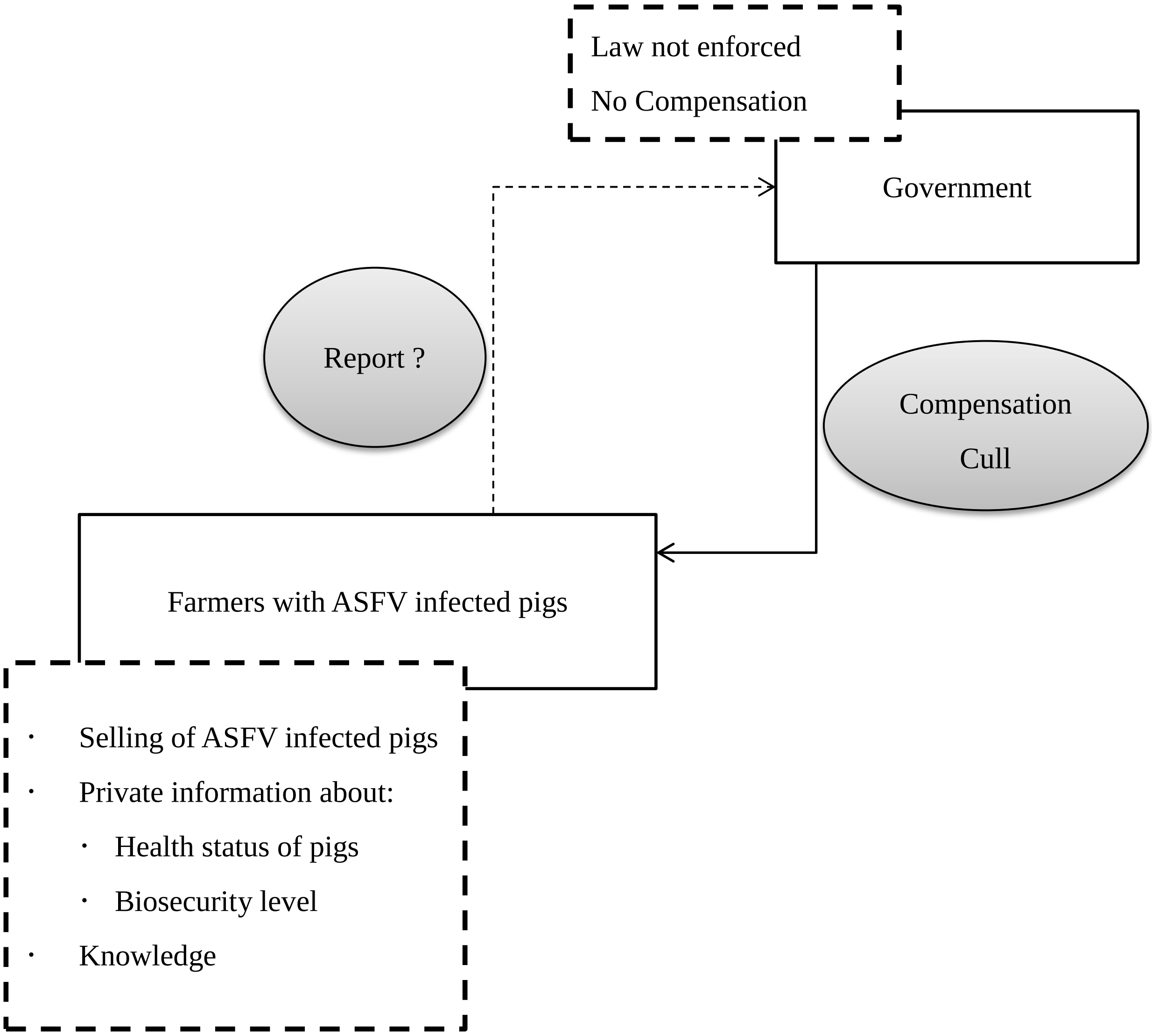

Figure 4.1 Summary of the background of Chapter 4

4.2 Methodology

4.2.1 Data collection

a- Pre-survey

For this chapter, the purpose of the pre-survey of 20 farmers was to test the questionnaire and ask farmers about the price of contaminated meat regardless of the pig diseases.

When asked directly to give the farm gate price at which farmers are selling their meat if it is uncontaminated by disease, and for the case of contaminated (whatever the pig disease); the average price of contaminated meat is 72% (±2%) of the farm gate price of the meat. The minimum was 54% and the maximum was 94% of the farm gate price. It indicates that all farmers do not expect a full price for contaminated meat.

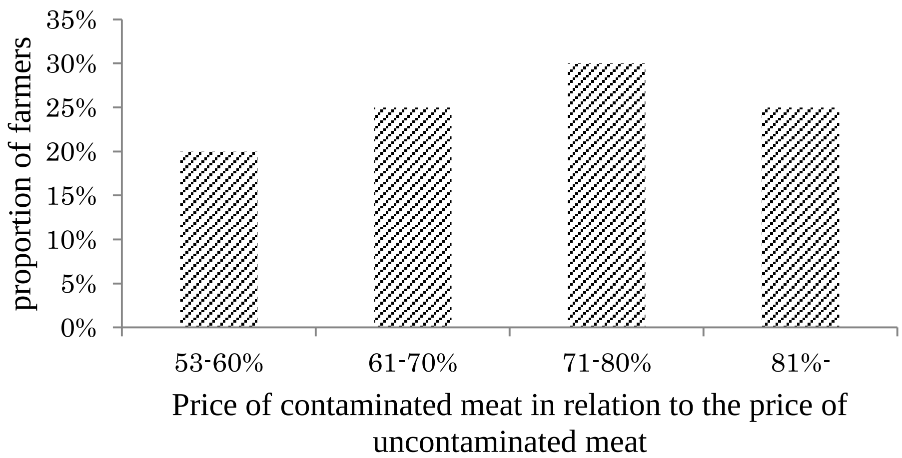

Figure 4.2 Distribution of the price of contaminated meat in relation to the price of uncontaminated meat

Source: Field survey (pre-survey), 2013

The distribution of their answer is shown in Figure 4.2. Most of the farmers (30%) expect a price of 30 to 20% less than the price of uncontaminated meat. However, the price expected is relatively evenly distributed across the interval of meat price.

b- Main survey

The data used in this chapter is that collected in December 2013 as mentioned in Chapter 1. The study area is Antananarivo Avaradrano district, Analamanga region (Figure 1.7). Among the 201 farmers that were interviewed, 175 had experience with ASF infection and 26 had not.

4.2.2 Farmers' knowledge about ASF

The same five true-or-false questions as in Chapter 4 were again considered in this chapter. The results were included as dependent variables in the model devised to explain farmers' attitude towards compensation. For example, if the farmer knows that ASF can be transmitted easily by ticks, it is assumed that he/she is more likely to accept compensation. Additionally, since farmers who have not experienced ASF were included in the sample, the proportion answering correctly each question was compared between farmers with and without experience; farmers who have not experienced ASF were assumed to have less knowledge than those with experience and thus to be less likely to accept compensation. This difference was ascertained using a modern and robust binomial test (Wilcox, 2005), which tests the null hypothesis that proportions from two independent groups are equal.

The questions were as follows. The correct answers are provided in parentheses.

Q1. ASF is the same as CSF (False)

Q2. ASF can affect humans (False)

Q3. ASF is transmitted by ticks from pig to pig (True)

Q4. ASF is not transmitted by direct contact between infectious and susceptible pigs (False)

Q5. Blisters on the upper edge of the hoof and in the cleft are symptoms of ASF (False)

4.2.3 Contingent valuation

For animals that are traded (broilers and fattened pigs), the compensation should be based on farm gate price (FAO, n.d.-c). The compensation rate that farmers can receive is given by Equation 4.1.

$$I = FP \times r, \qquad \text{(Equation 4.1)}$$

where I is the amount of compensation, FP the farm gate price, and r the compensation rate to be given for culling pigs, which is the percentage of the farm gate price that the government should pay.

Securing the farm gate price is relatively easy, but it is important to determine the percentage the government should pay, because, the lower the compensation, the lower the likelihood of farmers reporting the disease. Therefore, contingent valuation (CV) was used to determine the appropriate percentage that would encourage farmers to report the disease. The CV method also helps identify the factors influencing farmers' WTA compensation and verify the hypothesis that farmers' knowledge about ASF might be a contributing factor.

The single-bounded dichotomous-choice CV approach is used to elicit WTA or willingness to pay (WTP). The single-bounded version was used in this study because of the respondents' familiarity with it compared to other CV methods, owing to its similarity to market conditions (Desvousges et al., 1983). According to the CV procedure, respondents were first asked whether they are willing to accept a certain amount as compensation after describing the following scenario, to which they answered with "yes" or "no":

"As you might already know, ASF exists in our country. Almost 100% of infected pigs die from the disease. Additionally, there is no treatment or vaccination available for ASF. Hence, slaughtering infected pigs and then burying their bodies is the only way to control the spread of the disease in case of an outbreak. This can be done if farmers report suspected cases of ASF to the veterinary office or local authorities. Unfortunately, to date, pig farmers are not compensated by the government if a veterinarian culls and buries their ASF-infected pigs."

Subsequently, they were asked if they would be willing to report ASF cases to the veterinary office or local authorities if they would receive money as compensation every time they report an ASF infection. If their response was "yes," the following question was presented to them: "Would you be willing to accept a compensation of [a random bid] less than the farm gate price of uncontaminated meat?" Then, respondents answered with "yes" or "no." The procedure is summarized in Figure 4.3.

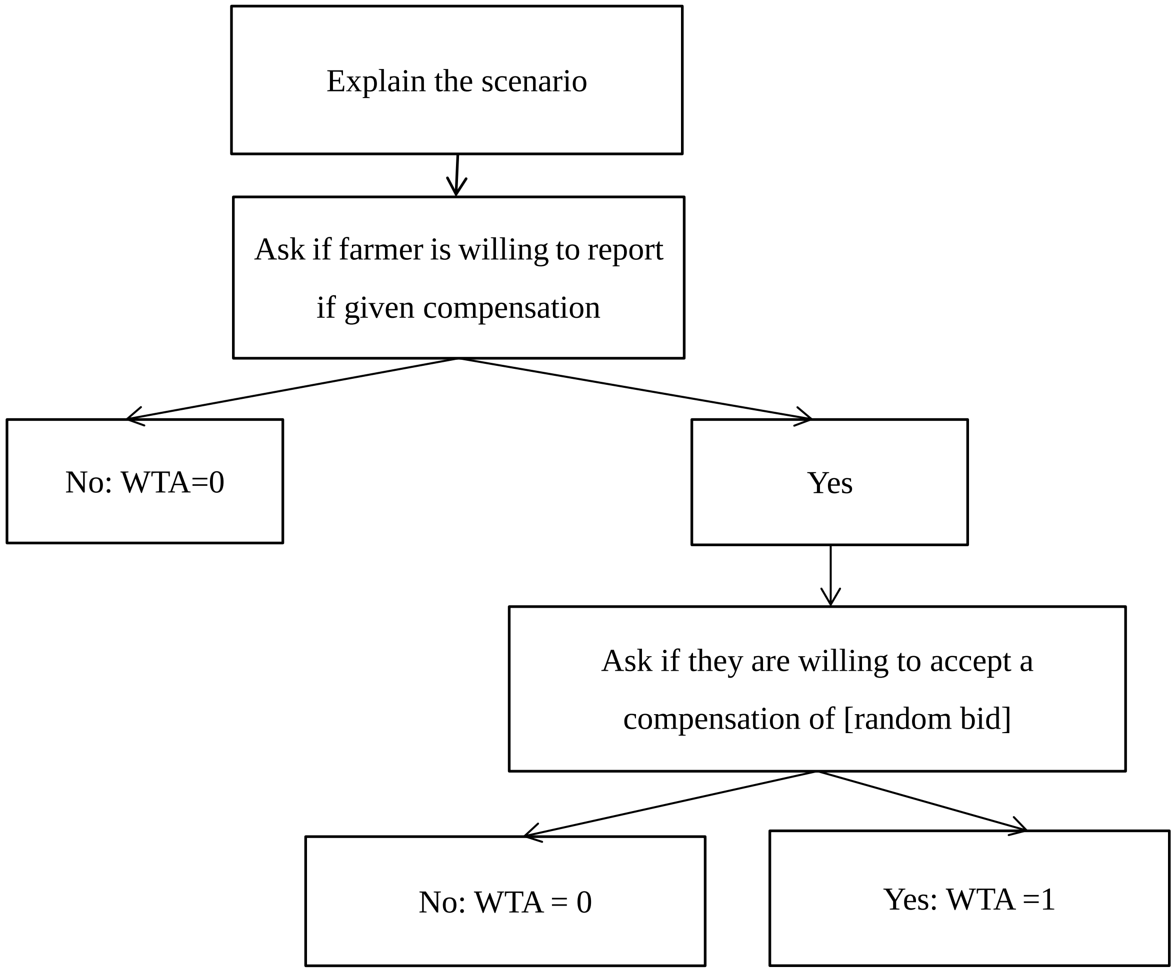

Figure 4.3 Process of eliciting WTA

To avoid moral hazard, the burden of an outbreak should be shared between the government and farmers, and, consequently, the compensation would have to be less than 100% of the farm gate price. Additionally, we selected random bids based on the results of the pre-survey, because farmers must be compensated at least as well as they would earn from the alternative of selling infected meat. During the pre-survey, farmers were asked the price of uncontaminated meat and then requested to state the price at which they would sell the pig meat if it were contaminated in any infectious way. The value of ASF-contaminated pig meat ranged from a minimum of 53% to a maximum of

94% of the farm gate price for uncontaminated meat. Whittington (1998) suggested that, to obtain a reliable estimate, the highest price should be rejected by 90–95% of respondents in developing countries. Hence, a bid of 60% less than the farm gate price for uncontaminated meat was included in the analysis. The random bids and related compensation rates are presented in Table 4.1. Bids were presented randomly, as one level per respondent as shown in Table 4. 1.

Table 4.1. Bid, related compensation rate, and respondents per bid

Bid (%)	10	20	30	40	50	60
Compensation rate (%)	90	80	70	30	50	40
Number of respondents	11	37	42	49	43	19

Note: Compensation rate is the percentage of the farm-gate price of meat that farmers will get as compensation. It is obtained by subtracting the bid value from 100%.

Each farmer's response can be categorized into two possible outcomes: he/she accepts the bid offered or rejects it. A farmer is willing to accept compensation ($D_i = 1$) if his/her true WTA is less than or equal to the bid offered, and he/she will not accept it ($D_i = 0$) otherwise.

$$D_i = \begin{cases} 1 \text{ if WTA} \leq B_i \\ 0 \text{ if } B_i < \text{WTA} \end{cases} \qquad i = 1, 2, \ldots, n, \qquad \text{(Equation 4-2)}$$

where B_i is the bid presented to the i^{th} farmer.

Farmer *i*'s WTA function for the compensation of each infected pig to be culled is as follows:

$$\text{WTA}_i = \alpha + \rho C_i + \mu Z_i + \varepsilon_i \qquad i = 1, 2,\ldots, n, \qquad \text{(Equation 4-3)}$$

where WTA_i is pig farmer i's unobservable true WTA (which is a percentage of the farm gate price for uncontaminated meat), and C_i is the compensation rate that farmer i can receive (100-B_i). Z_i is a column vector of observable characteristics of farm i and ε_i is the error term.

The probability that a farmer accepts the offered compensation, given the bid and the value of explanatory variables, is

$$\begin{aligned} \Pr (D_i = 1|C_i, Z_i) &= \Pr (\text{WTA}_i \leq C_i) \\ &= \Pr (\alpha + \rho C_i + \mu Z_i + \varepsilon_i \leq B_i) \\ &= \Pr (\varepsilon_i \leq B_i - \alpha + \rho C_i + \mu Z_i). \qquad \text{(Equation 4.4)} \end{aligned}$$

According to Lopez-Feldman (2012), Equation (4.3) can be estimated using a probit model. Because a coefficient of a probit model cannot be interpreted by itself, the marginal effect is calculated to determine the impact of variables on the probability of the pig farmer accepting the bid offered to him/her.

Additionally, the mean sample WTA was estimated as a function of the average of explanatory variables, according to Equation (4.5).

$$\text{mean WTA} = -(\hat{\alpha} + \hat{\mu}\bar{Z})/\hat{\rho}, \qquad \text{(Equation 4.5)}$$

where $\hat{\alpha}$ is the estimate of the intercept, $\hat{\mu}$ the estimate of factors associated with the WTA (coefficients of the bid and farmer characteristics in the probit model), $\bar{Z}$ the mean of farmer characteristics, and $\hat{\rho}$ the estimate of the compensation rate coefficient.

The data were analyzed using the statistical software Stata® 12.0. To estimate the marginal effect, the Stata® commands *dprobit* and *inteff* were used for the marginal effect of a single variable and for the interacted variable, respectively (Norton et al., 2004).

4.3 Results and discussion

4.3.1 Farmers' behavior when their pig is infected

The following Figure 4.4 shows farmers' behavior when their pig is infected. The pig disease considered in this result is any pig disease that has happened the year before the year of the survey. Only 25 farmers have experienced pig disease (including ASF) in the considered period. Most of the farmers were unable to name the disease but instead describe the symptoms such as loss of appetite and shaking. None of them cited reporting or seeking veterinarian's help when their pigs seem unhealthy. Regardless of the type of farm, most of the farmers will slaughter the pig and sell the meat. That situation is consistent with the result of Chapter 2 which found out that the majority of farmers sell the ASF infected meat.

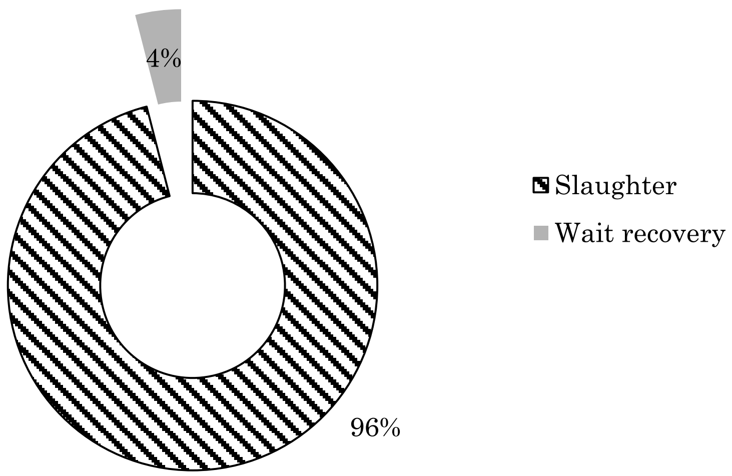

Figure 4.4 Farmers' behavior towards the disease

Source: Field survey, 2013

Note: percentages are calculated based on the total sample

4.3.2 Biosecurity in the pig farms

There is no government subsidy for pig vaccine in Madagascar meaning farmers have to bear the full cost of the vaccine. Figure 4.5 shows the proportion of farmers who administer vaccine against the three pig diseases that have vaccine produced locally.

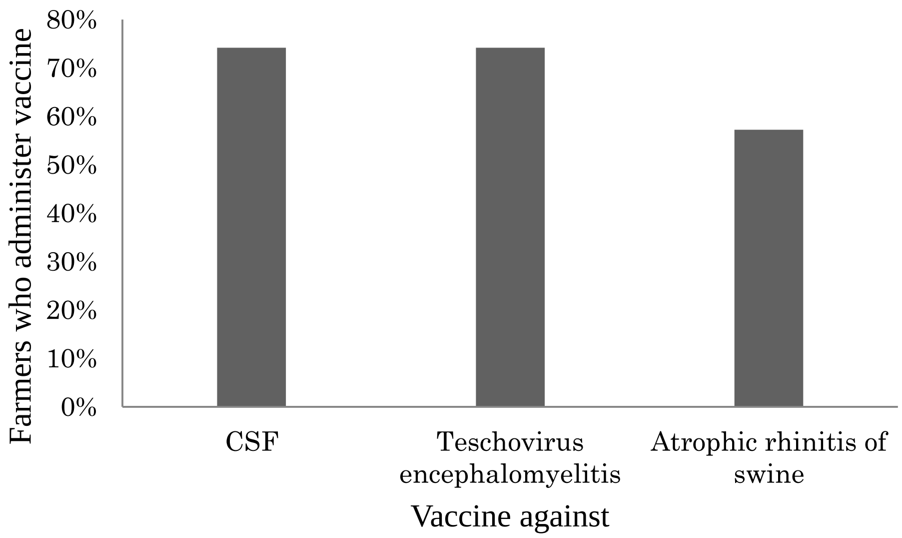

Figure 4.5 Pig vaccine administration

Source: Field survey, 2013

Note: percentages are calculated based on the total sample

More than 70% of the farmers administer vaccine against CSF and Teschovirus encephalomyelitis. It is probably because the vaccine administration is only once an eight months meaning it is about once during the pig's lifetime. In contrary, Atrophic rhinitis' vaccine should be administered more frequently (every three months) meaning it requires more time and money, causing the proportion of farmers who administer it to be lower. The fact that some farmers administer vaccine indicates the presence of some biosecurity measures.

4.3.3 Characteristics of farmers consider in the model

Table 4.2 shows the farm characteristics included in the probit model. Around 87% of interviewed farmers have reportedly experienced ASF at least once. Regarding the type of production, farms are fattening, farrow-to-finish, breeding, or boar farms, with the majority (47%) being fattening farms. A high percentage of farmers (75%) have administered vaccines against CSF despite both pig diseases having the same symptoms, meaning farmers probably think that CSF vaccine can protect their pigs from CSF and ASF.

Table 4.2 Descriptive statistics of the sample

Variable	Description	Mean
Asfexp	Dummy, 1 = with experience of ASF, 0 = without experience of ASF	0.87
Q1	Dummy, 1 = correct answer for question 1, 0 = false answer	0.57
Q2	Dummy, 1 = correct answer for question 2, 0 = false answer	0.72
Q3	Dummy, 1 = correct answer for question 3, 0 = false answer	0.52
Prodtype	Dummy, 1 = fattening only, 0 = otherwise	0.47
Csfv	Dummy, 1 = administered CSF vaccine, 0 = otherwise	0.75

Source: Field survey, 2013

The characteristics of farmers with and without experience were also compared to check sample bias. Table 4.3 shows that there is no statistical difference among subsamples regarding farm ownership, administration of CSF vaccine, type of production, and herd size. Therefore, the sample is homogeneous.

Table 4.3 Comparison of farmers with and without ASF experience

Variables	Number of farmers with experience of ASF	Number of farmers without experience of ASF	*p*-value
Ownership[a)]	25	164	0.735
Administer CSF vaccine	18	132	0.479
Production type[b)]	9	89	0.112
Herd size (3 or fewer pigs)	25	151	0.175

Note: [a)] All the pigs belong to the respondent. [b)] Farmers with fattening farms only.

Binominal test was used for the comparison

4.3.4 Farmers' knowledge about ASF

The percentage of pig farmers who answered each question correctly is given in Table 4.4. More than 50% of farmers, irrespective of whether they have experienced ASF, believe that ASF and CSF are the same disease. Additionally, around 28% of farmers incorrectly believe that ASF can be harmful to human health, most of these farmers having never experienced an ASF outbreak ($p < 0.05$). Regarding ASF transmission (Q3 and Q4), there is no significant difference between the proportion of farmers with and without experience with ASF who answered correctly. Additionally, almost half of respondents did not know that ticks are an important means of transmitting the ASFV in Madagascar (Ravaomanana et al., 2010).

Table 4.4 Proportion of farmers who gave correct answers to the questions pertaining to knowledge about ASF

Question		Total (%)	Farmers without experience of ASF (%)	Farmers with experience of ASF (%)	*p*-value of binominal test
Q1	ASF is the same as CSF	56.72	53.85	57.14	0.756
Q2	ASF can affect humans	71.64	53.85	74.29	0.031**
Q3	ASF is transmitted by ticks from pig to pig	52.24	65.38	50.29	0.154
Q4	ASF is not transmitted by direct contact between infectious and susceptible pigs	95.02	100.00	94.29	0.218
Q5	Blisters on the upper edge of the hoof and in the cleft are symptoms of ASF	49.25	19.23	53.71	0.001***

Source: Field survey, 2013

Note: ** and *** denote statistical significance at the 5% and 1% level respectively. *p*-value represents the difference between the proportion of farmers who gave the correct answer from the subsets of farmers with and without experience with ASF.

This situation partly explains the low biosecurity level identified by Costard et al. (2009). Fortunately, almost all respondents knew that ASF is transmitted by direct contact between infected and susceptible pigs (Q4). Therefore, they are likely to separate the infected pigs for culling from the non-infected ones, while waiting for professional assistance from veterinarians. A relatively high proportion of farmers who have experienced ASF (53.71%) were aware that the presence of blisters on hooves is not an indication of ASF. This proportion was significantly lower for farmers without ASF experience ($p < 0.001$).

4.3.5 Farmers' WTA compensation

All approached farmers were willing to respond to the questionnaire. Only one out of 201 farmers, who also experienced ASF, was unwilling to report ASF cases even if he were to receive compensation for the meat of the culled pigs, citing lack of familiarity with the veterinarian as the main reason. Consequently, that respondent was classified as not willing to accept compensation. The fact that 99.5% of respondents are willing to report ASF indicates that compensation can solve the adverse selection issue.

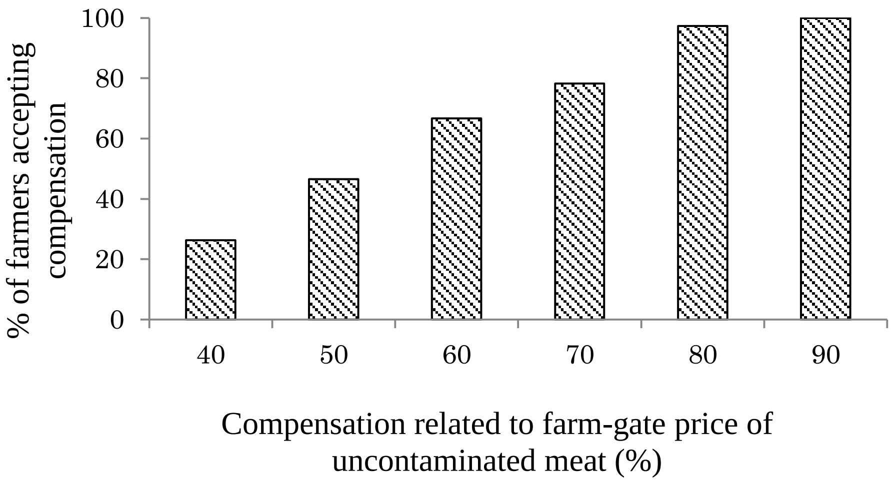

Figure 4.6 Distribution of farmers' WTA for each level of compensation

Source: Field survey, 2013

The percentage of farmers' WTA is shown in Figure 4.6 As expected, the proportion of pig farmers willing to accept compensation decreases with the decrease in compensation. A compensation of 90% of the farm gate price of uncontaminated meat is acceptable to all farmers, indicating their agreement that the value of contaminated meat is less than that of uncontaminated meat, which is consistent with the result of the pre-survey. However, majority of farmers accept a compensation of 70 or 80% of the farm gate price. This indicates that moral hazard may arise if farmers are given a very high compensation of 90%. In other words, farmers may totally suppress the biosecurity measures in the farm in order to receive the high compensation. Only 26% of farmers are willing to report if the compensation is only 40% of the farm gate price of meat.

The hypothetical scenario was designed to deter farmers from accepting a compensation lower than their true WTA. Therefore, we did not stress the positive externality of reporting, which the National Oceanic and Atmospheric Administration (NOAA) panel defines as “warm glow” (Arrow et al., 1993), but showed that reporting without receiving compensation is disadvantageous to the farmer.

Table 4.5 Factors associated with WTA (probit model)

Dependent variable: WTA (1 = accept the bid, 0 = do not accept the bid)					
Parameter	Variables	Estimate		Marginal effect	
		Coefficient	SE	Coefficient	SE
α	Intercept	1.982	0.713	-	-
ρ	Compensation rate	0.036***	0.012	0.013***	0.004
$\mu(Z_1)$	*Asfexp*	-0.027	0.525	-0.009	0.186
$\mu(Z_2)$	*Q1*	1.109	0.759	0.383	0.243
$\mu(Z_3)$	*Q2*	-0.479*	0.258	-0.160**	0.080
$\mu(Z_4)$	*Q3*	0.384*	0.231	0.137*	0.081
$\mu(Z_5)$	*Prodtype*	0.277	0.225	0.095	0.079
$\mu(Z_6)$	*Csfv*	-1.394**	0.598	-0.497**	0.214
$\mu(Z_7)$	*Asfexp* × *Csfv*	1.476**	0.652	0.371[a)]	-
$\mu(Z_8)$	*Q1* × *Ci*	0.034*	0.018	0.007[b)]	-

Source: Field survey, 2013

Note: SE stands for Standard Error.

Number of observations = 201, Log likelihood = -96.307, LR $\chi^2(9)$ = 69.88, Pr > χ^2 = 0.000, Pseudo R^2 = 0.266, McFadden's adjusted R^2=0.19.

*, **, and *** denote statistical significance at the 10%, 5%, and 1% level respectively.

[a)] and [b)] were calculated using the Stata command i*nteff* while *dprobit* was used for single variables.

Factors that affect the WTA compensation of pig farmers are presented in Table 4.5. McFadden's adjusted R^2 of the model is 0.190, which is relatively close to 0.2 and shows a good fit (McFadden, 1978). Additionally, the model passed the post-estimation tests for multicollinearity.

As expected, the coefficient of the variable compensation rate is positive and statistically significant. This means that farmers are more likely to accept compensation as the compensation rate increases. A 1% increase in compensation increases the likelihood of farmers accepting the bid by 0.013. A similar tendency was observed by Kuchler and Hamm (2000) when examining the history of a program intended to eradicate scrapie in sheep in the United States. They found that, when compensation payments were reduced, the incentive to find infected animals decreased, leading to fewer confirmations of scrapie cases.

Pig farmers who correctly understand that ASF cannot affect humans (Q2) are less likely to accept compensation. Their WTA is 0.16 less than that of pig farmers who are mistaken about ASF infecting humans. This means their true WTA is higher than the bid presented to them during the survey. Farmers who answered Q2 incorrectly were willing to accept compensation up to 51% less than the farm gate price for uncontaminated meat, while farmers who provided the correct answer were willing to accept a compensation of only 37% less than the farm gate price. For those farmers, compensation can probably be an incentive, if set higher than the price at which they can sell the infected pigs, since it was estimated that not only do around 70% of such pig farmers sell ASF-infected pigs, but they also consider it as non-sensitive behavior (Chapter 3). The results of the pre-survey and the fact that a percentage of farmers is willing to accept a compensation of 10% less than the farm gate price for uncontaminated meat (Figure 4.6) allow us to conclude that farmers are aware that contaminated meat's farm gate price is lower than that of uncontaminated meat.

Therefore, it must be explained to farmers that, although ASF is not harmful to humans and, as long as the disease is not eradicated, their pigs are always at risk. Therefore, the chance of losing income because of an ASF infection will always be present.

As for Q3, which states that "ASF can be transmitted by ticks from pig to pig," farmers who know this to be true are also more likely to accept compensation with a higher probability by 0.14 ($p < 0.1$). This indicates that knowing the risk of ASF spreading within the herd because of ticks makes farmers more favorable to reporting even when compensation rates are low. Therefore, the ASF control policy should also focus on informing farmers about the high risks related to the presence of ticks in the pigpen and the need of at least regularly cleaning the pigpen if they cannot afford disinfecting products.

However, we see no effect on WTA even for farmers who have experience with ASF. The WTA of farmers with and without ASF experience does not differ significantly; these are 41% and 42% less than the farm gate price of meat, respectively.

Farmers who have administered the vaccine against CSF are less likely to accept compensation. The probability that they accept the bid is 0.5 less than for farmers who did not administer the vaccine. These results indicate that all pig farmers may wrongly believe that the CSF vaccine will protect their pigs from ASF. When they do not administer the vaccine, they think that they did not prevent the ASF infection and, therefore, they accept the low compensation rate. Consequently, farmers should be encouraged to administer the CSF vaccine to prevent income loss due to CSF. Meanwhile, they should be warned that the CSF vaccine does not protect their pigs from ASF. Hence, they need careful ASF prevention, such as avoid being in contact with infected farms. However, farmers who have experienced ASF and administered the vaccine against CSF are more likely to accept compensation than others, with the probability being 0.37 higher. This shows that their experience made them risk-averse and, therefore, they protect their pigs from CSF and also accept compensation for the damage caused by ASF. In other words, although the compensation scheme is to be established, it is not likely that farmers will decrease the level of biosecurity practices, such as stopping the CSF vaccine administration.

Knowing that ASF is different from CSF (Q1) does not influence farmers' WTA. However, farmers who are aware that ASF differs from CSF (Q1) and who were offered a higher bid ($Q1 \times Ci$) are more likely to accept compensation, the probability being 0.007 higher.

Including all the explanatory variables mentioned in Table 4.5 in Equation (4.5), the estimated WTA mean for compensation is 41% less than the farm gate price for uncontaminated meat. In other words, pig farmers are willing to accept a compensation of 59% of the market value of the farm gate price for uncontaminated meat. This mean value is almost the same as the estimated cost of pig fattening production operations (Andriamparany, 2012).

4.4 Conclusion

Compensation can be an incentive for farmers in Madagascar to avoid adverse selection. Farmers agree that the farm gate price of infected pig is less than that of non-infected pig. Additionally, if a very high compensation such as 90% is available, moral hazard might arise. The results also show that farmers' knowledge about ASF affects their WTA compensation and their reporting of ASF cases. The fact that some farmers have the correct knowledge about ASF is a positive factor affecting their WTA. However, ASF not affecting humans and the practice of vaccinating pigs against CSF are barriers against reporting. Therefore, while farmers should be informed that ASF does not affect humans, they should be warned that not reporting outbreaks contributes to the spread of ASF, and an outbreak induces income loss. Additionally, farmers' knowledge about ASF is not perfect, and the government should educate them about good biosecurity practices and symptom identification.

The next chapter will discuss about the cost effectiveness of compensation program for ASF control.

CHAPTER 5

Fihavanana a social norm of mutual support, and the spread of African swine fever

5.1 Background

The diversity of livestock use and the complexity of livestock value chains in developing countries increase the effects of livestock diseases on livelihood relative to developed countries (Rich and Perry, 2011). Animal disease can ruin the basic resource of the livestock system for example through mortality of productive animal. At the output level, animal disease causes low productivity. As for human benefit, farmers may lose partly or entirely their income.

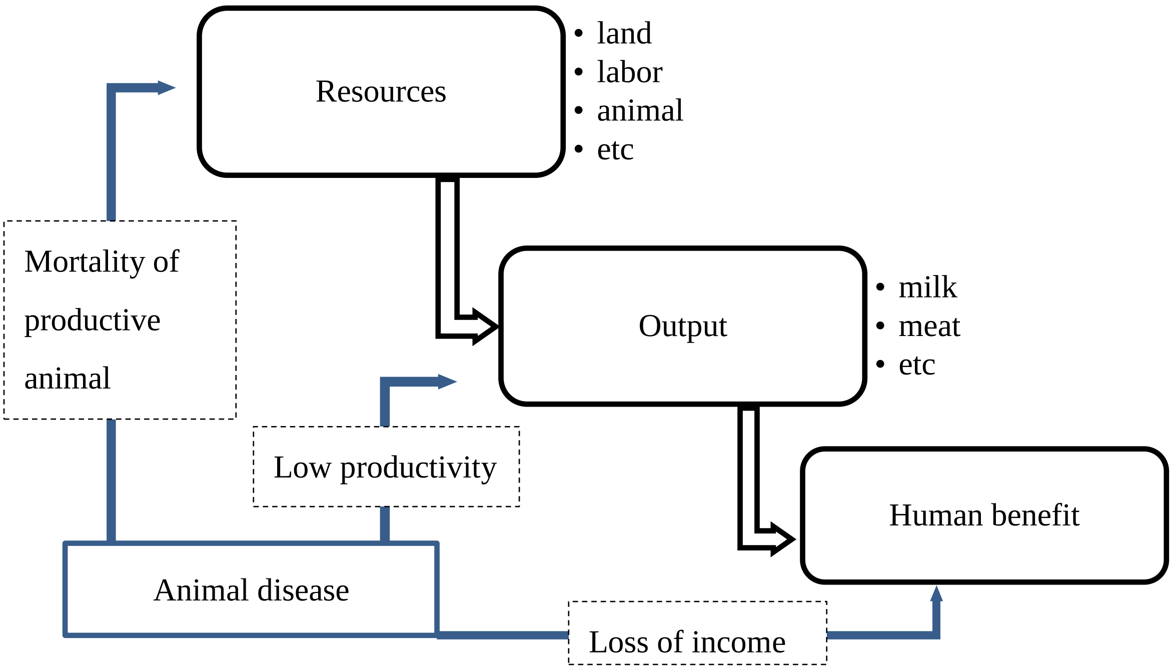

Figure 5.1 Effect of animal disease on livestock production

Source: modified from McInerney, 1996

Those effects of animal diseases on the livestock production system are summarized in Figure 5.1.

ASF infection is often caused by the introduction of infected pigs to pig populations or by the meat of infected pigs being fed as swill (Penrith, 2013). Farmers in Uganda who practice minimal swill feeding[17] were found to be less vulnerable to ASF (Nantima et al., 2015). Outbreaks caused by swill feeding are not a concern for African countries only; according to Nigsch et al. (2013), swill feeding is believed to play an important role in the spread of ASF over long distances and was responsible for most outbreaks in Europe in the past.

Swill feeding causes ASF infection when it contains ASF-contaminated pork that has been bought, for example, from neighbor farmers. From the viewpoint of behavioral economics, a farmer's decision to buy contaminated pork is described by his preferences and his restrictions (Kirchgässner, 2008). These restrictions include, among others, the farmer's income, the market price of the contaminated pork, and the reactions of other farmers. Concerning the reactions of other farmers, *fihavanana* is always present in social relations in Madagascar (Sandron, 2008). *Fihavanana* is a social norm that guides people's behavior, encompassing kinship, friendship, and mutual support between people. A previous study (Sirven, 2006) suggested that *fihavanana* leads to better self-rated human health. However, in this study, we assume that it has a negative impact on pig production. When pigs are penned permanently, the spread of ASF might be caused by the introduction of contaminated pork in households where swill feeding is practiced rather than through direct contact between infected and susceptible pigs. In addition, Rasamoelina-Andriamanivo (2006) assumed that swill feeding was one of the main sources of infection because farmers often buy and

[17] The act of feeding pigs with leftover food or food waste that contains meat or has been in contact with meat.

consume ASF-contaminated pork as a manifestation of *fihavanana*. This situation is the result of the lack of compensation for culling ASF-infected pigs. To compensate for their overall income loss, farmers often sell the ASF-infected pigs illegally (Chapter 3). Chapter 4 showed that the number of farmers who reported ASF cases increased with the size of the compensation provided for culling the infected pigs. We suppose that such behavior has an impact on the spread of ASF as well.

The main objective of this chapter is to examine the impact of economic incentive on ASF control taking fihavanana into account. Specific objectives are:

1. To determine the effect of *fihavanana* on ASF spread
2. To propose cost effective alternatives to control ASF

Due to the nature of the different factors that influence the spread of ASF, this study combines epidemiology and economics in the analysis. System dynamics (SD, henceforth) were used to analyze the spread of ASF. SD modeling helps analyze the complex interactions among the social, biological, and economic factors that affect the spread of an epidemic (Hannon and Ruth, 2009). Different scenarios were considered in the simulation:

1) A baseline scenario which represents the current situation where compensation is not provided, meaning government does not conduct stamping out and farmers sell ASF infected pigs (result of Chapter 3).
2) Three scenarios where compensation is available and government conduct stamping out at different culling rate according to the amount of compensation given to farmers (result of Chapter 4).

In addition, we use cost-benefit analysis because epidemiology and economics each play an important integrative role in helping decision makers understand their available options as well as the related costs and benefits (Perry et al., 2001). The background of this chapter is summarized in Figure 5.2.

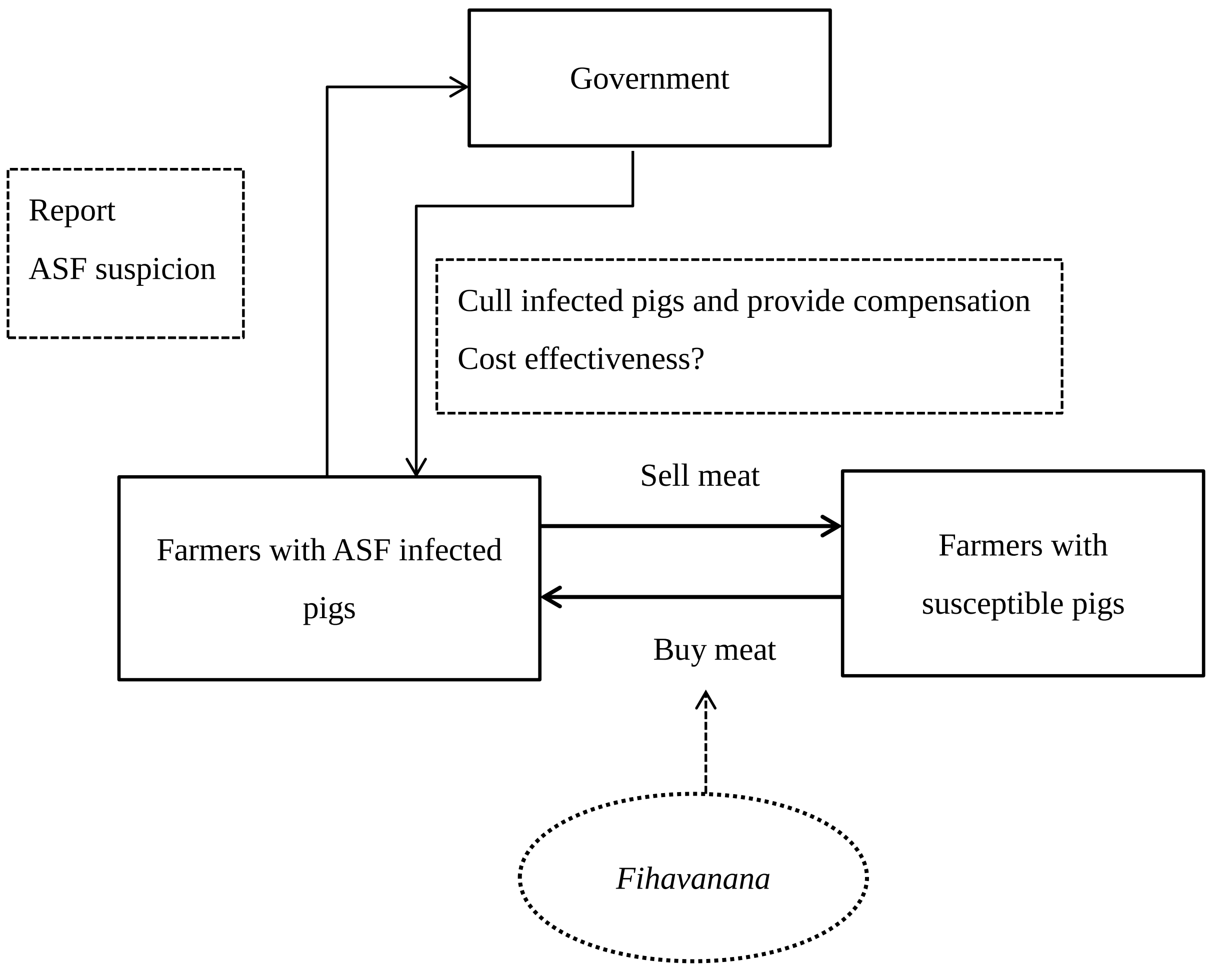

Figure 5.2 Summary of the background of Chapter 5

5.2 Methodology

5.2.1 Data collection

The objective of the survey was to collect data about the proportion of farmers who buy ASF-contaminated pork. The main reason was to estimate the proportion of farmers who practice swill feeding and buy ASF contaminated meat[18], as well as their main reason of that behavior. Farmers were also asked if they buy the contaminated meat regardless of the pig disease or they make an exception for some kind of pig disease.

Other parameters of the model were taken from previous studies. In line with the first 2 main analyses (Chapter 3 and 4), we focused our study on the Antananarivo-Avaradrano District. The farm size was, on average, 2.12 pigs, and the pigs were penned, which means there was no direct contact between pigs during the outbreak. The number of pigs in that district was 13,176 (MAEP, 2007).

5.2.2 System dynamics

Generally, an epidemiological model needs actual detailed outbreak data. Unfortunately, it is unavailable for the case of Madagascar. Another option is the method that was used by Barongo et al. (2015), who collected pigs' blood samples to identify the presence of ASF and recorded the farm's location. However, although those methods allow the impacts of animal disease to be quantified, they do not highlight the role of farmers' behavior (buying contaminated meat, reporting ASF cases to receive compensation, etc.) on the spread of disease in order to determine suitable policies for preventing the spread of ASF. As mentioned previously, *fihavanana* is the reason that farmers buy the contaminated meat that leads to the introduction of infection on their

[18] The swill feeding considered as source of ASF infection in this chapter is the swill from the farmers' kitchen not from restaurant.

farms. Consequently, it is an important social factor that has to be incorporated in the epidemiological model. As mentioned previously, SD can include social factors in the analysis of the spread of disease, and, therefore, it is an appropriate method to identify the impact of farmers' behavior on the spread of ASF. SD has been used recently to study the epidemiology of human diseases (Hannon and Ruth, 2009) as well as that of animal diseases (Rich, 2009).

In the basic epidemiological model, pigs are classified as Susceptible (*S*), Infected (*I*), or Removed (*R*) in an outbreak of a contagious disease. That model is called SIR model. There is also the SEIR model, in which the total population is divided into four compartments, which are susceptible (*S*), exposed (*E*) infectious (*I*) and recovered or dead (*R*). (*E*) corresponds to a stage where the pig is already infected but does not present clinical symptoms. SEIR model is often used when there is relatively significant delay between infection and onset of clinical signs. The development stages of the disease is as shown in Figure 5.3

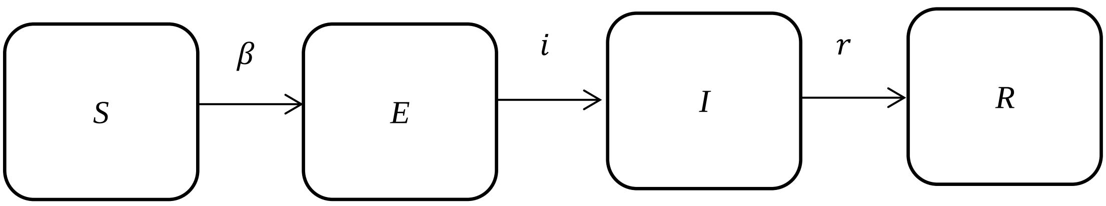

Figure 5.3 Basic SEIR model

In the SEIR model, β is the transmission coefficient (the rate at which individual becomes infected from being susceptible), i is the average latent period and r is the average recovery period. N is the total number of population ($N = S+E+I+R$). The individual moves from one compartment to another according to the following equations:

$$\frac{dS}{dt} = -\frac{\beta SI}{N}$$ (Equation 5-1)

$$\frac{dE}{dt} = \frac{\beta SI}{N} - \frac{E}{i}$$ (Equation 5-2)

$$\frac{dI}{dt} = \frac{E}{i} - \frac{I}{r}$$ (Equation 5-3)

$$\frac{dR}{dt} = \frac{I}{r}$$ (Equation 5-4)

The model in this study is a modified SEIR model meaning besides the SEIR compartments, there are more. Following Rich (2009), at the beginning of an outbreak, all pigs are classified as susceptible but not exposed to infection. We assume that if farmers buy contaminated pork from farms within a 1 km radius, then only pigs within that zone will be exposed to infection; we therefore call these pigs "susceptible exposed" (*Se*). Prior to that stage, pigs belong to the "susceptible non-exposed" (*Sne*) compartment. The radius of the exposed zone increases 1 km for every period *t* (one day) in the model (Figure 5.4).

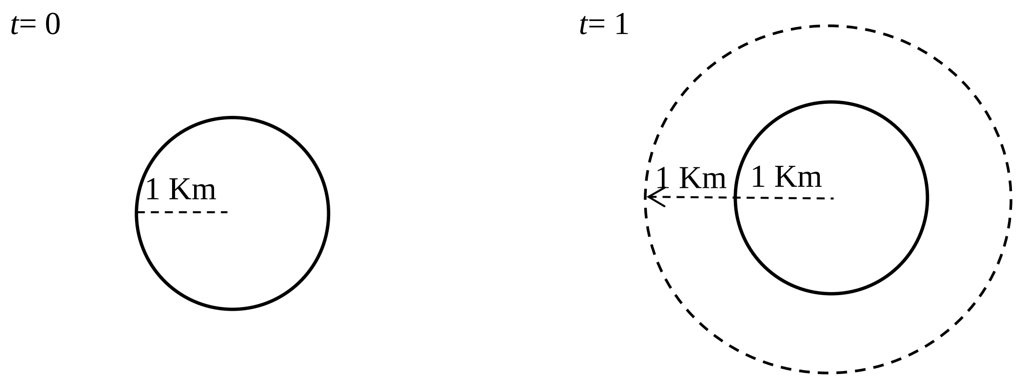

Figure 5.4 Expansion of exposure zone

Source: Rich, 2009

We also include in the model "Sold" (*Sd),* which represents the praxis of selling infected pigs, and "Culled" (*C),* which represents culling ordered by the government and which is based on the disease rate reported by farmers. Additionally, there is the "dead" *(D)* compartment which represents all the pigs dead due to ASF.

Our model reads as follows:

$$\frac{dS_{ne}}{dt} = S_{ne} - rd \qquad \text{(Equation 5-5)}$$

$$\frac{dS_e}{dt} = rd - \left[\frac{\beta Se(E+I)}{N - Sne} + c(S_{d1}+S_{d2})S_e \right] \qquad \text{(Equation 5-6)}$$

$$\frac{dE}{dt} = \frac{\beta Se(E+I)}{N - Sne} + c(S_{d1}+S_{d2})S_e - \frac{E}{i} - s_1 E - kE \qquad \text{(Equation 5-7)}$$

$$\frac{dI}{dt} = \frac{E}{i} - s_1 I - \frac{m}{d} I - kI - rR \qquad \text{(Equation 5-8)}$$

$$\frac{dR}{dt} = rR \qquad \text{(Equation 5-9)}$$

$$\frac{dC}{dt} = k(I+E) \qquad \text{(Equation 5-10)}$$

$$\frac{dS_d}{dt} = s_1 I + s_2 E \qquad \text{(Equation 5-11)}$$

$$\frac{dD}{dt} = \frac{m}{d} I \qquad \text{(Equation 5-12)}$$

where $\frac{dS_{ne}}{dt}, \frac{dS_e}{dt}, \frac{dE}{dt}, \frac{dI}{dt}, \frac{dR}{dt}, \frac{dC}{dt}, \frac{dS_d}{dt}$ and $\frac{dD}{dt}$ represent the change of the number of pigs per time step (per day) that are susceptible not exposed, susceptible exposed, infected without clinical signs, infected with clinical signs, recovered, culled, sold, and dead, respectively.

c is the contact rate between susceptible exposed and infected pigs being sold

$$c = m_b \times s_f \qquad \text{(Equation 5-13)}$$

k is the culling rate by the government

$k = r \times kn$ (Equation 5-14)

In equation (5-6), the expression $\left[\frac{\beta Se(E+I)}{N-Sne} + c(S_{d1} + S_{d2})Se\right]$ represents the number of pigs becoming infected. $\frac{\beta Se(E+I)}{N-Sne}$ is due to transmission within pen, while $c(S_{d1} + S_{d2})Se$ is due to transmission between pen. In Guinat et al. (2016), the transmission between pen is calculated based on epidemiological data. In this study, it is related to the contact rate between susceptible exposed (S_e) and infected pigs (with or without clinical signs) being sold (S_{d1} and S_{d2}), assuming each contact has a 100% chance to lead to infection.

The model (Figure 5.5) was developed using STELLA® 10.1 software[19]. This Figure 5.4 shows the interrelationships between social and economic behavior among farmers and the effect on the spread of ASF. As shown in Figure 5.4, the compartment "*being sold*" is connected to the transition between conditions of "*being infected*," indicating the involvement of *fihavanana*, which guides the behavior of buying ASF-contaminated pork, in the spread of ASF. The parameters of the model are shown in Table 5.1.

In the baseline scenario, a selling rate of ASF infected pigs of 73% was used, based on the findings in Chapter 3. In the intervention scenario that includes compensation, the government culling rate parameter assumes that the pig of a farmer who reports ASF cases will be culled if the farmer could correctly identified the symptoms of ASF. The relationship between report rate and culling rate is shown in Equation (5-13). Farmers who do not report ASF cases are considered to be sellers of infected pigs. However, the behavior of the remaining 27% of farmers who apparently do not sell infected pigs in the baseline scenario is not clear, and, consequently, when the government

[19] http://www.iseesystems.com.

compensation is 60%, it is assumed that only 6% (determined by subtracting the report rate from the initial selling rate of 73%) of farmers are selling ASF-infected pigs.

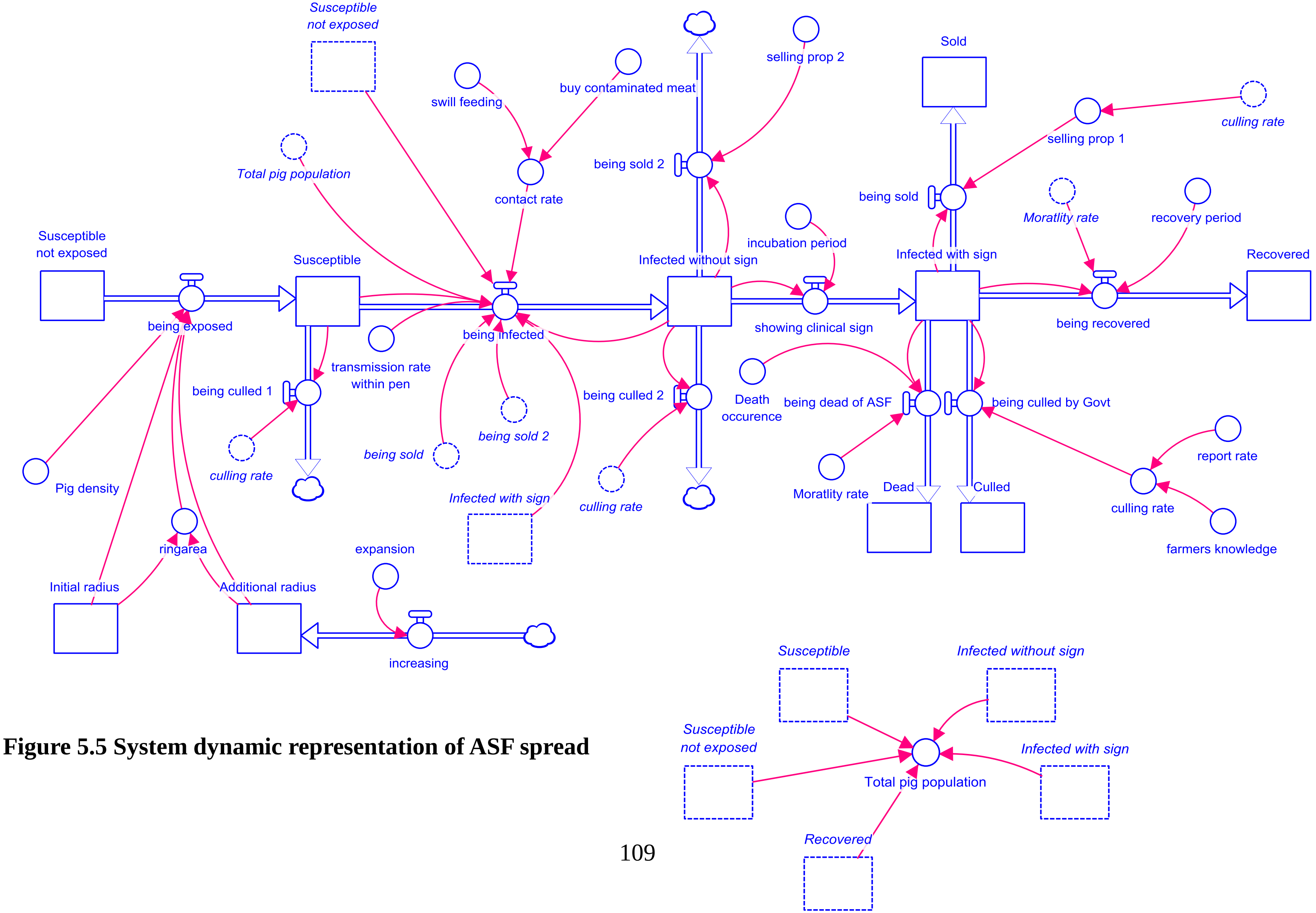

Figure 5.5 System dynamic representation of ASF spread

Table 5.1 Parameters of the model

Parameter			Description		Value	Source
SD model code		Equation				
	Transmission rate within pen	β	Transmission coefficient of ASF from one pig to another within pen		0.6	(Guinat et al. 2016)
	Incubation period	i	Period between infection and onset of clinical signs		5-15 days	(Sánchez-Vizcaíno et al., 2015) (Geering, 2011)
	Recovering period	r	Duration of illness	Acute form	-	(OIE, 2013)
Biological factors				Subacute form	5–30 days	
	ASF mortality proportion	m	Mortality rate	Acute form	100%	
				Subacute form	30-70%	
	Death occurrence	d	Death occurrence after symptoms appearance	Acute form	6-13 days	
				Subacute form	15-45 days	
Economic factors	Reporting proportion	r	Culling rate by government	No compensation	0%	Chapter 4
				Compensation of 50%	46%	
				Compensation of 60%	67%	
				Compensation of 70%	78%	

	Selling prop 1	s_1	Selling of pig with clinical sign rate by farmers	No compensation	73%	Chapter 3 and Chapter 4
				Compensation of 50%	27%	
				Compensation of 60%	6%	
				Compensation of 70%	0%	
	Selling prop 2	s_2	Selling of ASF suspected pigs without clinical sign(emergency sale)		20%	FS, 2016
	Swill feeding proportion	s_f	Proportion of farmers who practice swill feeding		67%	FS, 2016
Social factor	Buy contaminated meat	m_b	Proportion of farmers who buy ASF-meat		25%	FS, 2016
Other factors	Farmers' knowledge	kn	Farmers that can correctly identify ASF symptoms		Random (90-100%)	FS, 2013 and EO
	Pig density	d	Density of pigs in the study area		40 pigs/km^2	MAEP, 2011
	Ring area	r	Area of exposed zone		(1km+1km/day)	Rich, 2009

Note: FS = Field Survey, EO = Expert Opinion

After the first ASF case detection, culling is delayed by three weeks, to reflect the average time needed for laboratory testing. This delay is usually necessary, as ASF has the same symptoms as classical swine fever (OIE, 2013).

5.2.3 Social cost-benefit analysis

As there is no externality[20] involved, the benefit of a compensation program (CP) would appear to be the income from non-infected pigs. Based on SD modeling, it is expected that the number of infected pigs without a CP will be higher than when a CP is implemented. Therefore, in this social cost-benefit analysis, we would like to clarify whether the difference in the number of infected pigs is worth the cost associated with a CP. The farmers and the government may perceive costs and benefits differently. Consequently, for the social cost-benefit analysis, the costs and benefits for the farmers and the government were combined to form the social cost and benefit, respectively. In the case where there is no CP, there is no benefit for farmers while the costs are the income loss due to infection and the dead pig (if we assume that farmers do not sell the meat of dead pigs). The components of the cost and benefit analysis when CP is conducted are presented in Table 5.2.

Let I_{nCP} be the number of infected pigs when there is no CP; P_{ni} be the farm gate price of a non-infected pig, which is assumed to be the same whether or not there is a CP; C_l be the compensation level; I_{CP} be the number of infected pigs when a CP is present; A_c be the extra administrative cost of a CP; and C be the number of culled pigs when a CP is present. D_{CP} represents the number of pigs dead due to ASF even there is compensation program.

[20] Impact of the CP beyond the pig industry.

Table 5.2. Estimation of costs and benefits

Farmers' point of view	
Cost	Cost: $(D_{CP} \times P_{ni})$
Benefit	Income from pigs protected due to the CP: $[(I_{CP} - I_{nCP}) \times \mathrm{P}_{ni}]$
Government's point of view	
Cost	Compensation and administrative cost: $\mathrm{C}(\mathrm{C}_l + A_c)$
Benefit	Benefit: 0
Society's point of view (farmers and government)	
Social cost	$\mathrm{C}(\mathrm{C}_l + A_c) + (D_{CP} \times \mathrm{P}_{ni})$
Social benefit	$[(I_{CP} - I_{nCP})\mathrm{P}_{ni}]$

The calculations of the social cost-benefit analysis are based on the percentage value of a pig. Therefore, in the calculation of the social cost-benefit ratio (SCBR, henceforth), the value of a non-infected pig is 100 MGA, and we consider compensations of 50 and 60 MGA. In addition, an extra administrative cost of 15 MGA per pig was included in the model.

5.3 Results and Discussion

5.3.1 Farmers' behavior

A relatively high proportion (25%) of farmers buy contaminated meat from their neighbors (Field survey, 2016), regardless of the pig disease. It means, even the pig is contaminated by ASF, farmers will still buy it. Farmers who bought contaminated meat cited *fihavanana* as the main reason for their behavior, which is in line with the assumption of Rasamoelina-Andriamanivo (2006). As for the swill feeding, a proportion of as high as 67% of the farmers use leftover from their own household to feed their pig, and 29% add used water from their own kitchen to the pigs' feed. As for farmers who practice swill feeding (leftover and or used water), about 12% of them don't boil the swill before feeding to the pigs. It means, only 8% of the interviewed farmers did all of the following at once: buying contaminated pork, practicing swill feeding, and not boiling the swill. Not boiling the contaminated swill is an indicator of the infection risk because the *ASFV* can survive for a long period of time in uncooked or undercooked pork (OIE, 2013). Therefore, the contact rate between contaminated pork and susceptible exposed pigs was defined to be 8%.

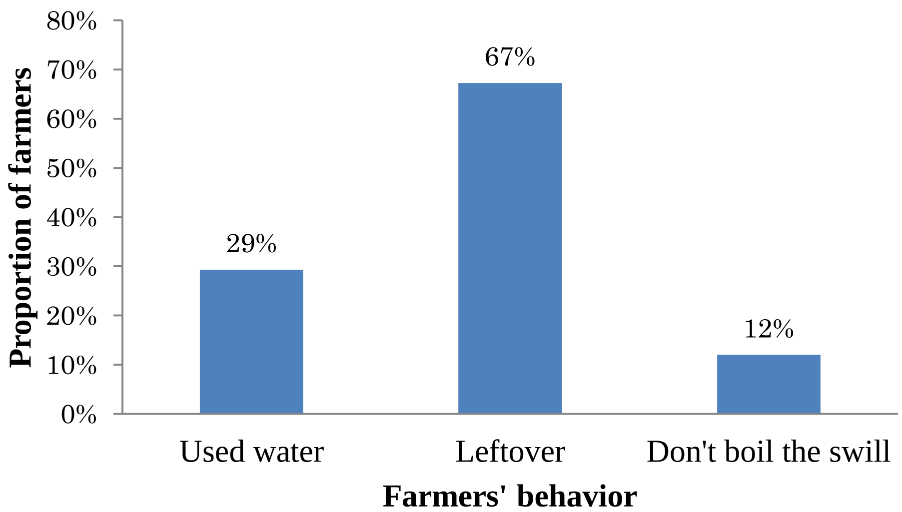

Figure 5.6 Farmers' behavior towards pig feeding

Source: Field survey, 2016

5.3.2 Impact of the compensation rate on ASF spread

Based on SD modeling, Figure 5.7 and 5.8 show the change in the number of infected pigs during the outbreak. The outbreak ends when the number of infected pigs becomes less than one.

In the case of an acute form of the disease, the outbreak ends after 40 days in the case without a CP, whereas the outbreak lasts only about 25 to 30 days when a CP is implemented, according to the amount of compensation given (Figure 5.7). The duration of outbreak is almost similar for the case of subacute infection (Figure 5.8). However, a there are a difference between the number of infected pigs for acute and subacute forms, as well as the respective number of dead pigs. The curves overlap from day 0 to day 21 because compensation starts only 3 weeks (21 days) after the first case of ASF infection.

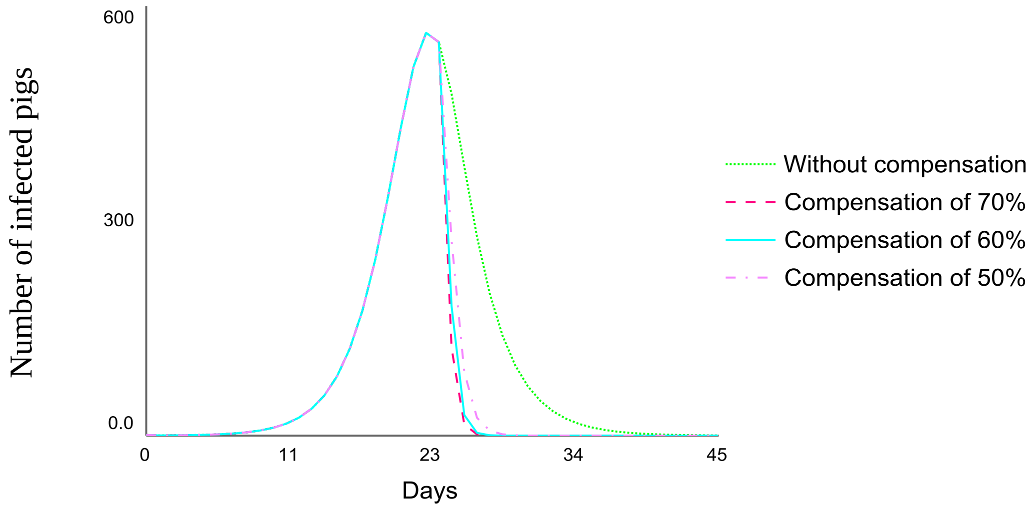

Figure 5.7 Change of the number of infected pigs in the case of acute infection

Source: Simulation

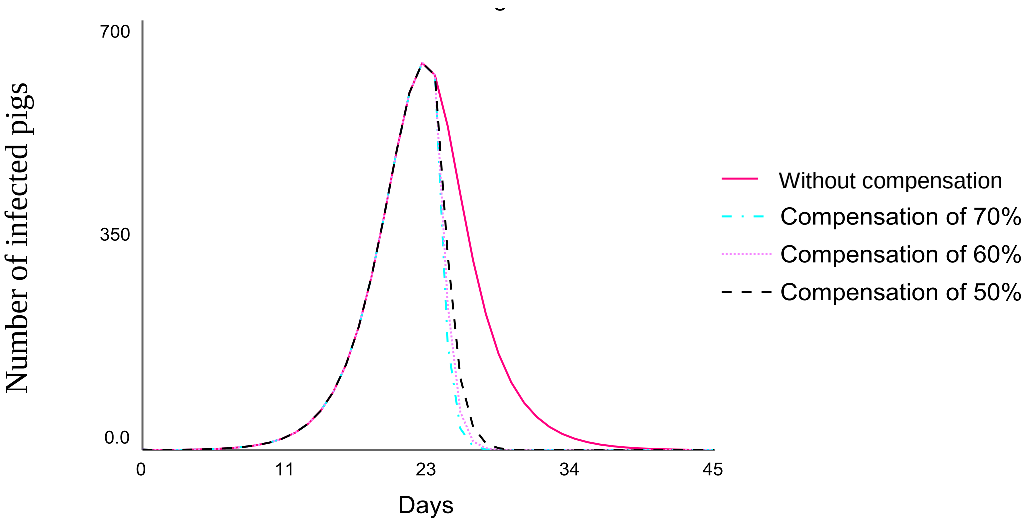

Figure 5.8 Change of the number of infected pigs in the case of subacute infection

Source: Simulation

As for the dead pigs due to ASF, the simulations show that there are more pigs that die due to ASF if there is no CP compare to the case when there is CP. Moreover, the difference between the number of dead pigs with and without CP decreases as the compensation increases (Figure 5.8 and 5.9). It indicates that government's intervention is advantageous for the farmers.

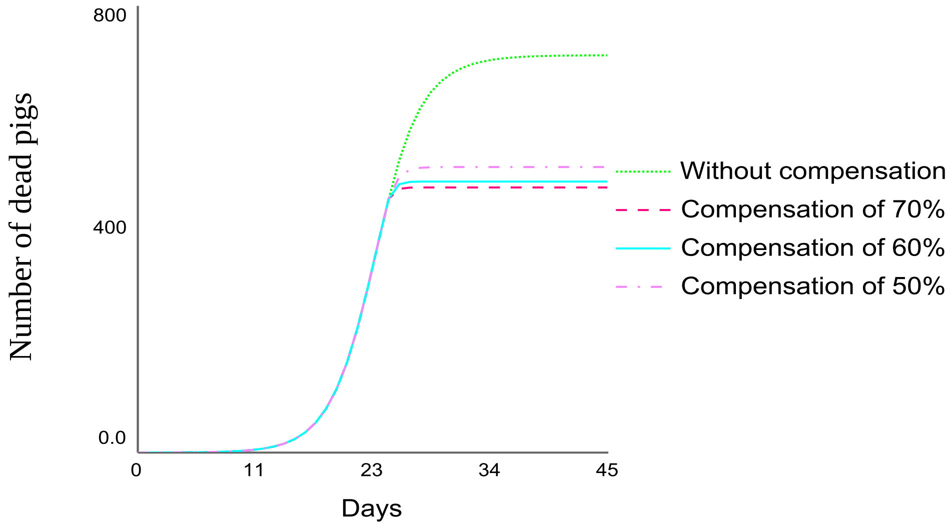

Figure 5.9 Dead pigs related to the level of compensation for the case of subacute infection

Source: Simulation

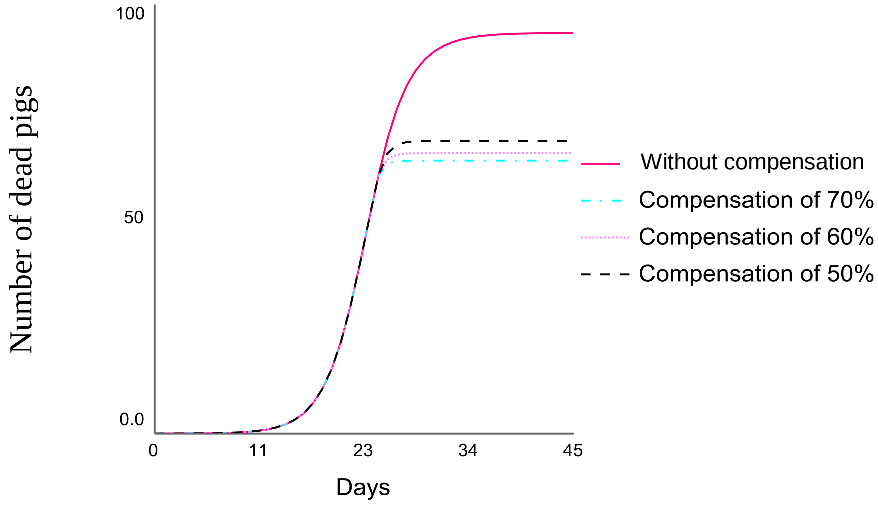

Figure 5.10 Dead pigs related to the level of compensation for the case of subacute infection

Source: Simulation

Table 5.3 and 5.4 present the total number of infected, dead and culled pigs in the case of acute and subacute infection, respectively. Without compensation, the prevalence[21] is 38% and 43% in the case of acute and subacute infection respectively.

Table 5.3 Number of infected dead and culled pigs in the case of acute infection

	Without compensation	**Compensation**		
		50%	60%	70%
Number of infected pigs (prevalence)	4,980 (38%)	3,568 (28%)	3,384 (26%)	3,319 (25%)
Number of dead pigs	712	510	483	474
Number of culled pigs	0	654	836	925

Source: Simulation

There is a negative correlation between the number of infected pigs and the level of compensation. The reason is that the higher the compensation, the lower the selling rate and the lower the rate of pigs moving from susceptible exposed to infected ($c\ (S_{d1}S_{d2})$).

[21] Number of infected pigs divided by the total number of pig population in the study area

When fewer pigs are infected, fewer farmers have to buy the infected meat. It means, fewer farmers have to practice *fihavanana*.

Table 5.4 Number of infected dead and culled pigs in the case of subacute infection

	Without compensation	Compensation		
		50%	60%	70%
Number of infected pigs (prevalence)	5,601 (43%)	3,612 (28%)	3,370 (26%)	3,286 (25%)
Number of dead pigs	93	68	65	64
Number of culled pigs	0	802	1,015	1,117

Source: Simulation

Interestingly, the number of infected pigs is higher in the case of subacute infection compare to acute infection, especially when there is no intervention. It can be explained by the difference in the pigs' chance of living after contracting ASFV. In the case of acute infection, death can happen after 6 to 13 days only. However, in the case of subacute, death happens only after 15 to 45 days and only 30 to 70% will certainly die. Meaning, there is a bigger chance that the ASF-infected pig will be sold during the infection period, indicating a bigger spread of ASFV.

5.3.3 Cost effectiveness of the compensation program

Table 5.5 and Table 5.6 show the related income loss (social cost) and the social benefit of each level of compensation in the case of acute and subacute infection, respectively. All three CP scenarios result in higher benefits than costs, indicating that investment in ASF control is worthwhile. A larger budget (cost) is required for a CP paying 60% than for a CP paying 50%, and the SCBR is higher for the latter. An SBCR of 2.25 means that the government can expect a benefit of 2.25 MGA for every 1 MGA in cost. Zhang et al. (2013) also showed evidence of the cost effectiveness of a pig culling compensation program for the highly pathogenic porcine reproductive and respiratory syndrome infection in Vietnam.

Table 5.5 Cost benefit analysis of CP in the case of acute infection

	Compensation		
	50%	60%	70%
Number of pigs saved from infection (Head)	1,412	1,596	1,660
Benefit (MGA) (a)	141,200	159,611	166,076
Cost (MGA) (b)	62,710	85,539	102,417
SBCR (a/b)	**2.25**	**1.87**	**1.62**

Source: Simulation and calculation

Table 5.6 Cost benefit analysis of CP in the case of subacute infection

	Compensation		
	50%	60%	70%
Number of pigs saved from infection (Head)	1,989	2,231	2,315
Benefit (MGA) (a)	198,900	223,100	231,500
Cost (MGA) (b)	54,630	78,925	97,845
SBCR (a/b)	**3.64**	**2.83**	**2.37**

Source: Simulation and calculation

Control of subacute infection is more cost effective because of its higher benefit and lower cost. The benefit is higher because, as mentioned previously, ASF spreads more in the case of subacute. Consequently, by culling some of the infected pigs, the number of infected pigs being sold will decrease. The cost also is lower because fewer pigs are dead due to ASF compare to the case of acute infection.

5.3.4 Discussion

a- Validity of the model

Data that shows the prevalence rate of ASF outbreak in the study area is unavailable. Therefore it is impossible to compare the result of the simulations of no CP situation, which show a morbidity rate of 38% and 43% for acute and subacute form of infection, respectively.

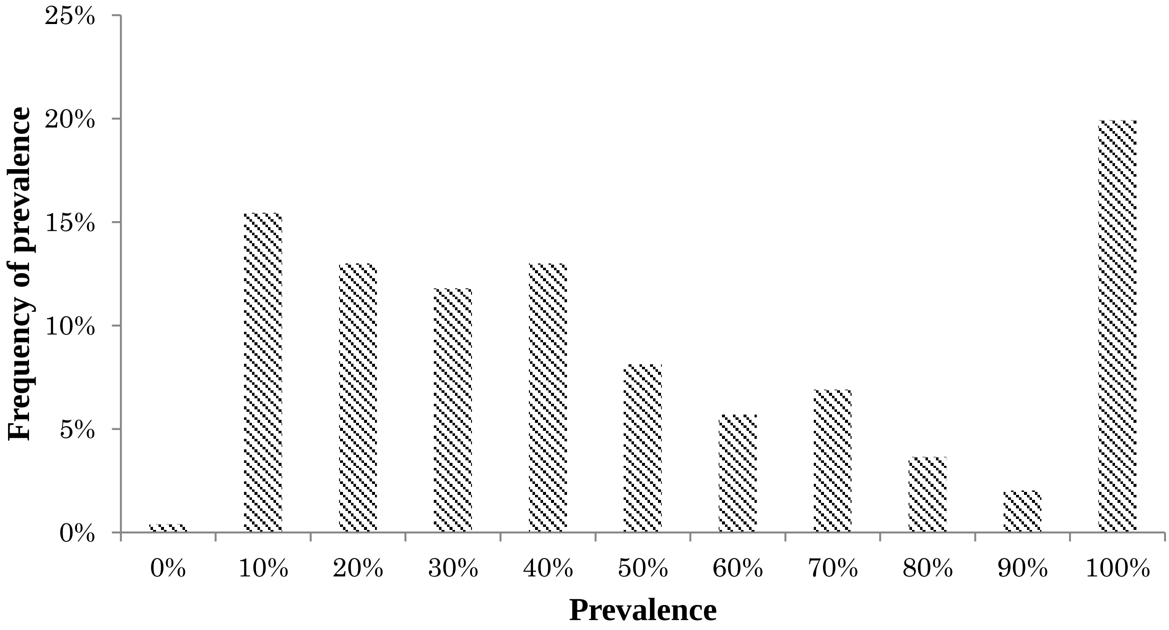

Figure 5.11 Morbidity rate of ASF in Madagascar

Source: Department of veterinary service Madagascar

However, in comparison to the epidemiological data collected from 246 communes[22] by the Department of Veterinary Services across Madagascar between 2004 and 2014[23], a prevalence of 30% or 40% can be seen at a frequency of 12% and 13% respectively in Figure 5.11. In addition, the average of the prevalence from those actual data is 46%. Therefore, we can conclude that our simulation reflects the reality.

b- Timing of intervention

It was shown that a CP that takes place 3 weeks after the first case of ASF results to a fewer number of infected pigs. The following figures (Figure 5.11and 5.12) shows with a compensation of 50%, there are more pigs infected if the intervention happens only 8 weeks after the first case rather than at 2 weeks; whether it is an acute infection or subacute infection. The number of dead pigs due to ASF also follows the same pattern (Figure 5.13 and 5.14).

[22] Administrative unit in Madagascar

[23] Data available from the Department of Veterinary Services, Ministry of Livestock, Madagascar, upon request.

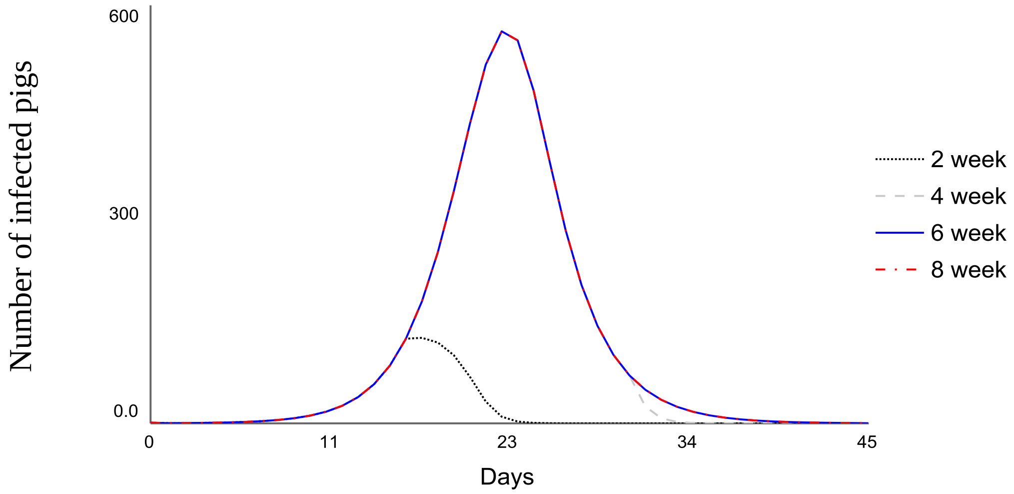

Figure 5.12 Number of infected pigs according to the timing of intervention in the case of acute infection

Source: Simulation

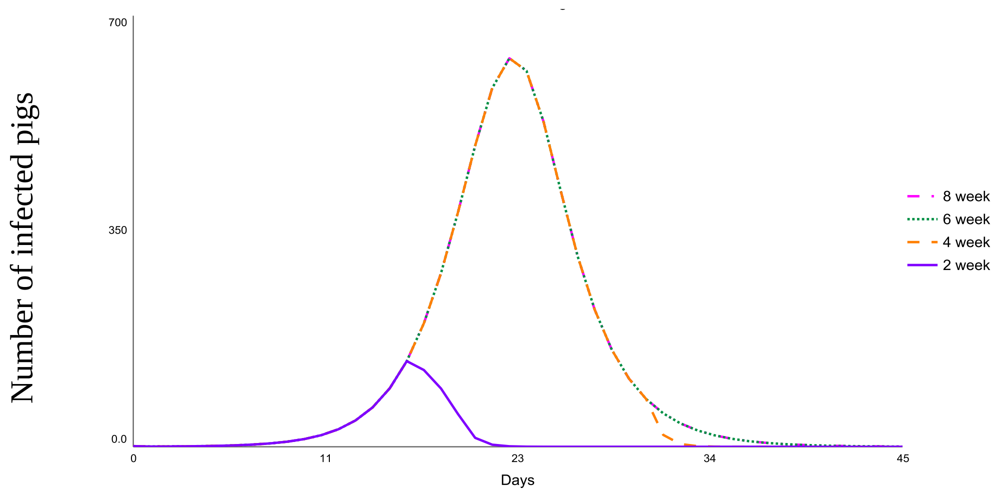

Figure 5.13 Number of infected pigs according to the timing of intervention in the case of subacute infection

Source: Simulation

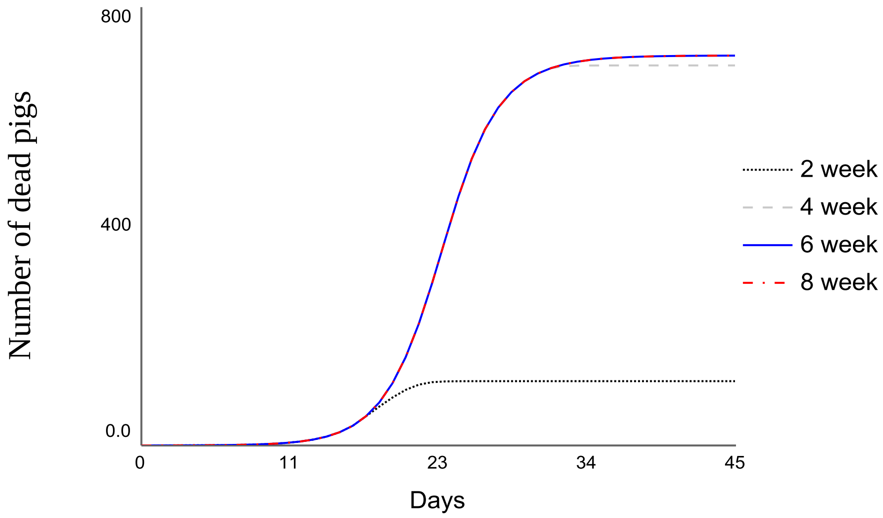

Figure 5.14 Number of dead pigs according to the timing of intervention in the case of acute infection

Source: Simulation

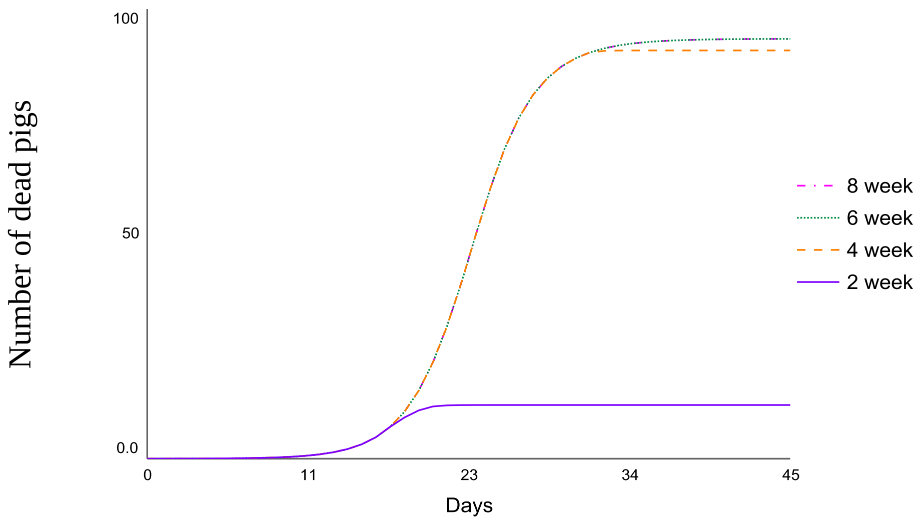

Figure 5.15 Number of dead pigs according to the timing of intervention in the case of subacute infection

Source: Simulation

Some period of time is needed to confirm ASF due to the symptoms similarity to CSF, and it can be longer when the test should be done outside the country. However, the more government waits for the intervention, the more pigs will be infected. Thus, it is then recommended starting the intervention as early as possible by skipping the official step shown in Figure 2.14 and sending the sample directly to the AHPD for laboratory testing.

c- Impact of fihavanana on the ASF spread

Initially, one might expect that *fihavanana* should have a positive effect on society by encouraging people to support each other. Contrariwise, this study demonstrates that *fihavanana* is one of the sources of ASF spread, implying a negative economic impact on pig production. From Table 5.3 and 5.4, it can be seen that when farmers have to support each other (without CP), more pigs are infected compare to the situation with CP. Therefore, the government should discourage farmers from following *fihavanana* in the case of an ASF outbreak. However, a farmer whose pig was infected by ASF needs financial support due to his income loss. For that reason, the government should give support to that farmer, such as by providing compensation to that farmer. In the scenario with a CP, the government bears the cost of culling, and farmers' cost is the loss of pig due to death. However, famers receive the benefits. Nevertheless, putting money toward a CP for ASF control could be a means for the government to support small-scale farms in the case of income reduction. Moreover, this study shows that a CP is cost effective. The reduction of the spread of ASF due to farmers reporting cases and receiving compensation can be interpreted as a positive externality, which means that the farmer receives compensation for his income loss but at the same time prevent another farmer's income loss. That positive effect should be emphasized when campaigning for ASF reporting because farmers will not need to buy contaminated meat from their neighbors because of *fihavanana*.

Consequently, it is recommended to use compensation as a tool to reduce the spread of ASF in Madagascar. However, compensation encourages moral hazard (Gramig et al., 2009) in the sense that if a CP is implemented, some farmers may neglect the prevention of infection. Therefore, only farmers who put in place significant biosecurity measures should be compensated. Moreover, the majority of farmers are practicing swill feeding and farming on a small scale; hence, it can be difficult to eliminate swill from the pigs' rations. The permanent confinement of pigs, especially during an ASF outbreak, should be monitored. Even though, together with the cost of culling, monitoring represents an extra administrative cost, the benefit is higher than the cost.

d- Government's budget

For a compensation of 50% of farm gate price of meat, with an average live finishing pig of 70 kg, and a price of 6,000 MGA/live weight kg; the budget needed for compensation is presented in Table 5.7.

Table 5.7 Budget needed for CP

	Acute infection	Subacute infection
Number of culled pigs (Head)	654	802
Budget needed for compensation (MGA)	137,340,000	168,420,000
Budget needed for administrative cost (MGA)	41,202,000	50,526,000
Total budget needed (MGA)	178,542,000	218,946,000

Source: Simulation and calculation

Compare to the budget allocated to the direction of veterinary service, the budget needed for a CP represents about 9.5% to 11.6% of the total budget which is about 1.9 billion MGA (Ministry of finance, 2015). It is relatively high because the pigs in the study area represent only 1.08% of the pigs in the whole country. However, if the government reallocates some money from the crop development to the budget for livestock (see Chapter 2), CP is financially feasible. Another option is also to use the fund from foreign aid for compensation since it is cost effective.

5.4 Conclusion

Majority of farmers practice swill feeding. Farmers manifest *fihavanana* by buying ASF-contaminated pork, which leads to ASF infections on their farms

This study demonstrates the complex interrelationship between the social and economic behavior of farmers and the biological characteristics of ASF in the spread of ASF. Reporting ASF cases instead of selling ASF-infected pigs was shown to reduce the spread of the disease and the duration of outbreak, indicating that reporting is an important factor in controlling farmers' behavior. Even a low reporting rate can generate a benefit higher than the cost regardless of acute or subacute infection. Therefore, it is recommended to discourage farmers from following *fihavanana* in the case of an ASF outbreak. Consequently, the government should provide compensation as support to the farmers, and, thus, the impacts of ASF outbreaks will decrease.

CHAPTER 6

General discussion

Recently, the number of ASF outbreak decreases every year (Figure 2.12), although the government's intervention in the ASF control was minimum. The most probable reason of the reduction of yearly outbreak is that the pig population has been decreasing until 2001 and starts to recover since then but has not reached yet the situation prior to the first ASF outbreak (Figure 2.8); because large pig population is also a risk factor of ASF (Penrith et al., 2013). Therefore, the Malagasy government should always be ready for an eventual big ASF outbreak when the pig population recovers or becomes larger.

6.1 Farmers' income and public health concern

Farmers who wrongly think that ASF is a zoonotic disease consider selling of ASF infected pigs as a sensitive behavior. Sometimes, farmers prioritize human safety over their income, such as the case of farmers in one region in India where the majority of farmers properly dispose the carcass of zoonotic infected animals regardless of their income level (Rajkumar et al., 2016). Farmers' correct knowledge about the diseases of being zoonotic has then helped for the diseases control.

In contrast, our result in Chapter 3 shows that even those farmers who are concerned about public health still sell the ASF infected pigs. Besides, farmers who have the correct knowledge of ASF as being a non-zoonotic disease are less likely to accept compensation when reporting ASF cases. Those findings are in line of that of Çakmur et al. (2015), which found that 80% of farmers have a positive attitude towards disposal of animal carcass contaminated with zoonotic disease, but only 22.5% of the farmers actually do it. In short, farmers are concerned about public safety. However, their need of income can be more important to them than other people's safety. It is also the case in Zimbabwe where about 60% of farmers sell the meat of cattle dead from anthrax to uninformed consumers, whilst more than 75% of farmers indicated that they would never eat meat from cattle found dead (Chikerema et al., 2013). This situation highlights our recommendation that compensation is needed to stop farmers from selling infected animals, especially if the disease is not of public health concern.

6.2 Incentive and punishment for farmers

Implication of policy makers in the control of ASF is required in for the eradication of ASF (Sánchez-Vizcaíno et al., 2012). Our findings in Chapter 3 suggest that the law that prohibits selling of ASF infected pigs should be enforced, which suggests farmers' illegal behavior should be fined. With the law, compensation might be an incentive for the farmer to report ASF if he can maximize his utility. In other words, farmers are willing to accept compensation if their utility from reporting is equal to or larger than any other utility they can get elsewhere.

This situation can be theoretically explained by principal agent model (based on Starbird (2005)) and following the idea of Gramig et al. (2009), namely that a fine would induce reporting. The government is the principal, and the farmer is the agent. That is, in order to maximize the government's utility for a limited budget for ASF control, it wants to create an incentive for the farmer to ensure that he will stop selling ASF-infected pigs and will report an infection to the government. Under imperfect information, where the government does not have information about farmer's behavior, the relationship between the government and pig farmers is represented by Equations (6.1) to (6.2). Equation (6.1) denotes the government's maximization of its utility for a limited budget for ASF control depends on the utility of farmers who report (R) and those who do not (1 - R). The utility maximization is under the constraints shown in Equations (6.2) and (6.3). Equation (6.2) represents the participation constraint, which means that the farmer's utility from the compensation should be at least as high as a certain minimum level $\underline{U}$. The incentive compatibility constraint presented in Equation (6.3) means that the utility from compensation should be higher than his expected utility from not reporting.

$Max\ E\ \{[RV(B - CPN)]\ +\ (1 - R)V[B + \alpha FN - (1 - \alpha)\delta N]\}$ (Equation 6.1)

subject to

$U[CPN] \geq \underline{U}$ (Equation 6.2)

$U[CPN] \geq \alpha U[-FN] + (1-\alpha)U[P'N]$ (Equation 6.3)

V and *U* are the principal's and agent's utility function respectively. *B* is the government's budget to control ASF. *C* is the compensation rate, *R* is proportion of farmers who report ASF cases, *F* represents the fine if farmers do not report and are detected, *P* and *P'* are the farm gate price of uncontaminated and contaminated meat respectively *(P> P')*, and *N* is the total number of pigs. As lack of reporting causes the disease to spread, let δ be the external failure cost (such as infection of the pigs in the neighborhood) of that behavior. The probability that farmers who sell ASF infected pigs will be caught by the government is α. In these equations, the farmer's effort level for implementing biosecurity measures was not considered because it might be difficult to measure in the context of Madagascar's predominantly small-scale farms.
There are three possibilities if a compensation program is implemented:

1) Farmers report to the government and receive compensation in return.
2) Farmers do not report to the government, are discovered, and therefore, pay a fine.
3) Farmers do not report to the government and undetected.

Figure 6.1 shows farmers' utility and expected utility according to their behavior. Malagasy farmers were found to be risk averse (Barrett and Moser , 2004; and Hanke et al., 2017) which allows us to use the shape of the utility function of a risk averse individual in that figure.[24]

As shown in Figure 6.1 (A), if the compensation is sufficiently high (C^H), some famers are willing to report an ASF infection as long as their utility $U^R(C^H pN)$, is higher than their expected utility (EU^{NR}) from not reporting. A low compensation (C^L) that gives a utility $U^R(C^L PN)$ lower than EU^{NR} cannot give an incentive for reporting.

In Figure 6.1 (B), it can be seen that when compensation rate *C* is given, but the probability of being caught is reduced to α' ($\alpha' < \alpha$); the utility $U^R(CPN)$ is lower than

[24] It is the traditional shape of the utility function that represents the utility of an overall gains and losses. However, the prospect theory of behavioral economics argues that people value gains and losses differently (See Appendix 6.1). The debate in the literature regarding the issue of the shape of utility function is still in progress (Wilkinson, 2008)

the expected utility $U^R(C'PN)$ which requires to increase the compensation level to C' ($C'<C$). In short, the less is the probability of farmers to being caught by the government, the higher compensation is needed.

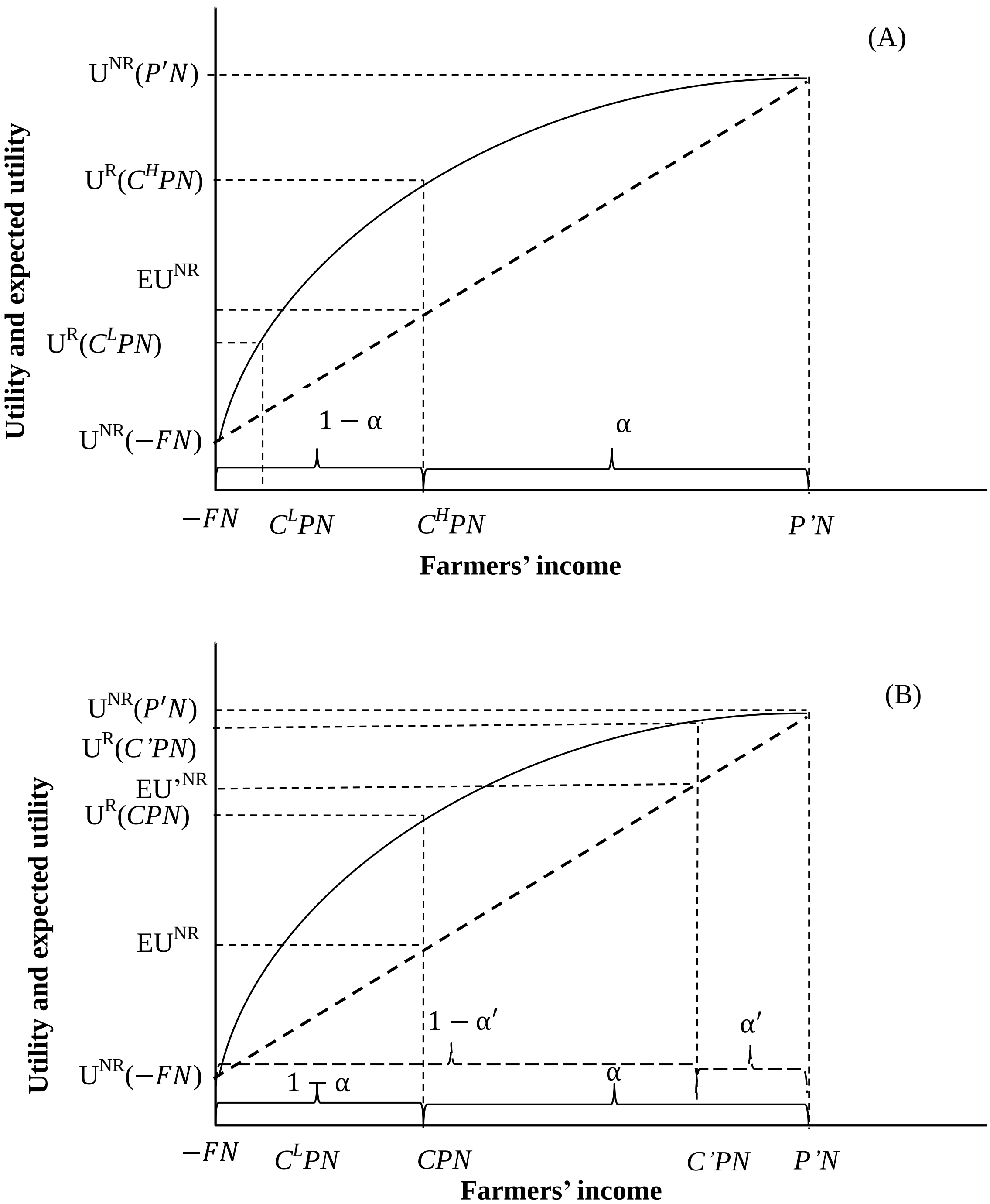

Figure 6.1Relationship between farmers' utility, expected utility, and income

This indicates that adequate compensation should be accompanied by an effective system of monitoring susceptible farms located around the infected farms. Thus, there is an adequate probability (α) that the government will detect farmers selling ASF-infected pigs illegally.

Prompt reporting has a significant effect on the spread of animal disease. Reducing the compensation for animals that die before the notification of infection significantly incentivizes early reporting by farmers (World Bank, 2006). This study did not consider WTA compensation for early reporting or notification of dead pigs.

6.3 Long term impact of compensation

A multiyear analysis for the compensation program was not done in this study because cost is incurred only when there is outbreak. Without outbreak, government does not need to spend money for stamping out. However, the impact of compensation in the long run can be discussed.

In the African continent, it is nearly impossible to eradicate ASF because of the involvement of wild pigs especially warthog (Penrith et al., 2013). This is the case of some Southern and East African countries (FAO, 2009). However, eradication of *ASFV* in domestic pigs may theoretically be feasible, on condition that there is no contact with wild pigs and ticks which are the sources of infection (Penrith et al., 2013).

In one hand, Ravaomanana et al., (2011) found that bushpig which is the only species of wild pigs found in Madagascar are not included in the cycle of ASF; but *Ornithodoros* ticks are a carrier of the virus. Moreover, in the environment, *ASFV* can survive for more than 15 weeks in decomposed blood and a minimum of 11 days in manure preserved at room temperature (FAO, n.d.-a). On the other hand, pigs that have recovered from ASF are not infectious to naïve[25] pigs. Consequently, eradication of ASF in Madagascar mainly depends on stamping out, disinfection and proper tick control.

Area where stamping out and disinfection have been done can become an ASF-free zone. The status of ASF-free zone is defined as lack of epidemiological evidence in a zone (area) of a country where ASF is notifiable. According to FAO (2009), even ASF endemic countries can possibly develop ASF-free zones through strict pig movement and quarantine controls and enhanced biosecurity of pig production units. For instance, Spain could eradicate ASF in 1995, although the eradication program has taken 30 years. One of the key factors was the elimination of all ASF infected pigs in an outbreak area along with provision of compensation for the farmers (Arias and Sanchez-vizcaino, 1999). The eradication program yielded a BCR of 1.23 (Bech-Nielsen et al., 1993). The BCR estimated in Chapter 5 is higher than 1.23 because unlike the case of Spain, the cost of serological surveillance of the pig farms after outbreak as well as the cost of

[25] Pig that has never been infected

improvement of the pig pens are not included in the estimation.

The proposed stamping out accompanied with compensation in this study is a short run solution for ASF control. However, with the stamping out, ASF prevalence should decrease with the time. Therefore, in the long run, by following the Spain example, serological surveillance and pig pen improvement should be introduced for the eradication of ASF.

To sum up, with the government's implication, eradication of ASF in Madagascar can be expected in the long term by making ASF-free zones after each outbreak.

Government's implication means there should be an annual allocated budget for ASF control rather than spending the 98% of the budget for crop production. Certainly crop production development is very important; however, the change in the proportion of population suffering from undernourishment in Madagascar is going to the opposite direction with that of the amount of supply of protein of animal origin (Figure 6.2).

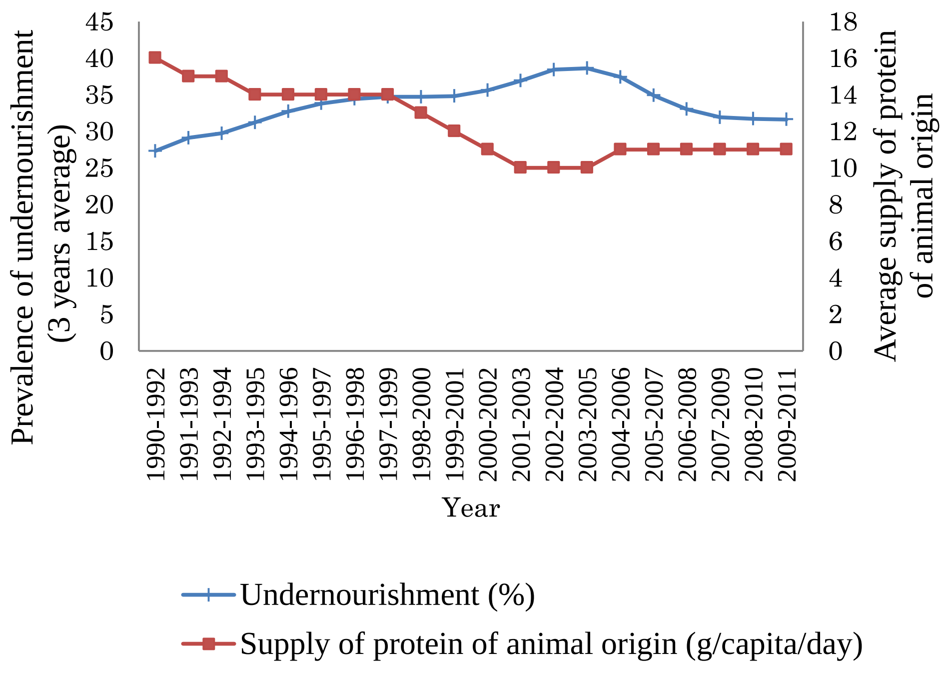

Figure 6.2 Supply of animal protein and undernourishment in Madagascar

Source: FAOSTAT, 2017

In fact the correlation coefficient between those two variables is -0.71, which indicates high correlation. In other words, when the supply of animal protein is increasing, the proportion of population undernourished is decreasing, and vice versa. It indicates that development of livestock is an effective strategy to solve undernourishment issue.

6.4 Application of the findings in sub-Saharan Africa

Like in Madagascar, selling of the pigs within the communities rather than sending it to formal abattoir is very common in Uganda and South Africa (Muhanguzi et al. 2012; Mokoele 2015). Moreover, selling of ASF infected pigs rather than letting the pig die from ASF is an ordinary practice among African farmers such as in Mozambique, Uganda, and South Africa (Penrith et al., 2007; Fasina et al., 2010; Fasina et al., 2012; Nantima et al., 2015). It indicates that the findings of our study can be adjusted to the situation of other sub-Saharan African countries.

Our study considers compensation as a measure to stop farmers from selling ASF infected pigs and report the ASF suspicion to the government (Chapter 4). However, another case that needs provision of compensation is when farmers sell massively at low price their pigs (infected and non-infected) during outbreak in Nigeria (Muwonge et al., 2012). Both cases cause ASF spread. Nonetheless, the latter one additionally leads to a decrease of pork price in the market which results to an income loss for other farmers even their pigs are not infected. Because farmers are willing to sell their pigs at a low price during outbreak, our finding that a compensation which is lower than the farm gate price of pork should be given to farmers is then valid regardless of farmers' reaction to ASF outbreak.

Absence of public safety net has lead African people to develop a culture of "force mutual help" (Firth, 1951). To our knowledge, there is no study related to the impact of that African culture in the spread of animal disease. However, the culture of mutual help which socially forced wealthy sub-Saharan African entrepreneurs to redistribute their income to the member of their family, has led to the development of informal sector because formality indicates economic success (Alby et al., 2013). This negative economic impact of social norm in Africa is similar to that of *fihavanana* on the spread of ASF in Madagascar. It indicates the need of sub-Saharan governments' effort in supporting poor farmers such as in case of ASF outbreak.

Appendix 6.1 Prospect utility theory

According to the prospect utility theory, people value gains less than losses. The prospect utility function represents the difference in utility that is achieved as a result of a certain amount of gain or loss. As shown in Figure 6.3, the absolute utility of gaining A amount of money ($U(A)$) is less than the absolute utility of losing A ($U(-A)$).

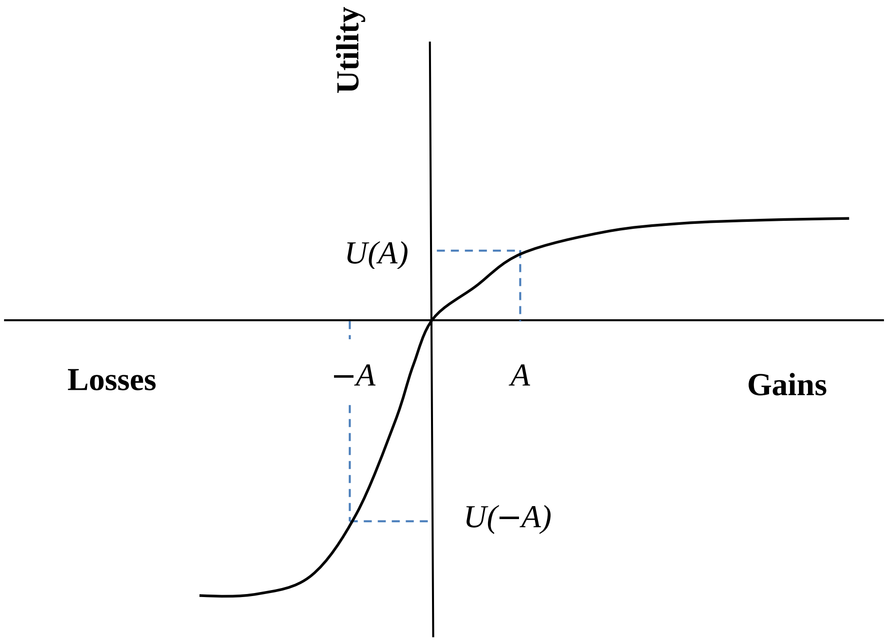

Figure 6.3 Prospect utility theory function

CHAPTER 7

Conclusion

The general purpose of this study was to draw policy implications for a successful control of ASF by focusing on farmers' behavior. The farmers' behavior considered in this study was selling of ASF-infected pigs, accepting compensation and showing of mutual support by buying ASF infected meat. Those are factors that influence the spread ASF.

Despite the law, a significant proportion of farmers sell ASF infected pigs, even those who think ASF is harmful to human. Fewer farmers who were found to have high level of knowledge about ASF sell ASF infected pigs compare to those with low level of knowledge. These results confirm our first hypothesis that farmers illegally sell the ASF infected pigs.

Instead of selling the ASF infected pigs, farmers are willing to accept compensation that is less than the farm gate price of non-infected pigs, and will inform the government about ASF suspicion in their farms. It means our second hypothesis that financial compensation might be an incentive for farmers to report ASF, is confirmed. Nevertheless, farmers who know that ASF is a non-zoonotic disease are less likely to accept compensation than those who think ASF can affect human. In short, farmers' knowledge about ASF also plays an important role in their behavior.

During an outbreak, if the government choses to intervene in the ASF control by giving compensation and slaughter the infected pigs, the simulations show that fewer pigs become infected, compare to the current situation where compensation is not available. Moreover, although it takes costs, the benefit is shown to be higher than the cost, especially when the ASF is in its subacute form. Additionally, the timing of intervention has a significant impact on the number of infected pigs; the earlier, the better. The third hypothesis which is ASF can be controlled cost effectively by considering social norm is also confirmed.

For a successful control of ASF in Madagascar, the government's intervention is very important to guide farmers' behavior. Therefore, the government should improve farmers' knowledge about ASF, and enforce the law that bans selling of infected pigs by farmers. As an accompanying measure, compensation should be given to the farmers in order to stop the behavior of selling of ASF infected pigs, receive the information about the presence of ASF in the farm, and end the necessity of mutual support among farmers. Government's intervention in ASF spread can help developing the livestock sector which can result in poverty reduction among farmers and decrease of Malagasy population's undernourishment in Madagascar.

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要約

農業は、アフリカの農村生活を支える主要な産業である。特に、多くのアフリカの農家は畜産に多くを依存している。ほとんどの養豚農家は一戸当たり10頭未満の小規模経営のなか、豚は主要な収入源、緊急資金源、貯蓄源となっているのである。したがって、家畜疾病はアフリカの畜産部門にとって大きな脅威となる。最も懸念される豚の疾病の一つであるアフリカ豚コレラ（ASF）は、アフリカの28カ国で流行しており、その致死率は100％に近いため経済的に多大な影響を与える。農家の生活を守るために、ASFの対策は必要不可欠といえる。

マダガスカルでは、豚は農家の主要な所得・貯蓄源である。さらに、国内の豚生産は国内消費に対して不十分であり、生産拡大が望まれている。しかし、ASFはマダガスカルにおいて風土病と化しており、農家にとって絶え間ない脅威となっている。したがって、豚生産の発展を保証するためにはASFを根絶する必要がある。ASF対策の主要な戦略はスタンピングアウトであるが、患畜および擬似患畜の報告において農家の協力が求められる。先進国における家畜疾病の対策では、と畜された家畜に対して補償が支払われるため、報告に対するインセンティブが与えられる仕組みになっている。しかし、マダガスカルでは、政府の予算制約と監視システムの脆弱性からこれらが未整備のままとなっている。本研究の目的は、農家の行動に焦点を当て、ASFを適切に制御するための政策的含意を提言することである。そのために、本研究は三つの視点から研究を行った。

調査は、マダガスカルの22地区のうち2番目に豚の飼養頭数が多いアナラマンガ地区で行った。最初の二つ分析に用いたデータは2013年12月に面接調査によって収集し、201戸の農家から回答を得た。また、3番目の分析に対しては2016年6月に116戸の農家を対象に調査が行われた。

現在、マダガスカルの養豚農家は法律によってASF感染豚の販売が禁止されており、疾病の拡大を防ぐためにASFの疑いがある場合は政府に報告することが推奨されている。しかし、スタンピングアウト対策は行われておらず、代わりに感染豚を隔離することが勧められている。既往研究では、家畜疾病に関する農家の知識が直面する疾病に対する行動に影響を及ぼすとしており、マダガスカルでも同様の状況が考えられる。これはつまり、農家はASFの拡大要因に関する知識が欠乏している場合、法律で規定されているが故にセンシティブな行動と考えられる感染豚の違法な販売を行っている可能性を示している。一つ目の課題は、ASFを拡大させる農家のセンシティブな行動を抑制するために政策措置を示すことである（第3章）。疾病についての農家知識を評価するために、ASFの重篤度、感染経路、症状に関連する質問を使用してアンケート調査を行った。さらに、ASF感染肉を販売しているかどうかについて、センシティブな行動に関与する人々の割合を、一つのサブサンプルには間接的、別のサブサンプルには直接的に質問し計測するアイテムカウントテクニック（ICT）を用いて明らかにした。ICTによる推定値が直接的な質問の割合よりも統計的に高い場合、その行動はセンシティブであると考えられる。知識の質問項目に関する興味深い結果の一つは、28％の農家が「ASFが人間に負の影響を及ぼす」と間違って信じていたということである。ICTの分析からは、ASFを経験したことのある農家のうち約73.2％がASF感染肉を販売していたことがわかった。当該推定値は、直接

的な質問によって得られた割合と統計的差異はなかった。ASFが人間に影響を及ぼす可能性があると信じている農家のグループでは、ICT推計値は直接質問の割合よりも高い値を示した。つまり、ASF感染豚を販売している農家は、法律というよりも消費者に害を及ぼす可能性を懸念して、その事実を隠しているということである。ASFの大流行に対して、マダガスカル政府はより厳格に法を適用すべきであり、スタンピングアウト対策によってASFを管理しなければならない。

ASF感染豚の販売を禁止する法律が厳格に施行されれば、感染豚を有する農家は所得ショックに陥る。スタンピングアウト対策を成功させるためには、農家がASFのケースを政府に報告することが求められる。一方で、豚の健康状態は農家だけが持っている情報であり、政府には明らかにしたくないかもしれない。この状況は情報の非対称性として知られている。二つ目の課題は、ASFを効果的に管理するため、農家の経済的インセンティブを明らかにすることである（第4章）。先の分析では、ASFに関する農家の知識が彼らの行動に影響することが判明したため、補償に対する彼らの態度にも影響を与えていると仮定する。仮想評価法（CV）を用いて、淘汰された豚の受入補償額を推計した。結果、ASFの経験のない農家は、ASF経験農家と比較してその症状に関する知識が少ないことが明らかとなった。また、CVの結果は、補償が増加するにつれてより多くの農家がASFを報告する意志があることを示唆している。しかし、報告の確率は農家に関連する特性、すなわち、農家のASFに関する知識、豚コレラワクチンの摂取、ASFの経験に依存する。これらの結果は、適切な財政的補償を提供することが、ASF発生の報告を推奨するために重要であることを示している。それでも、ASFが人の健康に有害ではないことを知っている農家が補償の受け取りを拒絶することを防ぐために、ASFの経済的影響についての意識喚起キャンペーンを実施する必要がある。言い換えれば、ASF感染に関する農家の意識を改善すべきである。

補償プログラムがなければ、農家はASF感染肉を販売して所得を回復させるだろう。さらに、他の農家はASF感染肉を購入することによって彼らを支援するであろう。その行動は、マダガスカルの相互支援行動を導く社会的規範である「fihavanana」によって推奨されている。一方で、ASF感染肉を購入することは、飼料給与時のASF感染拡大に対する危険性をともなう。それにもかかわらず補償プログラムを構築できない理由は、政府の予算制約にある。したがって、三つ目の課題は、「fihavanana」を考慮したASF管理に対する経済的インセンティブの影響を検討することである（第4章）。生物学的、経済的、社会的要因などASF拡大に影響を与えると考えられる様々な要因をシステムダイナミックモデルに入れ、ASFの動的傾向をシミュレートした。また、農家に与えられる補償水準を生産者価格の50%から70%に変化させることによって異なるシナリオを推計した。その後、費用対便益分析を実施した。結果は、ASF感染豚を購入したすべての農家が、仲間の農家に対する扶助行動の推進要因として「fihavanana」の存在をあげていた。さらに、システムダイナミックモデルは、農家が感染豚の淘汰に対する補償を受け取った場合、補償が与えられていない場合に比べて感染豚の数が少なくなることを示している。また、補償戦略は、補償水準にかかわらずその利益が費用よりも高いという意味で費用便益が高い。したがって、補償の提供に加えて、政府はASFの発生時に農家が「fihavanana」を実施するのを制止すべきである。

ASFの適切な管理のためには、農家の知識向上とASF感染豚販売を禁止する法律の厳密な実施が求められる。また、付随的措置としてASFケースの報告と、相互支援必要性の回避という二つのインセンティブを与えるために、農家に財政的補償を付与すべきである。一方、現在の政府予算は補償プログラムの実施に十分ではない。ほとんどの政府予算は作物生産の開発に当てられているが、マダガスカルの動物性たんぱく質供給不足による栄養不足を改善するために畜産部門へ多くの資金を投入する必要性がある。

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Dedication

I dedicate this work to

My husband: Fetra J. Andriamanohiarisoamanana
For his unconditional love and unfailing support.

My children: Nirina Omentsoa, Jaofetra Tiana, and Narifetra- Andriamanohiarisoamana
For their understanding and encouragement.

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