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M. DINH BAO TRUONG

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Directeur(s) de Thèse :

M. STEPHANE BERTAGNOLI

MME FLAVIE GOUTARD

Rapporteurs :

M. BENOIT DURAND, ANSES

M. STÉPHAN ZIENTARA, ANSES

Membre(s) du jury :

M. CLAUDE SAEGERMAN, UNIVERSITE DE LIEGE, Président

Mme FLAVIE GOUTARD, CIRAD MONTPELLIER, Membre

M. STEPHANE BERTAGNOLI, ECOLE NATIONALE VETERINAIRE DE TOULOUSE, Membre

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Abbreviations and acronyms

ARAHIS: Regional Animal Health Information System of the Association of Southeast Asian Nations

BCA: Benefit-cost analysis

BCR: Benefit-cost ratio

CAHW: Community of animal health workers

Ci: Confidence interval

CI: Credible interval

DAH: Department of Animal Health, subordinate of MARD

DVS: District veterinary station

EA: East Africa

ELISA NSP 3ABC: Non-structural 3ABC protein enzyme-linked immunosorbent assay

Euro-SA: Europe-South America

FAO: Food and Agriculture Organization

FMD: foot-and-mouth disease

FMDV: FMD virus

GDP: Gross domestic product

HCPC: Hierarchical clustering on principle components

HS: Haemorrhagic septicaemia

ISA: Indonesia

MARD: The Vietnam Ministry of Agriculture and Rural Development

Md: Median score

ME-SA: Middle East-South Asia

NLU: Nong Lam University

NPV: Negative predictive values

OIE: World Organisation for Animal Health

OR: Odds ratio

PCA: Principle component analysis

PE: Participatory epidemiology

PPV: Positive predictive values

Prev: FMD animal-level prevalence among the animals investigated

PRRS: porcine reproductive and respiratory syndrome

RAHO: Region animal health office

rRT-PCR: real-time reverse-transcription polymerase chain reaction

SAT: Southern African Territories

Sd: Standard deviation

Se: Sensitivity

SEA: South-East Asia

SEACFMD: South East Asia and China Foot and Mouth Disease

SMS: sum of median scores

Sp: Specificity

Stat.: statement. Only used with number to indicate the particular statement(s) that is (are) mentioning in Chapter 5

Sub-DAH: Sub-Department of Animal Health

USA: The United States of America

USD: US dollars

VND: Vietnam Dongs (Vietnamese currency)

WAHIS: World Animal Health Information System

Abstract

This PhD thesis aimed at evaluating the contribution of participatory epidemiology (PE) to improve the foot-and-mouth disease (FMD) surveillance and control activities, especially the involvement of farmers at local level. The first objective aimed at assessing the effectiveness of the FMD surveillance and vaccination strategy at local level by using PE approach. The second objective aimed at assessing the feasibility of applying PE tools to improve the involvement of farmers in the FMD surveillance in Vietnam.

PE methods performed in our study included informal interviews (focus group and individual), scoring tools (pairwise ranking, proportional pilling, disease impact matrix scoring and disease signs matrix scoring), visualization tools (mapping, timeline, flow chart) and sociological tools called Q methodology. 122 focus groups, 467 individual interviews, 339 questionnaire surveys were performed during two field studies in 2014 and 2015. 409 sera and 152 oesophageal fluids were taken. Conventional questionnaire surveys, Bayesian modelling and laboratory test (ELISA and rtRT-PCR) was used to validate the performance of PE in FMD surveillance.

Disease was considered by farmers as the most important issues in animal production. FMD was the most important disease for dairy cattle production, followed by haemorrhagic septicaemia. For beef cattle production, it was recorded in reverse order. The most important disease for pig production was porcine reproductive and respiratory syndrome while FMD was ranked fourth. Farmers showed their abilities in differential diagnostic of important diseases based on its clinical symptoms.

Sero-prevalence of FMD were estimated at 23% for population 1 (bordering with Cambodia) and 31% for population 2 (locating far from the border), respectively. Sensitivity and Specificity of PE were found to be 59% and 81%, respectively. The positive and negative predictive value were found to be 48% and 86% for population 1 and 58% and 81% for population 2, respectively. The presence of serotype A, lineage A/Asia/Sea-97 and serotype O with two separate lineages, O/ME-SA/PanAsia and O/SEA/Mya-98 supported virus circulation through trans-boundary animal movement activities.

Dairy farms frequently applied quarantine, disinfection and vaccination as prevention methods. Beef farms preferred cleanliness and good husbandry management practices. Pig farms considered that all prevention methods had the same importance.

Three distinct discourses “Believe”, “Confidence”, “Challenge”, representing common perceptions among farmers and accounting for 57.3 % of the variance, were identified based on Q methodology. Farmers take vaccination decisions themselves without being influenced by other stakeholders and feel more secure after FMD vaccination campaigns. However, part of the studied population did not consider vaccination to be the first choice of prevention strategy.

The benefit-cost ratio of FMD vaccination for dairy cow production in large-scale and in small-scale and meat cattle production were 5.9, 5.0 and 1.8, respectively. The sensibility analysis showed that FMD vaccination was profitable for all of production types even through the increase of vaccine cost and decrease of market price of milk and slaughter cattle.

From the focus groups organized at sentinel villages, 18 new villages, 40 farms were identified as potentially infected by FMD. 77 out of 128 sampled animals were confirmed positive for FMD, with viral serotypes O and A. Sensitivity and specificity of participatory surveillance were recorded at 0.75 and 0.70, respectively. The effectiveness of PE in FMD surveillance system to detect outbreak in Vietnam was demonstrated.

It was demonstrated that vaccination was the most effective and economic method to prevent FMD. Through the application of simple, adaptive tools which facilitate direct and active participation of farmers, PE allowed to reach a better acceptability of surveillance and to obtain qualified information.

Résumé

Cette thèse porte sur l'analyse des apports des approches participatives épidémiologiques (PE) dans l'amélioration de la surveillance de la fièvre aphteuse (FA), en particulier dans l'implication des éleveurs à l'échelle locale. Le premier objectif était d'évaluer l'efficacité de la surveillance et de la vaccination contre la FA à l'échelle locale en utilisant l'approche PE. Le deuxième objectif était d'évaluer la faisabilité d'application d'outils de PE pour améliorer l'implication des éleveurs dans la surveillance de la FA au Vietnam.

Les méthodes de PE employées ont été des entretiens informels (en groupes ou individuels), des outils de notation (classement par paires, empilement proportionnel, matrice de notation), des outils de visualisation (cartographie, lignes de temps, diagramme d'écoulement) et un outil sociologique nommé méthode Q. Au total, 122 entretiens en groupe, 467 entretiens individuels, 339 questionnaires ont été effectués en 2014 et 2015. De plus, 409 sérums et 152 fluides d'œsophagiens ont été prélevés. Les enquêtes par questionnaire, des tests ELISA et de rtRT-PCR, et la modélisation Bayésienne ont été utilisés pour valider la performance de l'approche PE dans la surveillance de la FA.

La maladie a été considérée comme le problème le plus important en production animale. La FA était la maladie la plus importante en production laitière, suivie par la septicémie hémorragique. Pour la production de bovins allaitants, l'ordre était inversé. La maladie la plus importante pour la production porcine était le syndrome dysgénésique et respiratoire porcin, tandis que la FA était classé en quatrième position. Les éleveurs ont développé des savoir-faire en matière de diagnostic différentiel des maladies, selon les symptômes observés.

La prévalence sérique de la FA a été estimée respectivement à 23% pour la population 1 (proche la frontière du Cambodge) et 31% pour la population 2 (loin de la frontière du Cambodge). La sensibilité et la spécificité de l'approche PE ont été estimés à 59% et 81%, respectivement. Les valeurs prédictives positive et négative ont été estimées à 48% et 86% pour la population 1, et 58% et 81% pour la population 2. La présence du sérotype A, de la lignée A/Asia/Sea-97 et du sérotype O, lignées O/ME-SA/PanAsia et O/SEA/Mya-98 signale la circulation du virus par des mouvements transfrontaliers des animaux.

Les fermes laitières ont fréquemment appliqué la quarantaine, la désinfection et la vaccination comme méthodes de prévention. Les fermes de bovins allaitants ont préféré appliquer des mesures d’hygiène et de bonnes pratiques de gestion de l'élevage. Les fermes porcines ont considéré que toutes les méthodes de prévention avaient la même importance.. Les éleveurs ont pris eux-mêmes la décision de vacciner et se sont sentis plus en sécurité après la vaccination contre la FA. Cependant, une partie de la population étudiée n'a pas considérée la vaccination comme le premier choix de prévention. L'analyse coût-bénéfice de la vaccination contre la FA a montré que la vaccination était rentable pour tous les types de production, y compris en cas d’augmentation du coût de la vaccination et de la diminution du prix du lait et de la viande.

Dix-huit nouveaux villages sentinelles et 40 fermes ont été identifiés comme potentiellement infectés par la FA. Sur 128 animaux prélevés, 77 ont été confirmés positifs pour la FA. La sensibilité et la spécificité de l’approche PE ont été estimées à 0.75 et 0.70 respectivement. L'efficacité des outils de PE pour détecter une épizootie de FA au Vietnam a été démontrée.

La vaccination s’est avérée la méthode la plus économique et la plus efficace pour prévenir la FA. Grâce à l'application des outils simples et adaptables qui facilitent la participation directe et active des éleveurs, l’approche PE permet d'obtenir une meilleure acceptabilité de la surveillance et des informations de qualité.

List of publications and communications

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D.B. Truong, T.T. Nguyen, N.H. Nguyen, M. Peyre, S. Bertagnoli, L.B. Kassimi, F.L. Goutard. Participatory surveillance of Foot-and-Mouth Disease: a pilot system in Southern Vietnam. **In preparation for Preventive Veterinary Medicine** (Chapter 7).

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3. Posters

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CHAPTER 1

GENERAL INTRODUCTION

1.1. Smallholder production in Vietnam

1.1.1. Overview of livestock production in Vietnam

Agriculture output value for cultivation and livestock contribute 25% to gross domestic product (GDP) in Vietnam, from which livestock production occupies 32% in GDP of total agriculture output (Nguyen, 2014). In Vietnam, nearly 70% people located in rural areas, in which almost 80% of people are involved in husbandry (Hoang, 2011). The total herd of pig, cattle and buffalos in 2014 were estimated at 26.8, 5.2 and 2.5 million, respectively (General Statistic Office (GSO), 2015). Pig and beef production are ranked as first and third largest industry in the livestock sub-sector (Pham et al., 2015). In Vietnam, livestock production meet 100% local demand for pig products, 95% for poultry products, 75-80% for beef meat and only 30% for fresh milk (Dao, 2015).

Vietnamese husbandry is mainly contributed from small households (Vo et al., 2010, Nguyen, 2014; Pham et al., 2015). Smallholder farmers produce 70% of pig heads, represent 60% of pork products (Nguyen, 2014). Extensive cow-calf grazing system (usually 1-2 heads/household) practiced by smallholder farmers accounts for 70-80 % of cattle in Vietnam (Pham et al., 2015). For dairy production, approximately 20000 smallholder dairy farmers produce 80% of milk volume (Gautier, 2008). Recently the number of intensive farms has rapidly increased but systematic planning for development is still lacking (Nguyen, 2014).

Livestock production in Vietnam is characterized by high production cost and low level of animal performance, animal productivity, labour performance, and product quality (Dao, 2015). Those characteristics limit the competitive capacity of the whole industry (Hoang, 2011). Regarding top 20 of pork producing countries, total raised sow of Vietnam is ranked as 3rd, while the relative pig products is classified at 7 or 8 in 2011-2012 after China, The United States of America (USA), Germany, Spain, Brazil and

Russia. Performance of Vietnamese sow is ranked as 20th among the world pig producing countries (Dao, 2015). Labour performance in husbandry sector in Vietnam is lower than other countries, e.g. one employee can handle a farm of 1000 sows in USA while it is only 50 sows in Vietnam. Cost of pig production in USA is 25 -30% lower compared to the cost in Vietnam. Meat product from imported Australian cattle that are fattening and slaughtered in Vietnam market is cheaper in price and better in quality compared to local cattle product (Dao, 2015).

In Vietnam, input for livestock production such as breed, feed ingredients, feed additive, drug depends mainly in importation. Vietnam has imported 90% of rich-protein material, 100% of mineral and vitamin. Cost of feed production in Vietnam is 10% higher compared to others countries. Moreover, 80% of vaccines used in Vietnam are imported from 17 countries (Anonym, 2015; Dao, 2015).

Livestock production system in Vietnam face serious challenges on high risk of infectious diseases, insufficient control for importation of animal and animal product including unsafe products, especially for smallholder (Hoang, 2011). These challenges increase cost of production, create an unstable market for costumer and lost chance for exportation of animal product as well as brutally decrease the number of small farm. Moreover, livestock planning and restructuring is difficult and slowly done due to limited land resource (Hoang, 2011).

1.1.2. Smallholder challenges in actual livestock system

Smallholder farms had a higher affection risk by infectious diseases due to lack of a full biosecurity system and disease management compared to semi-structural farms. As a consequence smallholder farms get less benefit (gross margin) than semi-structural farms (Hoang, 2011). Moreover, they have to deal with higher cost of input materials (feed, veterinary consultation service, medicament) which are decided by private company, feed distributors, vet shop, veterinary pharmacological company and private veterinarians. This factor influence on their high production cost. Trade of animal output is mainly influenced by trader system and slaughter-house who receive majority of benefit in the livestock production value chain. Smallholders are not be able to decide the price of animal and they need to accept the trader's offer which is not always the good one. Moreover, actual policies aim to help large-scale farm as well as to centralize livestock zone (Minister's Office of Vietnam, 2008) could be a critical point in current livestock system for keeping smallholder farmers. Therefore smallholder farmers need to either find the way to increase the production scale to be able to touch favourite conditions or disappear naturally.

Lapar et al. (2012) indicated that small-scale pig farming households in Vietnam faced with numerous risk factors such as poor genetic stock, low quality feed, animal diseases, and lack of access to timely and reliable market information. A household perception of pig farming study found that meat price, epidemic diseases, and production cost were perceived as the most important sources of risk in pig farming (Nguyen and Nanseki, 2015). Moreover, households often lack the requisite knowledge and information related to pig husbandry which leads most of them to operate pig farms mainly in individual families (Nguyen and Nanseki, 2015). Difficulties in beef production were identified as small and fragmented pasture area, high feed cost due to importation of feed and feed ingredients, semi-legal of beef importation from neighbour countries such as Laos, Cambodia, Myanmar, Thailand (Pham et al., 2015). Dairy farmers need higher milk price, more training opportunities, financial support, equipment/supply support, availability of veterinary services, biogas facility support, cooperation and experience exchange among dairy farmers and increase in availability of land to develop of Vietnamese dairy production industry (Ashbaugh, 2010). In terms of animal disease, Unger et al. (2015) reported that foot-and-mouth disease (FMD), porcine reproductive and respiratory syndrome (PRRS), pasteurellosis, paratyphoid suum, erysipelas, porcine high fever disease, salmonellosis were the most important diseases for pig production. Some agents such as *Mycobacterium bovis* (tuberculosis bovine), *Brucella abortus* (brucellosis), *Pasteurella multocida* (heamorragic septicemia), *Leptospira interrogans* (leptospirosis), *Theileria* (theileriosis), *Fasciola* spp (liver fluke infection), *Paramphistomum* (rumen flukes infection), *Giardia* (giardiasis), *Anaplasma marginale* (blood parasite), *Babesia bigemina* (blood parasite), *Neospora caninum* (neosporosis) are reported as agent of diseases in dairy production in Vietnam (Suzuki et al., 2006). Mastitis, FMD, bloody diarrhoea syndrome are reported as important diseases affected smallholder beef production (Vo et al., 2010; Bellet et al., 2012).

1.1.3. Social stratification of farmers in Vietnam

In terms of socio stratification, farmer in Mekong delta is a majority labour force in society (55.6% of population occupation) and can be divided into 3 groups based on the agricultural surface (Bui and Le, 2010). The high rank farmer (7.2% of population occupation), medium rank farmer (29.9% of population occupation) and low rank farmer (18.5% of population occupation) occupied more than 5000 m^2, between 1000 to 5000 m^2 and less than 1000 m^2 of agricultural surface per habitant, respectively. In order to measure social stratification of farmer, two basic indicators were used such as income (material received) and academic level (requirement of work that need to be satisfied) (Le and Nguyen, 2013). Average income of people in delta du Mekong varied from 10.5 million Vietnam Dongs (VND) per year (636 US Dollars, USD) to 15.9 million VND per year (963 USD) (average exchange rate was 1 USD equal to 16500 VND in 2008). In which, income of high, medium and low rank farmer was 19.3 (1169 USD), 12.2 (739 USD) and 7.3 million VND (442 USD) per year, respectively. Their income come majority from cultivation, livestock and non–agricultural employment. Moreover, livestock is not considered as the main income source while it is ranked as second for high rank farmer and third for medium and low rank farmer. The academic level of farmer is lower than average level of the whole country, which is not satisfied the requirement of work. Farmers in delta du Mekong are characterized by small-scale household, low quality labour and unstable income (Bui and Le, 2010).

1.2. Foot-and-mouth disease in South East Asia and control policy

1.2.1. Foot-and-mouth disease in South East Asia

FMD is an extremely contagious and destructive disease that affects many species of cloven-hoofed animals, domestic or wildlife. FMD causes by an *Aphthovirus* (family *Picornaviridae*) which includes 7 majors serotypes called A, O, C, Asia1, Southern African Territories (SAT) 1, SAT 2 and SAT 3 with no cross-immunity between them (Radostits and Done, 2007). Each serotype is divided into sub-serotype with variation in antigenic regions. 70 subtypes is identified around the world (Catley et al., 2012). Serotypes of FMD virus are divided in topotypes in case that the difference between strains European-Asia nucleotide and South-Africa nucleotide is higher than 15 to 20% (Knowles and Samuel, 2001). Serotype O include 8 topotypes such as Cathay, Middle East-South Asia (ME-SA), South-East Asia (SEA), Europe-South America (Euro-SA), Indonesia-1 (ISA-1), Indonesia-2 (ISA-2), East Africa (EA) and West Africa. Only 3 topotypes are identified for serotype A and C named Africa, Asia and Euro-SA. Serotype Asia 1 has a noname topotype. 5 topotypes were discovered for SAT 1, SAT 2 and SAT 3. Based on genome analysis and antigen, serotypes of FMD virus are divided into 7 pools. Each pool comprises a group of FMD serotypes that are cross-country circulating and developing. Serotype is identified when outbreak occurs in order to select relevant vaccine applied for each pool (EuFMD, 2014). The principal virus reservoirs are water buffalo and cattle.

In mainland Southeast Asia, FMD is endemic in many countries such as Cambodia, Laos, Malaysia, Myanmar, Thailand and Vietnam (Madin, 2011). The serotypes present in this region are serotype O (the most common), A and Asia 1. Three topotypes (strains) belong to serotype O are O/South-East Asia lineage Myanmar 98 (endemic in Southeast Asia, reported in Japan in 2010, South Korea in 2010, 2014 and 2016), O/ME-SA/PanAsia (detected in Southeast Asia in late 1990s) and O/Cathay (first detected in Hong Kong in early 1990s). Topotype A/Asia/South-East Asia 97 is indigenous in SEACFMD and being reported in Korea in 2010. Topotype Asia 1/Asian is last seen in Vietnam in 2007 and in China in 2009 (Madin, 2011). As members of OIE and South East Asia and China Foot-and-Mouth Disease Campaign (SEACFMD), FMD outbreaks and status of each country member are regularly reported by Information Focal Point in countries to the ASEAN Regional Animal Health Information System (ARAHIS) and through the World Animal Health Information System (WAHIS) for immediate notification and 6-monthly disease status report. The total number of outbreak reported in region increased each year from 2012 (142 outbreaks) to 2015 (344 outbreaks) (OIE South-East Asia and China for Foot-and-Mouth Disease, 2016). The legal and illegal movement of animal between provinces and countries are considered as an important risk factor on spread of FMD in region (Cocks, 2009).

FMD was firstly recorded in Vietnam in 1898 in Nha Trang city, Khanh Hoa province. Then, this disease persisted and spread through the country with outbreak recorded in year or period of year due to lacking of surveillance system (MARD, 2015). Since 2006, Vietnam has implemented a national plan of FMD prevention and control in which include a surveillance system for outbreak recording. Therefore, outbreak information, epidemiological and molecular information were well recorded and documented. FMD outbreaks mostly occurred in northern provinces, south-central coast, central highlands and south-eastern regions in 2006; mainly occurred in south-central coast regions, northern provinces, bordering with China (Lang Son and Lai Chau) in 2007 – 2009; in 4 northern and bordering provinces such as Cao Bang, Lang Son, Dien Bien and Lai Chau in 2010; in northeast and south-central coast in 2011 (MARD, 2015). FMD outbreak data from 2006 to 2012 showed a serious epidemic occurred every 2-3 years in Vietnam (in 2006, 2009 and 2011) with an average duration of 2.5 months. Peak of outbreak occurred in March – July in 2006 and September – March in 2009 and 2011. FMD occurred mainly in most part of the country such as provinces located in Northern part of country, in South Central Coast, Central Highlands and Southeast regions, especially those bordering with China and Laos. Moreover, an average incidence risk was 5.1 (95% CI 4.9 -5.2) FMD infected commune per 100 commune-years. This incidence risk varied according to year and geographical location. FMD outbreaks occurred repeatedly in more than 60% of communes in hotspot areas (Nguyen et al., 2014). The FMD prevalence was highest in buffalo (33.4%), followed by cattle (24.1%) (Nguyen et al., 2014) and pig (less than 1%) (Nguyen et al., 2014).

1.2.2. Prevention and control policy

FMD causes direct severe economic loss due to mortality of young animal, reduction in milk and meat production and in productivity (Knight-Jones and Rushton, 2013). FMD represents a major obstacle to international trading of animal and animal’s products because the one country that presence of FMD is block its exportation of livestock products to free-status FMD countries. Furthermore, eradication and fight against FMD are extremely important. For those reasons, FMD was considered as one of the most important disease in livestock (Perez et al., 2008). In order to tackle FMD infection and epidemic, disease management approaches have been implemented in Southeast Asia including surveillance, risk analysis, animal movement control and vaccination.

Vaccination against FMD is a key element in protection of susceptible hosts and thus control of the disease. In Southeast Asia this tool is still not widely used due to limited resource and regulatory constraints. Brunel, Philippine and Singapore are considered as free FMD countries, vaccination is not applied as control method. Other countries in region such as Malaysia, Thailand and Vietnam have applied a mass vaccination program focused on large ruminants with government fund. In Laos and Myanmar, vaccination campaign which has been funded by the Australian government and facilitated by the OIE SRR-SEA since 2012 has been applied and helped to reduce the disease occurrence. The selected location for vaccination campaign in Laos and Myanmar was based on the endemic nature of infection in the area and the importance of livestock trade within and beyond the country (OIE South-East Asia and China for Foot-and-Mouth Disease, 2016). In Cambodia, it was noted that irregular vaccination campaign has been implemented in the country (Tum et al., 2015).

Surveillance networks have been developed at national and regional levels (e.g. SEACFMD). Animal health surveillance and control systems are complex and influenced by epidemiological, sociological, economic and political drivers. The efficiency of surveillance and control program against FMD is challenged by the under reporting issue (Madin, 2011). Indeed FMD is often not considered as a priority for the farmers with its limited mortality rate even though the impact on the production yield could be important. However FMD causes significant financial losses for small producers and therefore threatens the livelihood and food security of the poorest communities' worldwide (Madin, 2011).

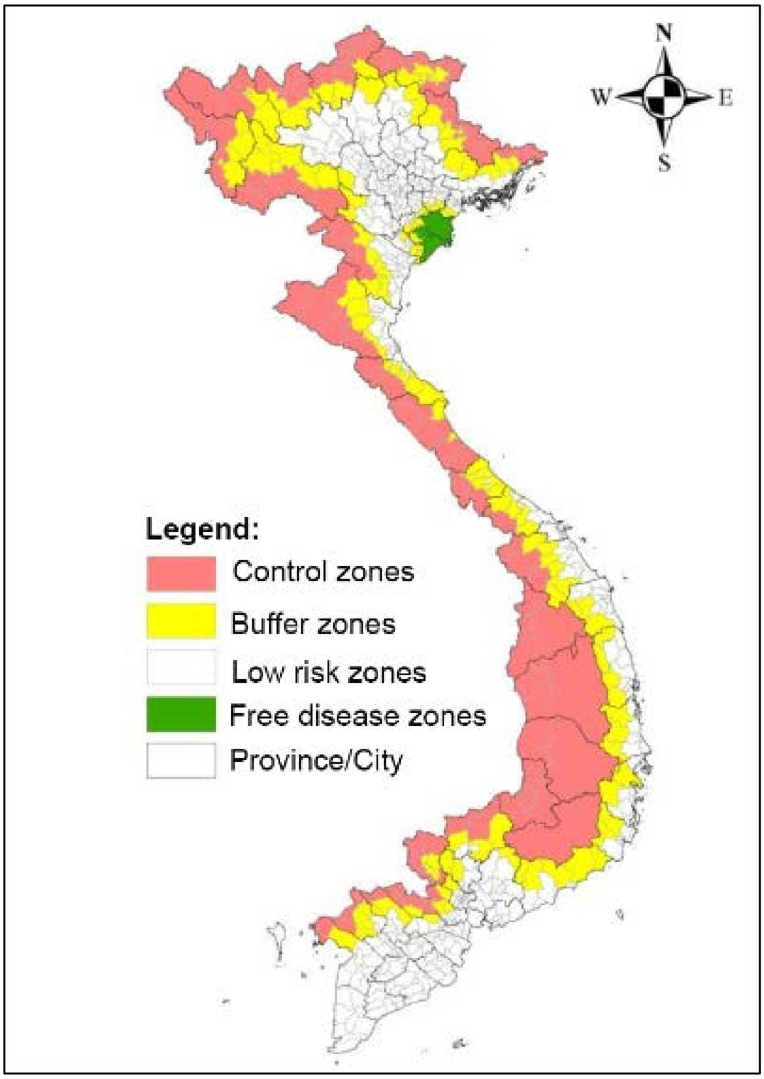
Control on animal movement at regional scale is either non-existent or not adequately enforced. Movement restriction creates hardships, particularly in smallholder-based system (OIE South-East Asia and China for Foot-and-Mouth Disease, 2016). Recent study on economic impacts of FMD acknowledged that difficulties in achieving FMD control in smallholder systems were mainly due to extensive contacts between farmers, intensive trading and dependent on communal grazing, coupled with fewer visible incentives to control FMD and logistical difficulties in achieving high levels of vaccine coverage (Knight-Jones and Rushton, 2013).

In terms of FMD control, smallholder-based and mixed-farming system, mainly practiced in the Asian agriculture cause specific problem. A large proportion of animal are kept in traditional small and backyard settings, often free ranging with a substandard biosecurity and limited resources. Women farmers play an important role as livestock caretakers. However, women has a poor access to market, services, technology, information and credit that decreases their ability to improve productivity and benefit from a growing livestock sector (FAO, 2003).

In Vietnam, biosecurity methods are applied in order to control FMD. Those methods include disinfecting the transportation means, issuing health certificates for animal trade, requiring cloth changing at farms' entrance and exit. Husbandry zone requires a fence to isolate with exterior location; cleanliness of building and equipment should be done frequently, new animals should be vaccinated and quarantined for 21 days before entering into the herd. Besides, the herd need to be vaccinated according to regulations of national FMD control program (MARD, 2006; Vietnam National Assembly, 2015). For imported animal, authority's agents verify health certificates issued by the exported countries, check for the cleanliness conditions, disinfect transport vehicles and monitor the residue treatment (MARD, 2006; Vietnam National Assembly, 2015). Besides, Department of Animal Health of Vietnam participate in region network of FMD surveillance in Southeast Asia (Southeast Asia and China for Foot-and-Mouth Disease Campaign) which aims to share outbreak information between countries, learn experiences and new approach of prevention and control this disease (zoning, movement control, veterinary hygiene and inspection, management of FMD outbreaks, communication/awareness).

Since 2006, Vietnam has implemented mass vaccination against FMD for all cattle and buffaloes within specific targeted areas, selected according to past outbreak occurrence. The total cost for FMD control in Vietnam has recently been estimated at 36, 32 and 41 million USD for each 5 years program from 2006 to 2020 (MARD, 2015). According to control objective, epidemiological and geographic situation, provinces of Vietnam are classified into control, buffer and low risk zone. The control zone consists of 8 provinces located at northern border, 6 provinces at southwest border between Vietnam and Cambodia, 5 provinces at Lao's border and Central Highlands. The buffer zone consists of provinces situated closed to the control zone. The low risk zone consists of 9 provinces in Red River, 4 important exportation provinces, 9 provinces in Mekong Delta, 3 provinces in South East and Ho Chi Minh City (MARD, 2006, 2011). The most updated version of national plan detailedly classified the zones at district level and set up a new free zone (including Thai Binh province) (MARD, 2015) (Figure 1). Vaccine used in the field contains serotype O and A based on serotypes currently present in Vietnam. The objective is to vaccinate 85-100% the cattle and buffalo population in the control and buffer zone. Vaccination is applied 2 times per year. In the low risk zone, vaccination is applied where old outbreaks occurred within the past 5 years. The principal strategy is to concentrate efforts in « hot-spots » areas wherein disease is endemic; where risk continually exists due to contact between susceptible species (OIE, 2013). Therefore, control by vaccination must allow to decrease the spread of virus and the impact of FMD in the application zone (MARD, 2011, 2006). Nevertheless, the implementation of FMD vaccination strategy faces many difficulties. Hot-spots are not easy to identify since the surveillance database is incomplete and uncertain which affects real prevalence of disease. Furthermore, farmers' sensibility to sanitary risk and local constraints influences the vaccination decision. Vaccination might be not the first choice of prevention method by farmers. Therefore, its effectiveness has to be questioned in terms of vaccine coverage and FMD control.

Figure 1. Classification of zones in Vietnam according to zoning policy for FMD control



(Adapted from MARD, 2015)

1.3. Participatory approach and its interest in epidemiology

1.3.1. Concept and approach

Quantitative methods has been widely used and accepted by scientists' community since long time. From these application in various fields, those methods have been questioned about the effectiveness. The first question is about the impractical in vast pastoral areas where human populations relatively small and mobile, poorly developed modern infrastructure and a common insecurity. Those methods are also being challenge while lacking of baseline data of context under study to support sampling procedures and the difficulty to follow the herds for longitudinal studies. The use of statistically representative samples can incomprehensible differences, surveys bases on questionnaires often long prove to be at the origin of data cemetery. Light and participatory techniques were designed in order to facing those challenges.

Participatory epidemiology (PE) is an emerging research field based on participatory techniques that help to harvest qualitative epidemiological intelligence within community observations, existing veterinary knowledge and traditional oral history. It relies on widely accepted techniques of participatory rural appraisal, ethno-veterinary surveys and qualitative epidemiology. This information can be used to design better animal health projects, to develop more effective surveillance and control strategies, and new perspectives for innovative research hypotheses in ecological epidemiology (Mariner and Paskin, 2000).

Basic concepts of participatory approach are a method of intelligent collection of qualitative data in order to understand a situation quickly and to formulate a plan of action. This method is oriented to the process of analysis and action. The approaches are using existing quantitative and qualitative data to interpret and explain the causality links.

The qualities required to apply participatory methods are the respect for local knowledge, willingness to learn and an open mind. Those requirements make sure an deeply understanding of local viewpoints that are not always similar to researcher' thinking. Participatory methods take into account the needs of local people and the point of view of representatives from government (local/ nation) and the private sector. Those methods promote local initiative, individual or collective. Through the application, those methods help people to communicate, to act and to make decision together meaning an allowing for a strengthening of civil society). It is believed that the links between local populations and the elected officials or local representatives is strengthened with helps of those methods. (Goutard, 2016). At the present, PE is widely applied in Asia and Africa such as Cambodia, Thailand, Sudan, Ethiopia, Kenya, Nigeria, Uganda (Catley et al., 2012).

From the 1980s, social scientists actively involved in agricultural research and human health projects. Their results demonstrated that rural people had their own complex knowledge called “indigenous technical knowledge" which had developed over many years according to local environmental and socio-cultural conditions (Catley et al., 2012). This term became popular in research and development organizations, not only as a research subject but also a mean to use local knowledge and experiences in the design of development projects (Brokensha et al., 1980). Professionals should acknowledge that rural people were not ignorant and could make important intellectual contributions to the development, thus attention to indigenous is necessary (Catley et al., 2012). A participatory approach is often explained by referring to ‘bottom-up’ development which is viewed as participatory and requires joint analysis, planning and monitoring with local people. In contrast, the ‘top-down’ approach refers to the proposal of development projects solely by professionals and academics, without any local consultation which limits local interest or commitment in supporting or sustaining the project activities (Catley et al., 2012).

PE aims at studying local knowledge about disease situation from farmers. Therefore, researcher is required to listen to and learn from farmers, and understand the collected information which is communicated in local language. Farmers have rich vocabulary to describe animal, production system, and sanitary information. They have traditional terminology reflecting symptom and diseases existing in their community, especially the one presenting for a long time (e.g. *"toi"* or *"sưng hầu"* for heamorragic septicemia, "*hà ăn chân*" for laminitis…used by Vietnamese farmers). Disease terminology can change from one community to another, therefore researchers need to carefully identify local term (Mariner and Paskin, 2000; Jost et al., 2007; ILRI and FAO, 2011). Farmer diagnostic experience and disease terminology are mutually consistent, hence traditional terminology have their own value contributing to the surveillance system (Catley, 2006).

A various application of participatory epidemiology in veterinary was summarized such as central disease survey and/or prioritization of diseases, disease investigation and diagnosis, descriptive epidemiology, economic or livelihoods impacts of disease, evaluation of disease control methods, veterinary public health, active surveillance, disease modelling, evaluation of veterinary service delivery and economic of veterinary delivery (Catley et al., 2012). From 1980 to 2014, 158 papers (included peer-reviewed papers, PhD reports and conference proceedings), 81 projects and 39 manuals (included manual, review and presentations) issued from more than 26 international institutions about application of participatory epidemiology in veterinary science recorded in PubMed database (Allepuz et al., 2017).

1.3.2. Participatory epidemiology tools

Participatory tools can be classified into 3 groups such as informal interviews, scoring and ranking methods, and visualization tools.

i. Informal interviews

Informal interviews comprise semi-structure interviews with key informants, focus groups or individuals. Interview is conducted with open questions and checklist (i.e. a list of objective that needs to be achieved after each interview) to facilitate free discussion following a defined direction. Interviewer based on interviewee's answers to ask more probing questions for further investigation (Mariner and Paskin, 2000). Interviewing is a specialized skill that gradually improves with practice. While information can be collected through an interview, the amount and reliability of information are greatly depend on the interviewers' experience (Mariner and Paskin, 2000). Semi-structured interview can be defined as guided conversation in which only the topics are predetermined and new questions or insights arise as a result of the discussion and visualized analyses (Thacker et al., 1988).

ii. Scoring and ranking tools

Scoring and ranking tools consist of proportional piling, matrix scoring of disease, syndromes and clinical signs, matrix scoring of disease impact, pair-wise ranking, and seasonal calendars. Those tools require informants to compare different variables using either rank or score. Scoring methods are more sensitive than ranking, allowing a weighting of responses. Those methods are easy to standardize and replicate in different informants and groups thanks to their numerical nature. Then, those collected data can be analysed using conventional statistical tests to evaluate the agreement level between groups on a specific subject (Catley et al., 2012).

iii. Visualization tools

Visualization tools comprise participatory mapping, timeline, seasonal calendar, cross-walk, Venn diagram, and radar diagram. Those tools help to articulate certain types of information that could not be easily expressed verbally or in writing. Moreover, illiterate informants can join discussion because objectives and signs can be used to depict important features on the diagram (ILRI and FAO, 2011; Catley et al., 2012).

1.3.3. Relation between participatory epidemiology and conventional research

Conventional research and participatory approach both require secondary source of information. Conventional veterinary methods mainly collect historical data while participatory methods collect them using timeline, key informant interviews, mapping of livestock movements and contact with vectors or wildlife, matrix scoring of disease signs and causes, proportional piling of mortality and morbidity, seasonal calendars of diseases, parasites and vectors. Laboratory tests (clinical examination, gross pathology) used in conventional methods similar to direct observation in participatory methods (Catley, 2004).

In conventional survey with questionnaire, information is provided using simple answers as yes/no or numeric which is pre-designed. Summary and comparison answers of different interviewees are quite easy and simple (Danielson et al., 2012). However, interviewer hardly figures out accurate information because the interview is not considered as common form of communication. Bias is normally present in the result analysis while farmers is stressed to give answers (McCauley et al., 1983). In PE, a pre-designed questionnaire is not existe. All of the objectives that need to be achived after each interview are summarised in a paper called checklist. Interviewer often introduces a topic in checklist using an open-ended question which allow interviewees feel comfortable to provide detail about their animal, even detail of each individual in their herd (Jost et al., 2007). General topic is introduces firstly for discussion in group, followed by detail topic. Moreover, interviewees can describe problem in their own terms, probing questions can be used to fill any gaps and to check for internal consistency within the individual accounts. Results from PE provide accurate information because an answer from one participant can be cross checked by others in group. However, during group discussion, personal idea is complicated and need to be change to adapt group point of view. In case personal idea of several interviewees is seen as inacceptable by the others in group or interviewer, they fell being disrespectful and then disconnect to discussion (Danielson et al., 2012). Triangulation data in PE is realized with secondary source of information that collected before implementation of study, with direct observation animals, farm, community in study site, with sampling and laboratory test (ILRI and FAO, 2011).

1.3.4. Participatory epidemiology and foot-and-mouth disease control for smallholder production

FMD has been targeted in 2012 by OIE as the first-priority animal disease to eradicate worldwide. Despite the availability of effective vaccines, successful control of FMD remains very limited. Difficulties in FMD surveillance and control arise from (1) under-declaration problem (Bellet et al., 2012) as despite its contagion, FMD cause little mortal compared with Haemorrhagic Septicaemia; and (2) decisions making by farmer, in particular the prevention, which are linked to economic and socio-cultural constraints (Chilonda and Van Huylenbroeck, 2001). Participative method can provide understandings about farmers' health priorities, their knowledge on diseases, and the socio-cultural and economic factors that underline their healthy choices between vaccination, treatment or animal sales. Farmer's perception of socio-economic impacts of animal diseases is very pertinent in priority's identification and establishment of disease control strategies (Rich and Perry, 2011). Participative epidemiology represent emergent branch in science veterinary research (Mariner, 2000). These methods are essential used in social sciences domain (as part of sharing natural resources), political sciences (utilization of participative for citizens can contribute in transparency way in political decisions) and continue to be developed and adapted in another domain like epidemiology (Catley et al., 2012). Utilisation of these approaches allow not only improve comprehension and dynamics of diseases, but also perception and actors' role in those dynamics (Jost et al., 2007). In fact, one of the principal objectives of this method is enhance ethno-veterinary knowledge, by taking into consideration needs, expectation, and demands of different actors (i.e. farmer, veterinary service, government representative). This direct implication of actors leads to individual and collective reflection, but also allows a better communication between groups who don't have possibility for active interaction.

1.4. Research questions and objectives of this thesis

1.4.1. Research questions and hypothesis

The first research question refers to the application of participatory approach: Is it possible to set up some developed tools that belong to this approach for widely use in developing country, especially in Vietnam, in order to better improve the participation of farmers in surveillance and control of FMD? The second question links to data collection process during study: Is data collection completed and qualified? Finally, the third question, link to potential advantages of this approach: is it allowed to generate directed and indirect profits for actors?

From existence database in literature, as well as our pass experiences, several hypotheses have been formulated as below:

Participatory approach will provide critical elements on the suitability of FMD surveillance and control programs by farmers in Vietnam and recommendations on how to improve their involvement. It will promote design of surveillance and control programs adapted to the constraints of the local producers. It will also set the ground and provide tools for improved partnership between local actors and policy makers to ensure effectiveness of the control measures in the field.

This project will provide qualified data on cost-effectiveness, farmers' constraints on vaccination strategy and implementation modalities for FMD control in Vietnam. This information is critical for decision makers to decide on the best efficient scenario for control of FMD in Vietnam.

Participatory methods allow a better acceptability of surveillance by directly involving actors in this process.

Application of participatory approach will build in capacities on the veterinary services. Participatory tools that developed during several field study will give evidence of their feasibility, simplicity and adaptive to Vietnamese context.

1.4.2. Objectives of the thesis

This PhD thesis aims at evaluating the contribution of participatory epidemiology approaches in order to improve the foot-and-mouth disease surveillance and control activities, especially the involvement of farmers at local level.

Main objective: Effectiveness of the Foot-and-mouth disease surveillance and control strategy at local level

The main objective of the thesis aims at assessing the effectiveness of the FMD surveillance and control strategy at local level by using PE approach. The first objective focuses on identification of farmers' prioritisation of the livestock's production constraints and animal diseases, and farmers' knowledge on differential diagnostic using participatory survey with smallholder farmers at local level. The second objective aims at evaluating the effectiveness of FMD vaccination program by evaluating farmer's perception of vaccination used to fight against FMD by using Q methodology, addressing local socio-economic constraints influencing on the effectiveness of FMD vaccination program and performing a benefit-cost analysis of vaccination at local level.

Second objective: Method development

The second objective aims at assessing the feasibility of applying a framework of different PE tools to improve the involvement of farmers in the FMD surveillance and control program in Vietnam. Those tools are developed and validated from case studies in different fields in the south of Vietnam. Validation of the data collection as well as evaluation the performance of PE methods in FMD control and surveillance is done with helps of statistic test such as Bayesian analysis and some gold standard laboratory test such as enzyme-linked immunosorbent assay (ELISA) and reverse transcription polymerase chain reaction (RT-PCR) on collected samples.

1.4.3. Organization of the field studies

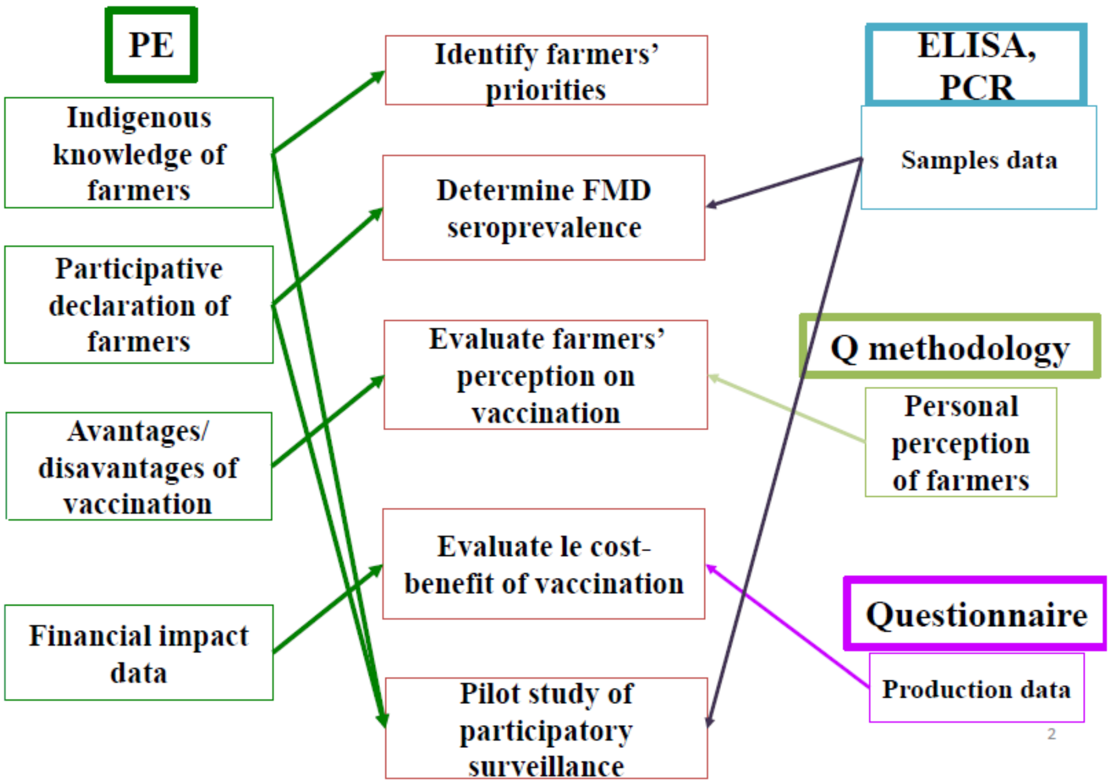
In order to respond to these objectives, two field studies were conducted in the context of surveillance and control of FMD using vaccination in Vietnam. The research was mainly conducted in Long An and Tay Ninh provinces because these areas have an importance in livestock production in the south of Vietnam, share border with Cambodia, have an importance of animal movements between provinces and countries and occurred outbreak during 2010-2013 period. Long An is situated in Delta Mekong region, border with Ho Chi Minh city, Tay Ninh, Tien Giang, Dong Thap province of Vietnam and Svay Rieng province of Cambodia. There are thirteen districts, one town and one city within this province. The climate is tropical type with monsoons, rainfall is high (average 966 – 1325 mm per year). Peak rainfall is seen August – October, combined with inundation which influences agricultural activities. Long An has an important livestock production including 13000 buffaloes, 84000 beef and dairy cattle and 260000 pig (General Statistic Office (GSO), 2015). Tay Ninh belongs to south western region and act as a bridge connecting Ho Chi Minh city and Phnom Penh capital of Cambodia kingdom through two international border gates called Moc Bai and Xa Mat. There are eight districts and one city within this province. The climate is also tropical type with monsoons. Average rainfall is 1800 – 2200 mm per year. Tay Ninh has a herd of 22000 buffaloes, 87000 beef and dairy cattle and 195000 pig (General Statistic Office (GSO), 2015).

The first field study, applied both participatory and laboratory methods, aimed at assessing the effectiveness of the FMD surveillance and control strategy at local level. It was carried out from June to October 2014 in eight districts of two provinces. We organized 53 focus group interviews with dairy, beef cattle and pig farmers, 201 individual interviews, including 46 interviews for Q methodology study, and approximately 600 questionnaires; samples included 301 seras and 24 oesophageal fluids were also collected. The second field study aimed at assessing the feasibility of applying a framework of different PE tools to improve the involvement of the farmers in the FMD surveillance and control program in pilot areas of three districts in Long An. From November 2015 to April 2016, 69 focus groups and 265 individual interviews were organized, 128 animals at risk were samples.

1.4.4. Outline

The thesis consists of eight chapters. Chapter 1 (this one) is the general introduction of the thesis. Chapters 2-7 have the format of scientific papers. Chapter 2 focuses on the evaluation of farmers' prioritisation of the livestock's production constraints and farmers' knowledge on differential diagnostic using participatory survey with smallholder farmers at local level. Chapter 3 aims at validating the PE methods in FMD surveillance by performing a Bayesian analysis and a gold standard laboratory test simultaneously. Chapter 4 addresses the evaluation of local socio-economic constraints influencing on the effectiveness of FMD vaccination program. Farmer's perception of vaccination to fight against FMD using Q methodology is evaluated in the Chapter 5 and a benefit-cost analysis of vaccination at local level is performed in Chapter 6. Chapter 7 aims at assessing the feasibility of applying a framework of different PE tools as a component in surveillance systems at sentinel villages to improve the involvement of the farmers in the FMD surveillance and control program in Vietnam. Finally, chapter 8 provides a general discussion, conclusions and recommendations of the work. The different data types collected using participatory epidemiology tools as well as other methodology (laboratory tests, Q-methodology, questionnaire) were summarised in the following figure (Figure 1).

Figure 1: Type of data collected and study allocated



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CHAPTER 2

EXPLORING FARMER KNOWLEDGE ON LIVESTOCK ISSUES' PRIORITISATION, ANIMAL DISEASE RANKING AND DIFFERENTIAL DIAGNOSTIC USING PARTICIPATORY APPROACH

In preparation for *Preventive Veterinary Medicine*

Exploring farmer knowledge on livestock issues' prioritisation, animal disease ranking and differential diagnostic using participatory approach

D.B. Truong[1,2*], *A. Binot*[1,5], *M. Peyre*[1], *D.Q.P. Phan*[2], *V.C. Nguyen*[2], *N.H. Nguyen*[2], *A. Delabouglise*[3], *S. Bertagnoli*[4], *F.L. Goutard*[1,5]

[1] CIRAD, UMR ASTRE, F-34398 Montpellier, France

[2] Faculty of Animal Science and Veterinary Medicine, Nong Lam University, Ho Chi Minh, Vietnam

[3] Center for Infectious Disease Dynamics, Department of Biology, The Pennsylvania State University, University Park, Pennsylvania 16802, USA

[4] IHAP, Université de Toulouse, INRA, ENVT, Toulouse, France

[5] Faculty Veterinary Medicine, Kasetsart University, 10900 Bangkok, Thailand

***** dinhbao.truong@hcmuaf.edu.vn/ dinh-bao.truong @cirad.fr

Abstract

A participatory epidemiological study was conducted with 53 groups of dairy, beef and pig farmers in 8 districts of Long An and Tay Ninh province, Vietnam. Participatory tools such as semi-structure interview, pairwise ranking, disease symptom matrix scoring and disease impact matrix scoring were used to evaluate livestock's concerns, farmer's priorities regarding dangerous diseases, perceived socio-economic impacts of diseases and farmers' competence in differential diagnosis. Animal diseases were perceived as the most important issue in animal production, followed by lack of capital for cattle farms and instability of product price for pig farm. Lack of breeding knowledge and high feed cost were considered as a third issue for dairy farmers and pig farmers, respectively.

Participants from dairy cattle farms considered foot-and-mouth disease (FMD), haemorrhagic septicaemia (HS), mastitis, inflammation of hooves, blood parasites and digestive diseases as the six most important diseases, in decreasing order of importance. For beef cattle farmers, the four most important mentioned diseases were HS, FMD, ruminant tympani and diarrhea with or without blood. For pig farmers Porcine Reproductive and Respiratory Syndrome, infection with *Escherichia coli*, Salmonellosis, FMD and pneumonia were the five most important diseases. The perceived importance of diseases was different for each farm type and differed from government veterinarians, responses. Throughout disease symptoms matrix scoring, farmers showed their abilities in differential diagnosis of important diseases based on their clinical symptoms and recognized several clinical signs related to diseases with high agreement between groups. Disease impact matrix scoring highlighted the perceived weight attributed to different effects of diseases on farmer's welfare. Capital loss i.e. death of animal) and income loss (i.e. decrease in productivity) were the highest impacts for all farm types. Local

knowledge of disease is substantial and might have a positive effect on the control of the different diseases present in farmers' herds.

Keywords: participatory methods, livestock' issue prioritisation, animal diseases, socio-economic impacts, Vietnam

1. Introduction

Agriculture represents 25% of Gross Domestic Product (GDP) of Vietnam and livestock production encompasses 32% in GDP of the value of agricultural production (Nguyen, 2014). 70% of Vietnamese people live in rural areas and 80% of rural household engage in animal husbandry (Hoang, 2011). In 2014, the total population of domestic pig, cattle and buffalos were estimated at 26.8, 5.2 and 2.5 million, respectively (GSO, 2015). Pig and beef farms are, respectively, the first and third largest livestock industry (Pham et al., 2015). Domestic animals are mostly kept in small-scale farms (Vo et al., 2010; Nguyen, 2014; Pham et al., 2015). Smallholders produce 70% of pig heads (Nguyen, 2014). 70-80 % of the cattle population of Vietnam is kept in extensive small-scale cow-calf grazing systems (usually 1-2 heads/household) (Pham et al., 2015). Regarding dairy production, around 20000 small-scale dairy farmers (Gautier, 2008) produce 80% of milk.

Several problems related to livestock can be addressed such as dependence of importation of raw materials for animal feeds, limited land areas for husbandry, lack of financial and technical investments for livestock sector, lack of systems of husbandry managements, veterinary services and breeding centers (Hoang, 2011). According to Lapar et al. (2012), Vietnamese small-scale pig farms are faced with numerous issues including poor genetic stock, low quality feed, diseases, and lack of access to timely and reliable market information. One study on household perception of pig farming in

Vietnam found that meat market price, epidemic diseases, and production costs are the 3 major concerns of pig farmers (Nguyen and Nanseki, 2015). Moreover, households often lack the necessary knowledge and information related to pig farming, which leads most of them to mainly operate pig farms in individual families (Nguyen and Nanseki, 2015). In beef farms, small and fragmented pasture area, high feed costs (feed and feed ingredients are mostly imported), illegal beef import from surrounding countries such as Laos, Cambodia, Myanmar and Thailand are perceived as the main issues (Pham et al., 2015). Training opportunities, higher milk prices, financial support, better equipment, availability of veterinary services, construction of biogas facilities, cooperation and teaching among farmers within the dairy community and increased availability of land are farmers' recommendations for promoting the development of dairy farm industry (Ashbaugh, 2010). In terms of animal disease, Unger et al. (2015) reported that foot-and-mouth disease (FMD), porcine reproductive and respiratory syndrome (PRRS), pasteurellosis, paratyphoid suum, erysipelas, porcine high fever disease and salmonellosis are the major threats on pig farms. Some agents such as *Mycobacterium bovis* (bovine tuberculosis), *Brucella abortus* (brucellosis), *Pasteurella multocida* (haemorrhagic septicaemia - HS), *Leptospira interrogans* (leptospirosis), *Theileria* (theileriosis), *Fasciola spp* (liver fluke), *Paramphistomum* (rumen flukes), *Giardia* (giardiasis), *Anaplasma marginale*, *Babesia bigemina*, *Neospora caninum* (neosporosis) are reported to affect dairy cattle (Suzuki et al., 2006; Geurden, 2008). *Fasciola spp*, *Strongyle*, *Cooperia*, *Haemonchus*, *Oesophagostomum*, and *Trichostrongylus* were diagnosed in beef cattle (Holland, 2000). Mastitis, FMD and bloody diarrhea are also commonly reported in small-scale beef farms (Vo et al., 2010; Bellet et al., 2012).

Participatory epidemiology (PE) is often used in animal health surveillance in developing countries where human and financial resources are scarce (Mariner and

Paskin, 2000). The application of PE in animal health surveillance allows for a better understanding of epidemiological drivers but also socio-economical contexts linked to disease emergence. Relying on local knowledge, these methods involve actively the farmers to gather sanitary information. Participatory methods allow understanding farmers' sanitary priority, their knowledge about disease, the determinants of their response to sanitary threats (e.g. vaccination vs. treatment vs. sale). Participatory methods can also be used to better involve farmers and other actors of livestock production in surveillance and to overcome some limits of conventional epidemiological methods (Catley et al., 2012). These methods combined with laboratory confirmation allow identifying clinical cases not picked up by passive surveillance. PE was applied in some developing countries such as Cambodia (Bellet et al., 2012; Vergne et al., 2012), Ethiopia (Shiferaw et al., 2009), Uganda (Nantima et al., 2012) in order to generate disease information, focused on FMD, to inform control programs. In Viet Nam, PE is being used to evaluate livestock diseases surveillance systems (Delabouglise et al., 2016) and to collect data to perform economic impact assessment of major pig diseases (Pham et al., 2016).

While local knowledge is considered as an important source of information in Africa (Catley et al., 2001a, 2004; Catley, 2006; Shiferaw et al., 2009), there is still lack of evidence of its usefulness Asia, especially in Vietnam. Farmer's ability to mitigate the impact of diseases on their livelihood with their limited resources, as well as the ability to carry out differential diagnosis, is not well documented. This study aimed to use PE methods to evaluate issues on livestock production and the impact of some important diseases on farmer's livelihood, to determine farmer's prioritisation of dangerous diseases of livestock, including FMD, and to evaluate farmer's competence at differential diagnosis between diseases.

2. Materials and methods

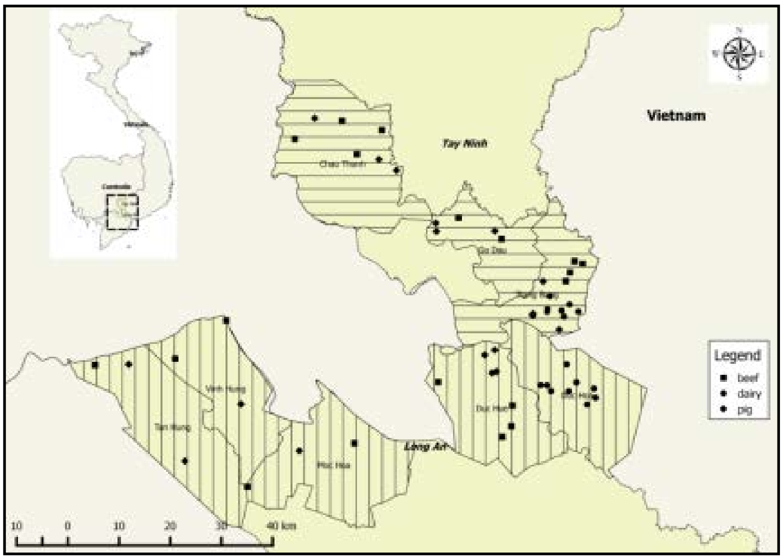
2.1. Study site

Our study was carried out in Long An and Tay Ninh provinces because these areas have a large livestock population, share border with Cambodia, record frequent animal movements with other provinces and countries and reported FMD outbreaks during the 2010-2013 period. Long An is located in the Mekong River Delta region and its livestock population includes 13000 buffaloes, 84000 beef and dairy cattle and 260000 pig (GSO, 2015).Tay Ninh belongs to the southeast region of Vietnam and its livestock population includes 22000 buffaloes, 87000 beef and dairy cattle and 195000 pig (GSO, 2015).

2.2. Sample size calculation

The study focused on 3 production types: dairy cattle, beef cattle and pig farms. 10 villages comprising at least 10 farms of each production type (dairy cattle, beef cattle and pig) were randomly selected in each province. The numbers of selected villages in each selected commune were proportional to the number of villages in the communes and the livestock population of the communes. The total number of villages involved in each district was proportional to the district's livestock population. In total, 60 villages were included in the study. Five districts named Vinh Hung, Tan Hung, Kien Tuong, Duc Hoa, Duc Hoa located in Long An province and 3 districts named Go Dau, Chau Thanh and Trang Bang located in Tay Ninh province (Figure 1).

Figure 1: Map of the study districts (hatched) showing the location of focus group interviews targeting the 3 production types (beef cattle, dairy cattle, pig) in the 2 study provinces of Long An (diagonal hatchings) and Tay Ninh (horizontal hatchings)



2.3. Survey organization

The research team included five members of the Faculty of Animal Science and Veterinary Medicine of the University of Agriculture and Forestry of Ho Chi Minh City: 1 veterinary student, 2 Master students and 2 lecturers. Each research's team member was trained in PE methods with certified trainers one month before conducting the study.

With permission of the provincial and district veterinary services, meetings were conducted in each study districts with commune and districts government veterinarians in order to explain the objective and to discuss the planning of the survey. Participant farmers in each focus group in each commune were randomly selected from a list of farmers recorded during previous vaccination campaigns and provided by the provincial veterinary services. Then, this list was adjusted in case some farmers did not practice livestock production anymore with helps of commune veterinary. Before each interview, each participant signed a written consent form stating their agreement to get involved in the study. Internal team meetings were organized frequently to review the day's work, identify bias and find ways of improvement in the interview process.

2.4. Participatory tools and data collection

Interviews were performed from June to October 2014. Each interview was performed in the place which was most convenient for the interviewees (usually at one of participants' house), was conducted in Vietnamese language, involved the participation of at least two members of the research team and lasted one hour on average.

Interviews were conducted using specific PE tools described by Bagnol and Sprowles, 2007; Catley, 2005; Mariner and Paskin, 2000: semi-structured interview, pairwise ranking and disease impact matrix scoring. FMD is notifiable disease and farmers are expected to hide suspected cases in their farms in case of a direct interview with FMD in objective. To avoid this obsequiousness bias during interview, discussion focused on disease management methods and specific topic focus on FMD was not mentioned at the beginning.

2.4.1. Semi-structured interview of focus groups: This tool was used throughout all the interviews to gather qualitative data with the help of a checklist of objectives prepared beforehand. Checklists included six big themes which needed to be addressed: (i) description of the production process; (ii) identification of issues related to livestock production; (iii) prioritisation of livestock diseases according to defined criteria; (iv) description of diseases' clinical signs; (v) differential diagnosis of the diseases perceived as most important by farmers; (vi) relative impacts of disease on farmers' livelihood. Effort was made to ensure that all attendants participated at least once in the discussion and actively exchanged ideas.

2.4.2. Pairwise ranking: Pairwise ranking was used to identify and weigh issues related to livestock production and livestock diseases. It was used to compare several elements two-by-two in order to understand the relative weight of each element. For example, when ranking livestock production issues, two cards representing two different issues were randomly picked and compared by groups of participants. The choice of placing one issue above another was explained by participants. The ranking process was continued with all the other pairs of issues. The results of the ranking game were compared with the ones of other games hereafter described.

2.4.3. Disease differential diagnosis matrix scoring: Matrix scoring was used to characterize the diseases according to their associated clinical signs described by farmers and, subsequently, understand how farmers perform differential diagnosis of these diseases. The classical matrix used in our study was based on Catley, 2004. In Long An province where this exercise was performed first, the matrix was built with the information collected at the beginning of the semi-structure interviews. Based on the information from Long An, a standardized matrix was built for each production type (pig, dairy cattle and beef cattle) and used in all focus group interviews in Tay Ninh in order to evaluate the agreement between different groups of participants of the same province. The content of standardized matrices was limited to the 4 or 6 most important diseases in terms of socio-economic impacts mentioned in each production type and the 12 most commonly reported clinical signs. The matrix was built in this way to simplify the exercise shorten its duration, as time needed is an important factor of the motivation of participants to pursue interviews (Catley et al., 2001, 2004; Catley, 2006). Participants were asked beforehand if any disease was missing from the standardized matrix. Once the matrix completed, probing questions were used to discuss the attributed scores and check their validity.

2.4.4. Disease impact matrix scoring: Matrix scoring was used to classify diseases, depending on criteria identified by farmers. Participant farmers gave a relative weight or score to several diseases according to their effects on some pre-defined criteria. The information provided by this exercise was twofold: ranking of disease according to their socio-economic impact and ranking of criteria to measure disease socio-economic impact. Firstly, most important disease in term of livelihood impact that identified in the pairwise ranking exercise by farmers was listed on a y-axis and farmers were asked to divide 100 beans according to their perceived general importance. Then, a list of impact criteria constituted the beginning of the focus group interview was drawn on an x-axis and they participants re-distributed the counters attributed to each diseases into cells corresponding to each impact criteria so as to rank the criteria impacted by each diseases in order of importance Probing question were asked to participants after the exercise to explain the responses and check their validity.

2.5. Data management and statistical analysis

Interviews were notes taken in the field and were then transcribed in electronic version. Data analysis was performed with the version 3.1.2 of R program (Wickham, 2009). Results of ranking exercises were described through simple statistics (median, minimum and maximum). The level of agreement between different groups of participant in the standardized disease symptom matrix scoring and disease impact matrix scoring exercises was assessed through Kendall's coefficient of concordance (W) test for non-parametric data. This test was performed with the help of the package "concordance" R package (Lemon et al., 2007). W varied from 0 to 1 and the higher W, the higher the agreement between groups. W was categorized as weak ($W<0,26$, $P>0,05$), moderate

(0,26<W<0,38, P<0,05), and strong (W>0,38, P<0,01) in the interpretation given by Siegel and Castellan (1988).

As data were collected in a non-standardized process in the first study province (Long An), results of pairwise ranking (on livestock issues and prioritisation of diseases) differed as list of disease names differed between interviews. In order to compare the impact of diseases, a standardized process was used (Ameri et al., 2009). All diseases and their ranks in each interview were pulled together, local names of diseases, and local terminologies used to describe clinical signs were listed, and some names were merged when it was considered they referred to the same disease. Then the rank of each disease in each interview was transformed into a score (hereafter named standardized score). The highest score was equal the total number of diseases mentioned in all interviews and diseases received the score 0 when they were not mentioned in the interview. Then, sum of standardized score was made and was changed to rank of diseases from different interviews.

3. Results

3.1. Composition of the groups

53 focus group interviews were conducted. 18, 19 and 16 focus groups were conducted with dairy cattle, beef cattle and pig farmers, respectively (Table 1). The number of participants per focus group ranged from 6 to 15. Focus groups gathered both male and female participants.

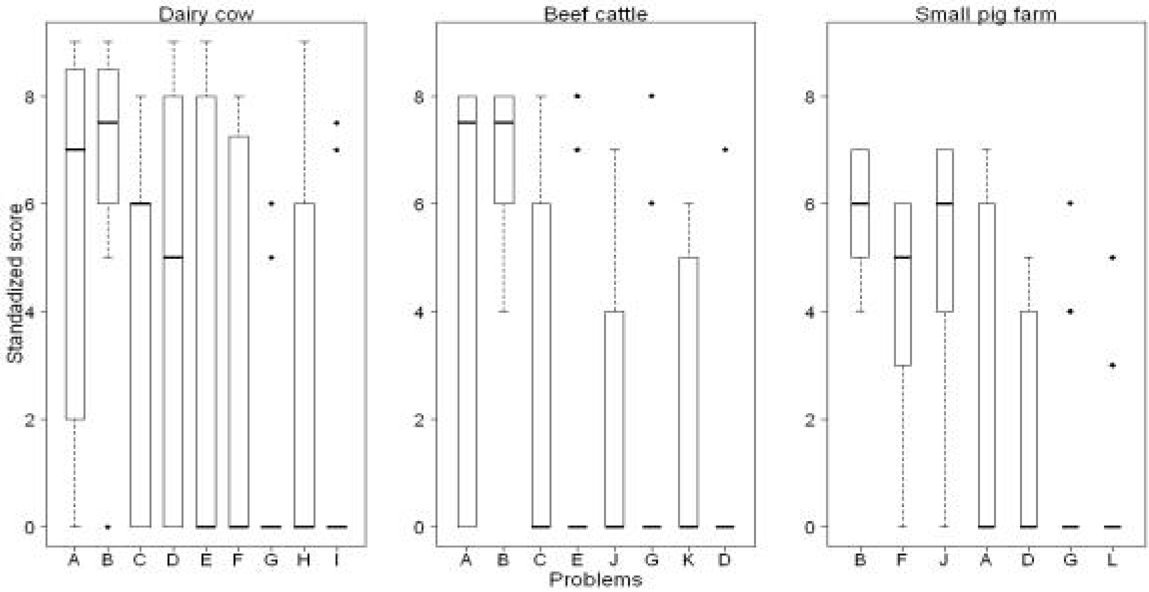
Table 1: Summary of number of focus group interview and participants in Long An and Tay Ninh province for beef cattle, dairy cattle and pig farm type

Province	Farm type	Focus group interview	Participants
Long An	**Dairy cattle**	10	87
	Beef cattle	9	117
	Pig	7	84
	Sub-total	26	288
Tay Ninh	**Dairy cattle**	8	74
	Beef cattle	10	95
	Pig	9	83
	Sub-total	27	252
Total		53	540

3.2. Animal production issues

In semi-structured interviews, dairy cattle farmers enumerated more many issues (10 issues) than beef cattle farmers (8 issues) and pig farmers (7 issues) (**Figure 2**). These results were generated from 15, 14 and 13 focus groups of dairy cattle, beef cattle and pig farm respectively. The issue which was given highest scores was diseases (median 9.0, 7.5 and 6.0 for dairy cattle, beef cattle and pig farm type, respectively). The issue which was given the second highest score was lack of capital in focus groups made with dairy cattle and beef cattle farmers(median 8.0 and 7.7, respectively) and instability of final product price in focus groups with pig farmers (median 6.0). Lack of technical knowledge about livestock husbandry was considered as third issue by dairy farmers (median)_but was not ranked as a major concern by beef cattle and pig farmers. The third highest scoring issue faced by pig farmers was the high feed cost (median 5.0). Some other issues were mentioned only in a minority of focus groups. Such issues were failure of insemination, low milk quality, lack of foraging surface, low quality of feed, low selling price of milk, breed, or other market related issues (such as the pressure of livestock traders on the end product price).

Figure 2: Overall of livestock's issues of dairy (n = 15), beef (n=14) and pig farm (n = 13) in Long An and Tay Ninh provinces

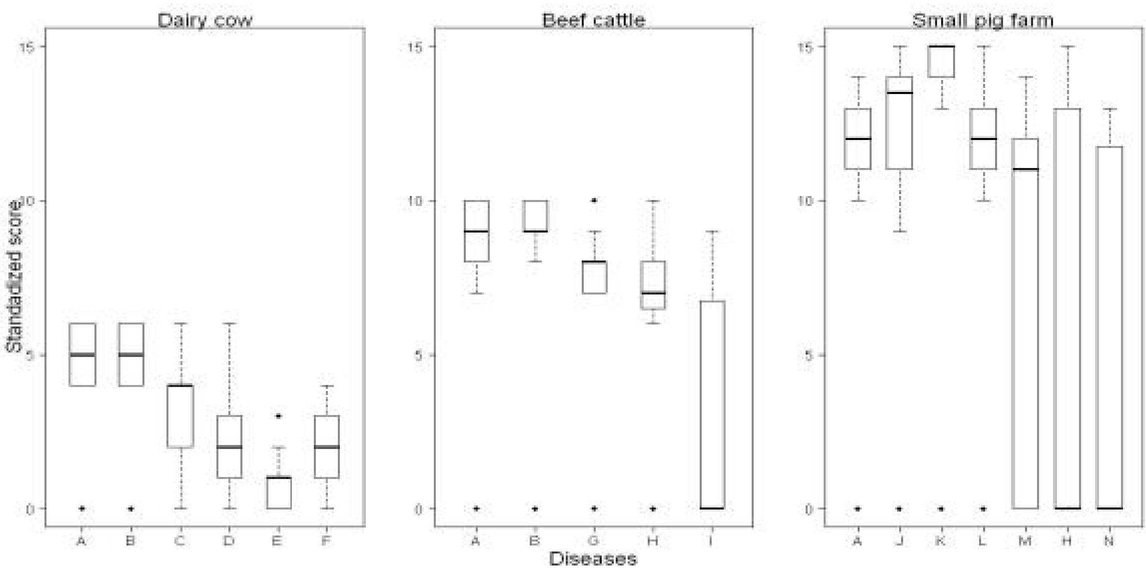


Legend: A: Lack of capital, B: Diseases, C: Lack of herb or herd's surface, D: Insufficiency of breeding knowledge, E: Failure insemination, F: high feed cost, G: Breed problem, H: Milk quality, I: Low price of milk sold, J: Instability of price of final products, K: External conditions, L: Low feed quality

3.3. Prioritisation of diseases

The number of reported diseases varied across production types (8, 10 and 15 diseases dairy cattle, beef cattle and pig farm respectively). These results were generated from 17, 19 and 16 focus group of dairy cattle, beef cattle and pig farm respectively. The six diseases which were given the highest score by dairy cattle farmers were, from the highest to the lowest: FMD (local name: *lở mồm long móng*), HS (*tụ huyết trùng, sưng hầu, toi)*, mastitis (*viêm vú)*, inflammation of hooves (*viêm móng*), blood parasites (*ký sinh trùng máu*) and digestive diseases (*bệnh tiêu hóa*) (Figure 3 and Table S1). For beef cattle farmers, the four diseases which were given the highest score were HS, FMD, ruminant tympani (*chướng hơi dạ cỏ*) and diarrhea with/without blood (*tiêu chảy* *lẫn/không lẫn máu*). PRRS (*tai xanh*), diseases due to *Escherichia coli* ((E.coli*; bệnh do vi khuẩn E.coli)*), Salmonellosis (*thương hàn*), FMD and pneumonia (*viêm phổi*) were the five most diseases which were attributed the highest score by pig farmers. The agreement between groups of participants of similar production type was high. The found Kendall's coefficient of concordance (W) in dairy cattle farmers, beef cattle farmers and pig farmers were respectively: W= 0.72 (p <0.01) (with 11 focus groups and 6 highest scoring diseases), W = 0.52 (p <0.01) (with 14 groups of beef and 4 highest scoring diseases) and W= 0.56 (p<0.01) (with 9 groups and 5 highest scoring diseases).

Figure 3: Ranking of selected diseases of dairy (n=17), beef (n=19) and pig farm (n=16) in Long An and Tay Ninh provinces



Legend: A: Foot-and-mouth disease, B: Haemorrhagic septicemia, C: Mastitis, D: Laminitis, E: Blood parasite, F: Digestive diseases, G: Ruminant tympany, H: Diarrhea, I: other diseases in beef (6 diseases), J: diseases associated with *E.coli*, K: porcine reproductive and respiratory syndrome, L: Salmonellosis, M: Lung inflammation, N: other diseases in pig (9 diseases).

3.4. Differential diagnosis of important diseases

Information on differential diagnosis of diseases of dairy cattle was extracted from 17 focus group interviews (9 in Long An, 8 in Tay Ninh) (Table 1). Results of a non-standardized matrix in Long An province are displayed in Table S2. Based on prior information from the first province, a new standardized matrix was created for Tay Ninh province (Table 2). The semi-structure interviews and matrix scoring exercises on diseases and related symptoms showed that participants understood and demonstrated good knowledge of the clinical signs of each disease. A strong agreement was observed between focus groups (W2 varied from 0.66 to 0.92, $p < 0.01$). Moreover, differences in weights given to clinical signs associated with more than one disease (e.g. fever, loss of appetite) were consistent between groups (the agreement W1 varied from 0.39 to 1, $p<0.01$). FMD was related to seven different clinical signs (W2=0.78, $p<0.01$) out of which 3 signs had high median scores (Md): loss of hooves (Md: 30), salivation (Md: 15.5) and lameness (Md: 12.5). HS was related to seven different clinical signs with strong agreement between focus groups (W2: 0.66, $p<0.01$): salivation, loss of appetite, fever, decreased rumination, ruminant tympani, respiratory distress or increased respiratory rate and drop in milk production. Five clinical signs were related to mastitis with strong agreement between groups (W2: 0.90, $p<0.01$): loss of appetite, fever, inflammation of udder, drop in milk production and rotten milk. Infestation with blood parasites was related to loss of appetite, fever, drop in milk production and jaundice (W2: 0.85, $p<0.01$). Laminitis was related to loss of appetite, fever, lameness and drop in milk production (W2: 0.77, $p<0.01$). Digestive diseases were related to loss of appetite, fever decreased rumination, ruminant tympani, respiratory distress and reduced milk production (W2: 0.92, $p<0.01$).

Table 2: Summary of standardized disease symptom matrix scoring of dairy cow diseases described by farmer's knowledge in Tay Ninh province, Viet Nam (n=8)

Symptom/ Disease	**Foot-and-mouth disease** W2= 0.78**,b	**Haemorrhagic septicaemia** W2= 0.66**, b	**Mastitis** W2= 0.9**, b	**Blood parasites** W2= 0.85**, b	**Laminitis** W2= 0.77**, b	**Digestive disease** W2=0.92**, b
Salivation W1=0.92**, a	15.5 (9-30)	11 (0-21)	0 (0-0)	0 (0-6)	0 (0-0)	0 (0-6)
Loss of appetite W1=0.58**,a	8 (5-17)	7.5 (0-10)	3 (0-4)	4 (0-7)	2 (0-5)	5 (0-11)
Fever W1=0.39*,a	3 (0-10)	11 (0-15)	6 (4-23)	3 (0-11)	4 (0-7)	0.5 (0-6)
Lameness W1=0.88**,a	12.5 (0-15)	0 (0-7)	0 (0-0)	0 (0-0)	16 (15-30)	0 (0-0)
Inflammation of udder W1=0.65**,a	0 (0-10)	0 (0-30)	30 (0-30)	0 (0-0)	0 (0-0)	0 (0-0)
Stop rumination W1=0.55**,a	2.5 (0-15)	11 (0-27)	0 (0-5)	0 (0-5)	0 (0-5)	9 (3-30)
Ruminant tympany W1=0.90**,a	0 (0-0)	15 (0-20)	0 (0-0)	0 (0-0)	0 (0-0)	15 (10-30)
Respiratory distress or increased respiratory rate W1=0.94**,a	0 (0-0)	20.5 (15-30)	0 (0-0)	0 (0-0)	0 (0-0)	9.5 (0-15)
Milk loss W1=0.55**,a	5 (1-9)	4.5 (0-8)	10.5 (5-19)	3 (0-5)	4 (1-5)	3 (1-5)
Jaundice W1=1.00**,b	0 (0-0)	0 (0-0)	0 (0-0)	30 (30-30)	0 (0-0)	0 (0-0)
Rotten milk W1=1.00**,a	0 (0-0)	0 (0-0)	30 (30-30)	0 (0-0)	0 (0-0)	0 (0-0)
Hoof loss W1=0.87**,a	30 (19-30)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-11)	0 (0-0)

n:number of focus groups;
Number in cell: score in median (min-max) for each symptom;
Kendall coefficient of concordance W1: agreement level for each symptom;
Kendall coefficient of concordance W2: agreement level of a group of symptoms related to a disease;
*, **: p value for Kendall coefficient of concordance (* $p < 0.05$, ** $p < 0.01$);
a, b: number of focus groups containing completed data for Kendall coefficient of concordance calculation (a=7, b=5)

Information on differential diagnosis of diseases of beef cattle was extracted from 19 focus group interviews (9 in Long An, 10 in Tay Ninh) (Table 1). Results of a non-standardized matrix in Long An province are displayed in Table S3. Based on prior information from the first province, a new standardized matrix was created for Tay Ninh province including 4 diseases and 10 symptoms (Table 3). The semi-structure interviews and matrix scoring exercises on diseases and related symptoms also showed that participants from beef farms understood and demonstrated good knowledge of the symptoms of each disease. A strong agreement between groups was noted in Tay Ninh province regarding weight of symptoms within a diseases and groups of symptoms in a particular disease (W1 varied from 0.53 to 1.00; W2 varied from 0.68 to 0.88, $p<0.01$, respectively). FMD was related to 5 different clinical signs (W2: 0.88, $p<0.01$), out of which hyper-salivation and hooves separation or loss had high median scores (Md: 13 and 20, respectively). HS was related to 8 clinical signs with strong agreement between groups (W2: 0.71, $p<0.01$). Ruminant tympani was related to 5 symptoms (W2: 0.80, $p<0.01$). Bovine diarrhea was related to fever, loss of appetite and watery faeces with bad smell (W2: 0.68, $p<0.01$).

Table 3: Summary of standardized disease symptom matrix scoring of beef cattle diseases described by farmer's knowledge in Tay Ninh province, Viet Nam (n=10)

Symptom/ Disease	**Foot-and-mouth disease** W2=0.88**,a	**Haemorrhagic septicaemia** W2=0.71**,a	**Ruminant tympany** W2=0.80**,a	**Bovine diarrhea** W2=0.68**,a
Fever W1=0.7**,a	8 (0-14)	6,7 (5-8)	2,3 (0-5)	2,5 (0-4,8)
Respiratory distress or increased respiratory rate W1=0.69**,a	0 (0-12)	8,5 (5-13)	10 (0-14)	0 (0-2)
Ruminant tympany W1=0.68**,a	0 (0-6)	8 (0-13,6)	11 (6,4-20)	0 (0-10)
Loss of appetite W1=0.66**,a	5,7 (4-9)	5,5 (4,8-10)	4 (3-9)	2,7 (0-4)
Stop rumination W1=0.53**,a	5,5 (0-8)	6 (3-11)	7,5 (3-12)	0 (0-3,2)
Salivation W1=0.84**,a	13 (5,6-20)	6 (0-10)	0 (0-5,6)	0 (0-1,6)
Hoof separation or loss W1=1**,a	20 (20-20)	0 (0-0)	0 (0-0)	0 (0-0)
Swelling of pharynx W1=0.91**,b	0 (0-6)	20 (14-20)	0 (0-4)	0 (0-0)
Sudden death W1=0.82**,a	0 (0-0)	20 (7-20)	0 (0-13)	0 (0-0)
Diarrhea, feces liquid with bad smell W1=0.84**,a	0 (0-0)	0 (0-13)	0 (0-0)	20 (7-20)

n:number of focus groups;
Number in cell: score in median (min-max) for each symptom;
Kendall coefficient of concordance W1: agreement level for each symptom;
Kendall coefficient of concordance W2: agreement level of a group of symptoms related to a disease;
*, **: p value for Kendall coefficient of concordance (* $p < 0.05$, ** $p < 0.01$, ***$p < 0,001$);
a, b: number of focus groups containing completed data for Kendall coefficient of concordance calculation (a=10, b=9)

Information on differential diagnosis of pig diseases was extracted from 16 focus group interviews (7 in Long An, 9 in Tay Ninh) (Table 1). Standardized matrix included 5 pig diseases and 12 symptoms for Tay Ninh province using the same approach as beef cattle diseases (Table 4). Results of a non-standardized matrix in Long An province are displayed in Table S4. Significant agreement was observed between focus groups in Tay Ninh province (W1: 0.1 – 1.0; W2: 0.46 - 0.81; p<0.01). PRRS was related to 6 symptoms (W2: 0.58, $p<0.01$) out of which 4 signs had high median scores: abortion (Md: 17), blotchy reddening of the skin (Md; 15), fever (Md: 10) and quit eating (Md:9). Diseases due to *E.coli* was related to 4 symptoms (W2: 0.81, $p<0.01$). This description reflects upon two separate diseases associated with *E.coli*, first for oedema in head and eye, and second to diarrhea in piglet. Salmonellosis was related to 6 symptoms (W2: 0.46, $p<0.01$). FMD was related to 5 symptoms (W2: 0.71, $p<0.01$) out of which 3 signs had high median scores: vesicles on mouths (Md: 25), salivation (Md: 19) and hooves separation (Md: 25). Finally, pneumonia was related to 4 symptoms such as fever, loss of appetite, coughing and respiratory distress (W2: 0.54, $p<0.01$).

Table 4: Summary of standardized disease symptom matrix scoring of pig diseases described by farmer's knowledge in Tay Ninh province, Viet Nam (n=9)

Symptom/ Disease	**Porcine reproductive and respiratory syndrome** W2= 0.58**,d	**Diseases due to *E.Coli*** W2= 0.81,**, d	**Foot-and-mouth disease** W2= 0.71**,d	**Salmonellosis** W2= 0.46**,d	**Pneumonia** W2= 0.54**,d
Fever W1=0.62**,a	10 (7-15)	3 (0-8)	2 (0-5)	5 (0-6)	6 (3-10)
Quit eating W1=0.38**,a	9 (4-10)	0 (0-9)	2 (0-7)	6 (2-10)	5 (2-13)
Coughing W1=0.62**,a	0 (0-22)	0 (0-3)	0 (0-0)	4 (0-9)	18 (0-25)
Blotchy reddening of the skin W1=0.56**,a	15 (6-25)	0 (0-10)	0 (0-4)	4 (0-10)	0 (0-11)
Periocular oedema W1=1**,a	0 (0-0)	25 (25-25)	0 (0-0)	0 (0-0)	0 (0-0)
Twitching W1=0.53**,a	7 (0-25)	13 (0-25)	0 (0-0)	0 (0-18)	0 (0-0)
Abortion W1=0.7**,a	17 (7-25)	0 (0-0)	0 (0-6)	7 (0-10)	0 (0-5)
Diarrhea W1=0.65**,a	0 (0-15)	15 (3-25)	0 (0-0)	5 (0-12)	0 (0-2)
Vesicles on mouth W1=0.1**,c	0 (0-0)	0 (0-0)	25 (25-25)	0 (0-0)	0 (0-0)
Salivation W1=0.51**,b	3 (0-25)	0 (0-3)	19 (0-25)	0 (0-0)	0 (0-3)
Respiratory distress W1=0.45**,a	0 (0-11)	0 (0-11)	0 (0-25)	4 (0-9)	11 (0-25)
Hoof separation W1=0.63**,b	0 (0-17)	0 (0-0)	25 (0-25)	0 (0-0)	0 (0-8)

n:number of focus groups;
Number in cell: score in median (min-max) for each symptom;
Kendall coefficient of concordance W1: agreement level for each symptom;
Kendall coefficient of concordance W2: agreement level of a group of symptoms related to a disease;
*, **: p value for Kendall coefficient of concordance (* $p < 0.05$, ** $p < 0.01$, ***$p < 0,001$);
a, b, c, d: number of focus groups containing completed data for Kendall coefficient of concordance calculation (a=9, b=8, c=6, d=5)

3.5. Socio-economic impacts of diseases

From the data produced by 13 out of 17 focus group interviews of dairy cattle farmers were suitable for analysis. Nine impact criteria of diseases were identified (Table 5). Among them, capital loss (death of animal) and income loss were given the highest accumulated score (sum of median scores (SMS)) and had the significant agreement between focus groups (W: 0.57 and 0.6, $p<0.01$, respectively). Except reduced reproduction capacity and loss of friendship had insignificant levels of agreement, the level of agreement between focus groups on the 5 other impacts varied significantly (W: 0.34-0.73, $p<0.01$). FMD had the highest effect on livelihood and income of farmer (SMS: 62), followed by HS (SMS: 59) and mastitis (SMS: 37). This result was aligned with prioritisation of disease for dairy cattle. Blood parasites, laminitis and digestive diseases had lowest SMS (SMS: 12, 11, 18, respectively). FMD and mastitis had less effect than HS on capital loss (Md: 7, 3 vs. 17, respectively), cattle mortality (Md: 11, 0 vs. 18, respectively), and anxiety of farmer (Md: 3, 0 vs. 6, respectively) but had more effect than HS on farmer’s income (Md: 9, 20 vs. 6, respectively). FMD had more effect than the two other diseases on the time spent by farmers on treating sick animals. Income loss was the highest scoring effect of mastitis (Md: 20).

Table 5: Summary of disease impact matrix scoring of dairy cattle production in Long An and Tay Ninh province (n =13)

Impact	Foot-and-mouth disease	Haemorrhagic septicaemia	Mastitis	Blood parasites	Laminitis	Digestive disease
Anxiety W=0.73**, a	3 (1-21)	6 (3-15)	0 (0-6)	1 (0-2)	0 (0-1)	1 (0-1)
Income loss W=0.6*, e	9 (5-16)	6 (0-12)	20 (8-33)	1 (0-2)	0 (0-1)	2 (0-3)
Milk loss W=0.34**, b	3 (2-10)	4 (1-6)	5 (2-6)	2 (1-3)	1 (1-2)	2 (1-3)
Cattle mortality W=0.73**, e	11 (3-13)	18 (8-26)	0 (0-0)	0 (0-3)	0 (0-0)	3 (0-5)
Time spent for treatment W=0.72**, d	5 (3-4)	1 (1-1)	2 (1-3)	1 (0-1)	1 (0-1)	2 (1-2)
Cost of treatment W=0.63**, c	5 (4-8)	4 (2-4,5)	6 (3-7)	2 (1-4)	2 (1-2)	2 (1-2)
Capital loss (death of animal) W=0.57*, e	7 (2-8)	17 (13-18)	3 (2-5)	3 (2-8)	2 (2-4)	4 (2-5)
Loss of friendship W= na, f	9 (9-9)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
Reduced reproduction capacity W= na, f	10 (10-10)	3 (3-3)	1 (1-1)	2 (2-2)	5 (5-5)	2 (2-2)

n: number of focus groups;
Number in cell: score in median (min-max) for each impact;
Kendall coefficient of concordance W: agreement level for one impact caused by different diseases;
*, **: p value for Kendall coefficient of concordance (* p < 0.05, ** p < 0.01);
a, b, c, d, e, f: number of focus groups containing completed data for Kendall coefficient of concordance calculation (a=10, b=9, c=8, d=6, e=4, f= 1)
na: not applicable.

For beef cattle farmers, eight impacts were identified through 15 out of 19 focus group interviews (Table 6). The level of agreement between focus groups on the impacts varied significantly such as income loss (W: 0.6, p<0.01), capital loss (W: 0.6, p<0.01), cost of treatment (W: 0.88, p<0.01), debt (W: 0.89, p<0.01), time spent for treatment (W: 0.97, p<0.01). Anxiety (W: 0.34, p>0.05), reduced draft power and fear of propagation had insignificant levels of agreement. Capital loss was still the most important impact with the highest SMS (SMS: 41). HS caused the most impacts for livelihood and income of beef cattle farmers compared to FMD (SMS: 68 and 77, respectively), which was aligned with the results of disease prioritisation for beef cattle. FMD was less important than HS in contributing to capital loss (Md: 16 vs. 21, respectively) and debt (Md: 11 vs. 16, respectively), but more important in treatment cost (Md: 7 vs. 5, respectively) and time spent for treatment (Md: 5 vs. 4, respectively).

Table 6: Summary of disease impact matrix scoring of beef cattle production in Long An and Tay Ninh province (n =15)

Impact	Foot-and-mouth disease	Haemorrhagic septicaemia	Ruminant tympany	Bovine diarrhea
Anxiety W=0.34 ns, d	5 (2-8)	11 (1-16)	4 (1-21)	2 (1-6)
Income loss W=0.6 **, c	5 (3-27)	5 (0-23)	4 (0-18)	2 (0-9)
Time spent for treatment W=0.97 **, d	5 (2-19)	4 (2-11)	2 (1-7)	2 (0-4)
Cost of treatment W=0.88 **, a	7 (3-17)	5 (2-9)	3 (0-5)	2 (1-5)
Capital loss (death of animal) W=0.6 **, b	16 (3-67)	21 (5-32)	2 (0-13)	2 (0-14)
Debt W=0.89 **,e	11 (4-21)	16 (1-24)	1 (0-1)	0 (0-7)
Reduced draft power W= na, f	7 (6-7)	4 (0-6)	4 (0-4)	2 (0-3)
Fear of propagation W= na, f	12 (11-13)	11 (10-13)	0 (0-0)	0 (0-0)

n: number of focus groups;
Number in cell: score in median (min-max) for each impact;
Kendall coefficient of concordance W: agreement level for one impact caused by different diseases;
ns, *, **: p value for Kendall coefficient of concordance (ns: $p>0.05$, * $p < 0.05$, ** $p < 0.01$);
a, b, c, d, e, f: number of focus groups containing completed data for Kendall coefficient of concordance calculation (a=10, b=9, c=7, d=6, e=4, f= 2);
na: not applicable.

For pig farmers, 7 impacts were identified from 10 out of 16 focus groups. Capital loss was the most important impact caused by disease (SMS: 49), followed by debt (SMS:

31), income loss (SMS: 23), anxiety (SMS: 21), cost of treatment (SMS: 17) (Table 7). The level of agreement between focus groups was identified for anxiety, capital loss and cost of treatment (W: 0.58, 0.52, 0.49, respectively). Other impacts (i.e. time spent for treatment, income loss, debt, family conflict) had insignificant levels of agreement. PRRS was given highest median scores for all identified impacts compared to other diseases and caused highest impacts for livelihood and income of pig farmers (SMS: 91). This was aligned with the results of disease prioritisation. FMD and diseases due to *E.coli* had the same SMS (SMS: 18) and higher than salmonellosis (SMS: 12) and other diseases (SMS: 10).

Table 7: Summary of disease impact matrix scoring of pig production in Long An and Tay Ninh province (n =10)

Impact	**Porcine reproductive and respiratory syndrome**	**Diseases due to *E.Coli***	**Foot-and-mouth disease**	**Salmonellosis**	**Other diseases**
Anxiety W=0.58 **, a	11 (3-16)	3 (0-11)	4 (0-7)	2 (0-10)	1 (0-4)
Time spent for treatment W=0.53 ns, d	4 (2-6)	0 (0-3)	0 (0-1)	2 (0-3)	1 (0-2)
Cost of treatment W=0.49 **,b	8 (0-28)	1 (0-5)	3 (1-6)	3 (1-6)	2 (1-7)
Capital loss (death of animal) W = 0.52 **, a	31 (6-48)	5 (0-15)	5 (0-15)	4 (0-9)	4 (0-8)
Income loss W=0.46 ns, c	9 (3-15)	8 (0-10)	4 (0-6)	1 (0-5)	1 (0-4)
Debt W = 0.69 ns, d	27 (12-28)	1 (0-7)	2 (1-27)	1,2 (0-4)	1 (0-4)
Family conflict W= na, e	1 (1-1)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)

n:number of focus groups;
Number in cell: score in median (min-max) for each impact;
Kendall coefficient of concordance W: agreement level for one impact caused by different diseases;
Ns, *, **: p value for Kendall coefficient of concordance (ns: $p>0.05$, * $p < 0.05$, ** $p < 0.01$);
a, b, c, d, e: number of focus groups containing completed data for Kendall coefficient of concordance calculation (a=9, b=7, c=4, d=3, e=1);
na: not applicable

4. Discussion

4.1. Advantages and limits of methods used

PE approach proved its value by encouraging farmer to participate in meetings with thorough discussions and knowledge exchange. It allows collecting semi-quantitative data with help of standardization process in some exercises (matrix scoring, pairwise ranking) and validating agreement between groups about studied subject with non-parametric statistic test. This approach is flexible to adapt for any situation. Data of pairwise ranking exercise not only showed ranking of different elements (animal production issues, diseases) throughout SMS and Md but also showed frequency of elements based on their importance to community. In fact, an element considered as less important and appearing less frequently will be presented with median score nearly zero (Figure 2, 3). In matrix-scoring exercise, two ways of ranking provided same effectiveness on results. Agreement between groups through Kendall's coefficient concordance indicated that standardized matrix was repeatable and reproducible (Catley et al., 2001b).

Our survey using participatory methods is the first application in the field without prior references about livestock production issues and diseases. Therefore, a lot of information had been collected at the beginning making it hard to classify in a proper way for analysis; some data are even lost due to limited capacity of PE team member. Working with key informant might be a good solution in order to generate information about location and cultural knowledge that can help to lead and discuss with participants in a particular location. Presence of commune veterinarians could be a bias as farmers asked for help from them to solve questions related to clinical signs of disease. It is necessary to obtain agreement with veterinarians regarding their involvement in meetings. Standardized step applied in matrix scoring exercise helps to normalize collected data and allow for quantitative data analysis but this resulted in loss of flexibility of participatory approach especially when we proposed farmer to talk about a diseases that was not present in the standardized matrix.

Catley et al. (2012) mentioned an intra-validation step by adding one or two control diseases in matrixes are helpful to evaluate understanding level of participants. This work is missing in our survey because of limited prior information, so the evaluation part is not fully performed and is recommended in next study. The disease matrix needs to be improved especially on the clear distinction between disease due to *E.coli* and diarrhea. One possible way to do this is to define oedema due to *E.coli* and merge diarrhea caused by *E.coli* into diarrheal disease. In fact, diarrhea is a multi–factor disease caused by various viral and bacteriological agents (Radostits et al., 1994).

4.2. Animal production issue priorities

Our survey confirmed that there are still a lot of issues for farmer in livestock such as diseases, lack of capital, lack of grazing surface and insufficiency of breeding knowledge for dairy production; lack of capital and diseases for beef production; diseases, instability of final product prices and high feed cost for pig production. Our finding is similar to what was mentioned by other authors (Suzuki et al., 2006; Ashbaugh, 2010; Vo, 2011; Lapar et al., 2012; Nguyen and Nanseki, 2015). While resource capacity is still limited for farmers, this finding is very useful to advise them to concentrate their resource in solving those issues. Issues in dairy farms are mainly link to its origin. Dairy farms are not a traditional practice in Vietnam and have been developing for the past 20 years thank to increase in milk demand for domestic consumption (Suzuki et al., 2006). Many farmers think they can look after the high performance animals in a similar way with the local beef breed at the beginning. However, dairy cattle require more specialized husbandry than local beef to achieve their full performance. Even though they had been trained dairy production management for a short time (several weeks) with support of different institutions, e.g. milk collector company, government projects (Suzuki et al., 2006; Vo, 2011), it seemed that achieved knowledge from training still was not enough for them. Besides disease, lack of capital was the most important issue that beef farmers faced. The issue of instability of final product prices was due to the way of selling final product. Traders purchased final products from farmers and decided the price of live animals. High feed cost was due to importation of raw materials in Vietnam (Hoang, 2011). Diseases were an important issue in all types of livestock production. It was mainly due to lack of bio-security application by smallholder farmers (Nguyen, 2014). It was reported that pig farmers rarely used disinfection, did not wear protective cloths or boots, visitors were often able to access the pig area and pig feed storage with signs of mould was present in farm (Unger, 2015). Moreover, farmers had risky practices while handling of sick and dead animals such as emergency selling or home consumption (Unger, 2015). Lack of bio-security practice for beef and dairy farms are not well documented but we can consider that bio-security problem exists in all type of smallholder farms.

4.3. Livestock disease priorities

The farmer’s disease priorities were more complicated than those of the veterinary services because farmers had to face many diseases in cattle farming (e.g. FMD, HS, mastitis, inflammation of hooves, blood parasites, digestive diseases, ruminant tympani, diarrhea) and in pig farming (e.g. PRRS, diseases due to *E.coli*, salmonellosis, FMD and pneumonia). Veterinary services only focused on the control of notifiable diseases, e.g. FMD and PRRS because of the important economic impact, high morbidity, mortality and quick transmission (Veterinary regulation, 2015). This showed that farmers had a more holistic animal health view and took into consideration all of livelihood's impacts while prioritising diseases. The difference in disease priorities between two main actors implied that animal health surveillance and control system can subsequently influence negatively on farmer's adoption of disease control strategies (Chatikobo et al., 2013).

Our findings highlighted that FMD played different role in the three farm types, particularly regarding the impacts of important diseases on farmer's livelihood. This can be explained by using the risk analysis theory applied by farmers. According to this theory, two elements that farmers took into consideration in case of presence of infection risk were the probability of infection and the consequences (Yoe, 2012). For cattle farmers, the probability of being affected was higher in dairy cattle (18.4%) than in beef cattle (15.8%) (Carvalho Ferreira et al., 2015). Moreover, difference in consequence could be an interesting variable to explain the distinction of farmers' ranking of FMD between dairy cattle and beef cattle. Dairy cattle farmers' income depends on their daily sale of milk. In case of FMD outbreak, a part of their income will be lost in long term because of reduction of milk production. As mentioned by some authors, reduction of milk production is one of the main direct impact of FMD, which varied from 33% to 80% in some defined conditions (Barasa et al., 2008; Bayissa et al., 2011). In addition, time spent for treatment and cost of treatment seems to be more important in dairy farm than in beef farm. In fact, high productivity of dairy cattle in Vietnam which were mainly imported from other countries (Vo et al., 2010) were more sensitive to infection and complication than local race. Income from beef cattle comes when the animals were sold after several months or years of fattening and an affected animal could be sold with a normal price several months after receiving clinical treatment. Therefore, beef's farmer considered that the impacts caused by FMD were not so important. This explained why beef farmers ranked FMD less important than dairy cattle farmers. Results of disease ranking in beef was quite similar with Bellet et al. (2012) in Svay Rieng, Cambodia. For the pig farmers, the FMD affected probability was lower with the prevalence less than 1% (Nguyen et al., 2015) and minor consequences because of the possibility of emergency selling. Moreover, impacts from other infectious diseases, e.g. PRRS, were considered more severe than FMD, especially if secondary infections occurred with agents such as *Mycoplasma hyopneumonia*, swine influenza virus, *Salmonella choleraesuis* or *Streptococcus suis* (Holck and Polson, 2003). Therefore, they ranked FMD far after PRRS, diseases associated with *E.coli* and Salmonellosis.

4.4. Differential diagnostic of diseases

The results of matrix scoring clearly showed the good knowledge about animal diseases from local farmers in the study area. Farmers could recognize some basic and specific symptoms of diseases. However, they could not recognize particular symptoms related to one disease and distinguish the important level of a symptom that is presented in different diseases. Moreover, the diagnosis was based on clinical symptoms and lesions presented outside of animals that were results of direct observation by farmers and they did not perform clinical examination on a sick animal as practiced by veterinarian. Local description of disease name and symptoms were largely related to modern disease signs described by veterinary medicine textbook (Radostits et al., 1994). Similar study has not been performed with commune veterinarians in order to compare knowledge between actors (farmer and veterinarian) but we noted that disease description were quite similar between farmers and veterinarians during open discussion. It justified that indigenous knowledge of Vietnamese farmers was as valued as those of African farmers (Catley, 2006). This knowledge came mainly from their experiences with diseases in their farm, daily information exchange, television and journals. In fact, experienced farmers often shared their information during the interview. Daily information exchange is a regular activity of farmer in study zone while they take morning coffee. In addition, they share with research team their interest of watching television, journal in order to update situation around them.

4.5. Socio-economic impact of diseases

Our survey clearly identified important level of prioritized diseases in each farm type. Impacts of FMD, HS and PRRS were the most important for dairy, beef and pig farm, respectively. FMD caused thirteen impacts on livestock production according to our survey. Among them, capital loss was the most important impact because capital loss meant that farmers lost their family's saving in the form of animals. From farmer's point of view, FMD in beef and dairy cattle is treatable but FMDV can not be eliminated through those methods. For dairy farmers, they recognized consequences of FMD directly through daily income loss due to reduction of milk during treatment period with local medicine or not-selling milk in several days when antibiotics were used. For beef cattle, farmers inform us that FMD caused weight loss because of loss of appetite and required a long time for recovery, at least 2-4 weeks to reach normal state and one year for hooves fixation. Therefore, beef cattle farmers considered the impact of FMD less important than HS, which causes sudden death within 24 hours if not treated on time. HS infection meant that farmer loss immediately their capital and caused anxiety for them. Evaluation of PRRS impact in pig farm in our survey was in line with Pham et al. (2016) about financial impact study of pig diseases in Vietnam. Bellet et al. (2012) also noted the impacts of difficulty to treat, reduced selling price, reduced meat consumption and reduced manure production for pig, buffalo and cattle farm in Svay Rieng, Cambodia.

5. Conclusion

Our surveys highlighted that livestock issues, disease impacts and farmer prioritisation on important diseases were different according to the farm types. Moreover, farmer prioritisation on diseases was not always in accordance with authority's point of view. Indigenous knowledge at local state has its value and helped farmers deal with different diseases present in their herd. It needs to be incorporated in surveillance system for early detection of suspect cases of infectious disease. Therefore, farmers need to be motivated and act as a valuable collaboration in surveillance system at local level. Further research on disease impacts with quantitative data need to be performed to achieve a full picture diseases impacts in Vietnam.

6. Recommendation

Clinical symptom information of infected animal given by farmer is valuable in diagnosis procedure. Combining those with laboratory test not only triangulate information value but also provide exact data of suspect case, particularly in case of infectious disease in a given location. Those accuracy data can be used to guide treatment protocol or control methods. In the context of early detection, if farmer is satisfied with their information of a suspect case and accept to declare immediately after observation, control method applied would have higher efficiency. In fact, early information will guide veterinary authority to investigate, collect samples and concentrate limited resources in effective control measures in a small-scale. Economical loss would be minimized for farmers, neighbours and government.

Applying matrix-scoring exercise in the field allowed participants to contribute, share and revise their knowledge in an open environment. This exercise can be applied as a training framework for farmers with presence of an expertise in focused topic. After collecting all information, expert can help to synchronize, leave some comments and correct inexact or confused information. This training method will help farmers understand, remember and motivate them to participate in training. This new approach is more effective than conventional seminar using top-down direction (one talk and one hundred listen). Working in a small group capacity is an inconvenience of this approach and that needs to be taken into consideration while applying it in the field. Good communication skills, comprehension of local culture, skills in statistic are necessary for researcher to perform this kind of activity in the field.

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Supporting information

Table S1: Overall ranking of animal diseases of dairy cattle, beef cattle and pig production among groups of farmers in the study zone from June to October 2014

Disease	Dairy Cattle				Beef Cattle				Pig			
	n	Median score	Sum z – scores	Rank	n	Median score	Sum z - scores	Rank	n	Median score	Sum z - scores	Rank
Foot-and-mouth disease	13	2	70	1	18	2	163	2	14	4	169	4
Haemorrhagic septicaemia	13	2	68	2	18	1,5	170	1	2	-	23	8
Mastitis	13	3	51	3	na	na	na	na	na	Na	na	na
Inflammation of hooves	13	5	35	4	1	-	8	8	2	-	22	10
Blood parasites	11	6	32	5	na	na	na	na	na	Na	na	na
Digestive diseases	13	4	16	6	na	na	na	na	na	Na	na	na
Ruminant tympany	na	na	na	na	18	3	143	3	na	Na	na	na
Diarrhea (+/- blood)	na	na	na	na	16	4	119	4	5	-	70	6
Intestinal disease	na	na	na	na	1	-	9	6	na	Na	na	na
Hernias in calf	na	na	na	na	1	-	6	10	na	Na	na	na
Salmonellosis	na	na	na	na	1	-	8	8	14	3	174	3
Flu_like illness	na	na	na	na	3	-	20	5	2	-	23	8
Freezing muscle	na	na	na	na	1	-	9	6	na	Na	na	na
Disease due to *E.coli*	na	na	na	na	na	na	na	na	15	2	193	2
Porcine reproductive and respiratory syndrome	na	na	na	na	na	na	na	na	14	1	206	1
Pneumonia	na	na	na	na	na	na	na	na	10	4	119	5
Classical Swine Fever	na	na	na	na	na	na	na	na	2	Na	28	7
Arthritis	na	na	na	na	na	na	na	na	1	Na	9	15
Porcine parvovirus	na	na	na	na	na	na	na	na	1	Na	11	14
Pseudo-estrus	na	na	na	na	na	na	na	na	1	Na	12	13
Coccidiosis	na	na	na	na	na	na	na	na	1	Na	13	12
Ship-fever	na	na	na	na	na	na	na	na	1	Na	15	11

n: number of disease repetition mentioned by farmer during a meeting;
sum z cores: sum of standardized scores for a disease;
na: not available

Table S2: Summary of standardized disease symptom matrix scoring of dairy cattle diseases described by farmer's knowledge in Long An province, Viet Nam (n=9)

Symptom/ Disease	**Foot-and-mouth disease** W2= 0.88**, c	**Haemorrhagic septicaemia** W2= 0.72**, c	**Mastitis** W2= 0.93**, c	**Blood parasites** W2= 0.59**, c	**Laminitis** W2= 0.77**, c	**Digestive disease** W2= 0.76**, c
Salivation W1=0.88**,a	18 (12-23)	10 (3-18)	0 (0-3)	0 (0-7)	0 (0-12)	0 (0-1)
Loss of appetite W1=0.82 **,a	8 (3.6-14)	8 (1-15)	2 (0-9.6)	1 (0-3)	1 (0-4.8)	8 (2.4-16)
Fever W1=0.66**,b	6 (3-14)	8.5 (3-13)	7.1 (5-10.5)	0.5 (0-5)	3 (2-10.5)	0.5 (0-4)
Lameness W1=0.97**,a	15.6 (12-30)	0 (0-3.6)	0 (0-0)	0 (0-0)	14 (9-18)	0 (0-0)
Inflammation of udder W1=1**,a	0 (0-0)	0 (0-0)	30 (30-30)	0 (0-0)	0 (0-0)	0 (0-0)
Stop rumination W1=0.68**,b	5.5 (0-8)	9 (0-30)	0 (0-1)	0 (0-0)	0 (0-0)	13.5 (0-25)
Ruminant tympany W1=0.86**,a	0 (0-0)	0 (0-15)	0 (0-0)	0 (0-0)	0 (0-0)	30 (15-30)
Respiratory distress or increased respiratory rate W1=0.61**,a	4.8 (0-20)	15 (0-21)	0 (0-3)	0 (0-4)	0 (0-3)	8 (0-15.6)
Milk loss W1=0.54**,b	6 (4-10.8)	6 (2-10.8)	4 (2.4-8)	2.5 (0-4)	3.5 (3-5)	5 (2.4-12)
Jaundice W1=0.44*,b	0 (0-13)	0 (0-15)	0 (0-0)	22 (0-30)	0 (0-0)	3.5 (0-11)
Rotten milk W1=0.92**,b	0 (0-9)	0 (0-0)	30 (21-30)	0 (0-0)	0 (0-0)	0 (0-0)
Hoof loss W1=0.88**,b	30 (0-30)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-14)	0 (0-0)

n: number of focus groups;
Number in cell: score in median (min-max) for each symptom;
Kendall coefficient of concordance W1: agreement level for each symptom;
Kendall coefficient of concordance W2: agreement level of a group of symptoms related to a disease;
*, **: p value for Kendall coefficient of concordance (* $p < 0.05$, ** $p < 0.01$);
a, b, c: number of focus groups containing completed data for Kendall coefficient of concordance calculation (a=7, b=6, c=5).

Table S3: Summary of standardized disease symptom matrix scoring of beef cattle diseases described by farmer's knowledge in Long An province, Viet Nam (n=9)

Symptom/ Disease	**Foot-and-mouth disease**	**Haemorrhagic septicaemia**	**Ruminant tympany**	**Bovine diarrhea**
Fever	5,6 (1,6-8)	8,8 (0-14)	2 (0-6)	2,4 (0-4)
Respiratory distress or increased respiratory rate	0 (0-3,2)	12,4 (4,8-20)	14,8 (9,6-20)	0 (0-0)
Ruminant tympany	0 (0-8,8)	0 (0-11,2)	20 (20-20)	0 (0-0)
Loss of appetite	4,9 (0-12)	5 (0-12)	5 (4-9,6)	1,8 (0-5,6)
Salivation	13,6 (8-20)	1,2 (0-12)	0 (0-5)	0 (0-0)
Hoof separation or loss	20 (20-20)	0 (0-0)	0 (0-0)	0 (0-0)
Swelling of pharynx	0 (0-0)	20 (12-20)	4 (0-8)	0 (0-0)
Feces liquid with bad smell	0 (0-10)	0 (0-6)	0 (0-2)	20 (2-20)
Erosions in mouth, tongue; presence of vesicles	20 (20-20)	0 (0-0)	0 (0-0)	0 (0-0)
Lameness	6,5 (0-20)	0 (0-20)	0 (0-0)	0 (0-0)

n: number of focus groups;
Number in cell: score in median (min-max) for each symptom

Table S4: Summary of standardized disease symptom matrix scoring of pig diseases described by farmer's knowledge in Long An province, Viet Nam (n=7)

Symptom/ Disease	Porcine reproductive and respiratory syndrome	Diseases due to *E.Coli*	Foot-and-mouth disease	Salmonellosis	Diarrhea	Other diseases
Fever	6 (0-14)	2 (0-6)	0 (0-5)	8 (3-30)	5 (0-6)	10,9 (0-25,2)
Quit eating	7 (6-17)	5 (0-7)	4 (0-13)	8 (6-13)	9 (0-12)	4 (0-18)
Coughing	0 (0-0)	0 (0-0)	0 (0-0)	20 (11-30)	6 (6-6)	6,8 (0-13,5)
Blotchy reddening of the skin	30 (30-30)	0 (0-0)	0 (0-0)	0 (0-0)	5 (0-11)	9,6 (0-19,2)
Periocular oedema	3 (0-6)	18 (6-30)	0 (0-0)	6 (6-6)	6 (6-6)	3 (0-6)
Vesicles on mouth and foot	0 (0-0)	0 (0-0)	30 (30-30)	0 (0-0)	0 (0-0)	0 (0-0)
Salivation	0 (0-0)	0 (0-13)	24 (12-30)	3 (0-5)	0 (0-0)	3 (0-6)
Diarrhea	0 (0-0)	5 (0-13)	0 (0-0)	0 (0-11)	30 (17-30)	7,8 (0-22,8)
Respiratory distress	3 (0-6)	0 (0-10)	0 (0-0)	2 (0-5)	0 (0-0)	27,6 (14,4-30)
Red discoloration in ears and noise	8 (8-8)	0 (0-0)	0 (0-0)	14 (14-14)	4 (0-7)	30 (30-30)
Lameness, hoof separation, difficulty of movement	5 (0-10)	0 (0-16)	2 (0-7)	0 (0-0)	0 (0-0)	23,5 (4,8-27,6)
Shivering	6 (0-7)	3 (0-7)	0 (0-0)	11 (6-22)	8 (6-11)	8 (0-30)

n: number of focus groups;
Number in cell: score in median (min-max) for each symptom

CHAPTER 3

DETERMINATION OF FOOT-AND-MOUTH DISEASE SERO-PREVALENCE USING A COMBINATION PARTICIPATORY EPIDEMIOLOGY APPROACH AND SEROLOGICAL SURVEY IN SOUTHERN VIETNAM

Submitted to *Transboundary and Emerging Diseases*

Determination of Foot-and-mouth disease sero-prevalence using a combination participatory epidemiology approach and serological survey in southern Vietnam

D. B. Truong[1,2*], A. Romey[3], F. L. Goutard[1,4], S. Bertagnoli[5], L. B. Kassimi[3], V. Grosbois[1]

[1] UMR ASTRE, CIRAD, F-34398 Montpellier, France

[2] Faculty of Animal Science and Veterinary Medicine, Nong Lam University, Ho Chi Minh, Vietnam

[3] UMR Virologie 1161, Anses, Laboratoire de Santé Animale de Maisons-Alfort, Laboratoire OIE de référence Fièvre Aphteuse, Université Paris-Est, 14 rue Pierre et Marie Curie, 94700 Maisons-Alfort, France.

[4] Faculty Veterinary Medicine, Kasetsart University, 10900 Bangkok, Thailand

[5] IHAP, Université de Toulouse, INRA, ENVT, Toulouse, France

* dinhbao.truong@hcmuaf.edu.vn or dinh-bao.truong @cirad.fr

Short title: FMD infection and true sero-prevalence estimation

Abstract

Bayesian modelling was implemented to estimate the true prevalence of foot-and-mouth disease (FMD) from two sources of information: a participatory epidemiology approach (PE) and a serological survey, to estimate the sensitivity (Se), specificity (Sp) and predictive values of PE at animal level. The second objective was to compare the circulating viruses in the study zone with those isolated in other geographical locations. PE was performed in 19 villages in 4 districts of Long An province, representing two distinguished population according to geographical location. Population 1 encompassed three districts at the border of Cambodia while population 2 consisted of one district located far away from the border. This included 26 focus groups and 65 individual interviews. Sera (n=301) and oesophageal fluid samples (n=24) from cattle and buffalo were collected in villages after focus group discussions on the local FMD situation. Sera were tested with non-structural 3ABC protein ELISA and oesophageal fluid were submitted for screening, serotype identification and virus isolation. The Bayesian modelling combined the data collected through PE and serological test results. The true FMD sero-prevalence at animal level in population 1 and 2 were estimated at 23% and 31%, respectively. Se and Sp of the PE were 59% and 81%, respectively. The positive and negative predictive values of PE were estimated at 48% and 86% for population 1, and 58% and 81% for population 2, respectively. The presence of serotype A, lineage A/Asia/Sea-97 and serotype O with two separate lineages, O/ME-SA/PanAsia and O/SEA/Mya-98 and their linkage to other isolates from surrounding countries supported the circulation of multiple serotypes in study area and maybe in other areas of Vietnam and raised hypothesis of disease transmission caused by to unlimited trans-boundary livestock movement. Our study, one of the first experiments to apply PE to animal health in Southern Vietnam, may be applicable in other developing countries.

Keywords: Bayesian method, Foot-and-mouth disease (FMD), participatory epidemiology (PE), sero-prevalence, Vietnam

1. Introduction

Foot-and-mouth disease (FMD) is known to have a significant impact on the performance of small producers and is therefore a threat to the livelihood and food security of the poorest communities worldwide (Madin, 2011). In Vietnam, FMD remains a major threat while causing outbreaks almost every year (T.T. Nguyen et al., 2014). Three serotypes and seven lineages have been reported as circulating in Vietnam, including O/SEA/Mya-98, O/SEA/Cam-94, O ME-SA/PanAsia, O MESA/Pan Asia2, O/Cathay, A Asia/Sea-97 and unknown lineages of serotype Asia1 (Le et al., 2010; Abdul-Hamid et al., 2011; Lee et al., 2011). Data on FMD outbreaks from 2006 to 2012 showed that, on average, a serious epidemic occurred every 2-3 years in Vietnam. The average incidence risk at the commune level was 5.1 [95% confidence interval (Ci) 4.9 - 5.2]. This risk varied among years and geographical locations. FMD outbreaks occurred repeatedly in more than 60% of the communes located in hotspot areas (Nguyen et al., 2014). It has been estimated that each FMD affected farm in Vietnam suffers an economic loss between $84 and $930 (Tung and Thuy, 2007 as cited in Forman et al., 2009).

Vaccination has been recognised as a helpful tool to control FMD and is an essential part of the progressive FMD control pathway from the World Health Organisation (OIE Sub-Regional Representation for South East Asia, 2011; OIE and FAO, 2012). In Vietnam, this tool has been integrated as a major technical solution in FMD national program applied since 2006 to improve FMD control at national level with the objective to reach an eradication of this disease. Based on the epidemiological situation, geography, husbandry practices, socio-economic factors, financial capacity and disease control targets, Vietnam has implemented FMD control program by dividing the country in three zones (control, buffer, and low risk zones). The vaccination policy and budget is different for these three zones. FMD vaccination has been applied for cattle and buffalo in control and buffer zones. For other animals, vaccination can be done at the livestock owners' expenses. In the control zone, vaccines are supplied free of cost while in the buffer zone vaccines are supplied at subsidized rate (50%) and in the low risk zones, vaccination against FMD is encouraged to the farmers but the government do not supply the free vaccines. Currently, the two major FMD serotypes O and A are circulating in Vietnam (Le et al., 2011; MARD, 2015; WRLFMD, 2017). Vaccines currently in use are either monovalent (targeting serotype O) or bivalent (targeting serotype O and A). Vaccination is usually implemented twice a year in March-April and September-October. In Long An province, five districts which borders Cambodia are classified as control zones. 100% of cattle in those districts receive two injections every year which is supplied free of cost by the government subvention (national level). Cattle in two other important districts such as Duc Hoa and Chau Thanh receive one free injection per year with support of provincial budget. This policy is applied only for herds having less than 20 heads and free vaccine is supplied for the second injection of vaccination campaign (September-October). For pigs, vaccination is supplied free for one time per year in the important districts such as Chau Thanh, Duc Hoa, Ben Luc, Tan Tru, Tan An, Thu Thua (2 communes), Can Duoc (3 communes), Can Giuoc (3 communes) for farms where herd size is less than 50. These farms are encouraged to maintain immunity in their herd by not missing the second vaccination. Other farmers who are not involved in subvention policy are mobilized to practice vaccination on their expenses (DARD Long An, 2014). Vaccine types used in cattle varied from year to year. In 2013, Long An authorities used monovalent vaccines in cattle populations in all districts before using bivalent vaccines in 2014 for 5 bordering districts and monovalent for the others. The delay in the delivery of vaccines led to the delay in the vaccination program by 1 to 2 months from the planned program (DARD Long An, 2013, 2014).

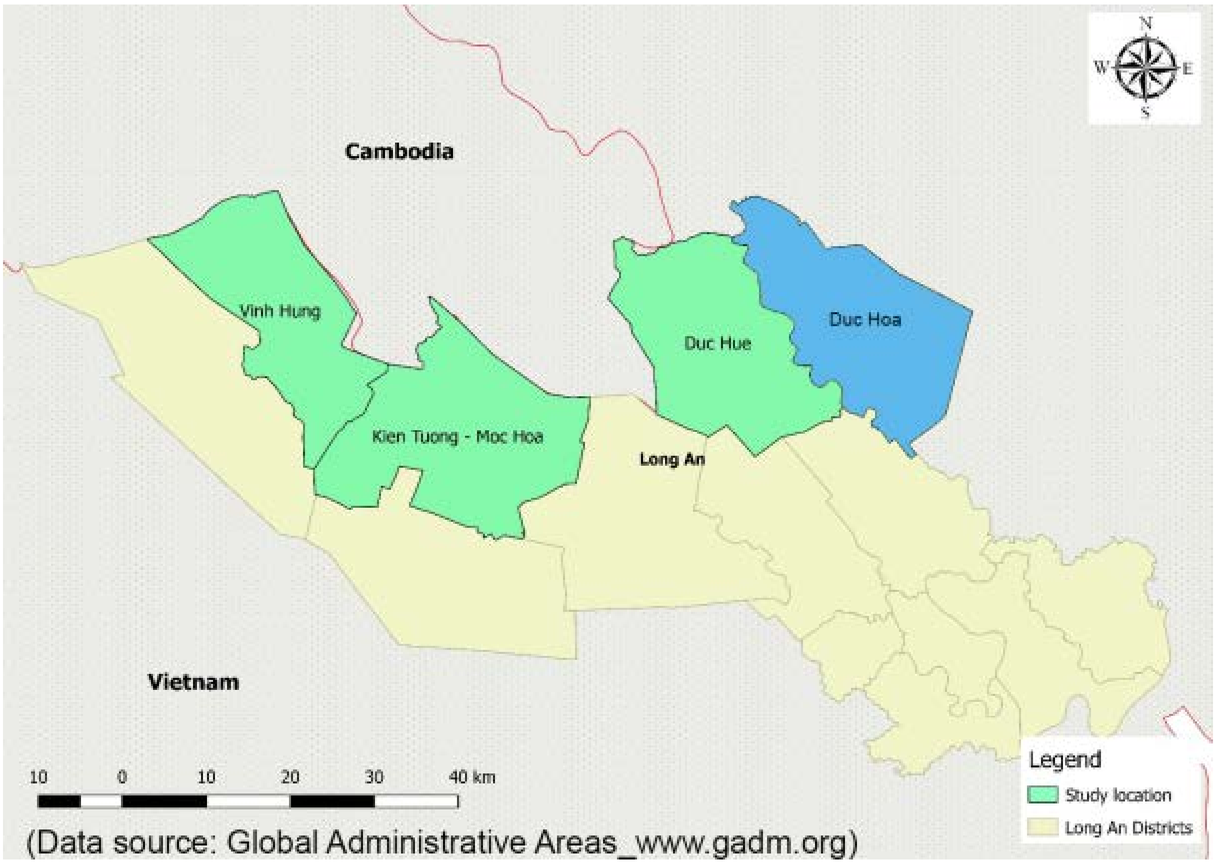
As an adaptation of participatory rural appraisal techniques in epidemiology, participatory epidemiology (PE) is used to collect and analyse qualitative epidemiological data. PE is an approach through which information and knowledge from local farmers are collected and combined with direct observation and other conventional clinical tools (Mariner and Paskin, 2000; Mariner, 2009). PE actively involves the farmers in gathering sanitary information. PE has been used to understand the perception of FMD in rural communities in Ethiopia, to understand the motivation of farmers' sanitary choices (vaccination vs. treatment vs. sale) in Sudan, to describe the epidemiological situation of FMD and investigate its relative incidence and impacts in Cambodia (Catley et al., 2001; Shiferaw et al., 2009; Bellet et al., 2012). While local knowledge in this domain is considered as an important source of information and is well-documented elsewhere, it remains lacking in Vietnam. As mentioned by Bellet et al. (2012), the quantitative validation of PE, achieved by comparing disease diagnosis obtained from PE with standard diagnostic tests, is advisable. In the present study, we aimed to estimate the true prevalence of FMD from two sources of information (PE and serological test) using a Bayesian approach and then to estimate the value of PE through parameters such as sensibility, specificity and predictive values at animal level. The second objective of the study was to compare the circulating viruses in the study area with the isolates in other geographical locations, including surrounding countries, using molecular analysis.

2. Materials and methods

2.1. Study location

The research team conducted the field work, i.e. interviewed farmers and sampled cattle in 19 villages of four districts of the Long An province (Figure 1). These districts were selected, in agreement with the sub-Department of Animal Health of Long An province, based on (1) the importance of livestock production, (2) the proximity to the Cambodian border, (3) the importance of animal movements between provinces and countries, and (4) the high-risk zones for FMD control.

Figure 1: Map of study zone showing location of four districts in Long An province, South Vietnam



Yellow shaded area of the districts in Long An province, green shaded area of districts under study.

2.2. Sample size calculation

The sample size calculations were based on an individual animal prevalence of 30% (Phan, 2014) as well as sensitivity (Se) and specificity (Sp) of non-structural 3ABC protein enzyme-linked immunosorbent assay (ELISA NSP 3ABC) PrioCHECK test (Se=92.6%, Sp=96.1%) (Brocchi et al., 2006). Sample size was set to 18 animals per village which was our assessment of the minimum requirement to detect, with a reasonable probability, at least one seropositive animal in infected villages. This assessment was done using WIN EPISCOPE 2.0 (Thrusfield et al., 2001). A total of 540 samples were needed from 18 randomly selected animals per village. Our required sample was computed as 30 villages, i.e. ten villages in each production type (dairy, beef and pig farm). A stratified (by production system) random selection of 30 villages was selected from four districts to ensure the study's representativeness. The number of villages selected from each district was proportional to the districts' animal population. At least ten farmers (stratified selection by production type) were interviewed in each village. Due to disagreement of pig farmers, samples from pig were unable to be taken, then 10 villages belongs to pig production were excluded from our study. A total of 360 samples (18 cattle multiply with 20 villages) was recalculated and used in our analysis. Sampling was not performed in pigs due to field constraints (i.e. refusal of owners, time limitation).

2.3. Participatory epidemiology tools

The field data collection was done using participatory tools such as semi-structured interviews of focus groups or individuals including open questions and checklists. The research team conducted the field work from June 2014 to October 2014, interviewing 26 focus groups and 68 individuals. During the focus group interviews, which included 6 to 15 people (Mariner and Paskin, 2000), farmers were asked to describe the disease situation in their village. Farmers who declared having suspect cases of FMD in their farm during 2013 and 2014 were then interviewed individually. Checklists for individual interviews included details about suspected cases (total animals at risk, vaccination situation, morbidity and mortality) in their herd which were recorded with the help of a technical sheet of clinical signs in animals.

2.4. Sample collection

Blood samples were collected from July to October 2014 in villages where group interviews on the disease situation had been completed. Farms that had declared a recent history of FMD infection, within the 2013 and 2014 period were prioritised for sampling their animals. The goal of this activity was to cross-check information between farmers based on clinical signs and the sero-positivity of individual animals. The owner's prior agreement was obtained by telephone beforehand. The number of samples was generally limited to 5 animals per farm and 19 villages were included in this activity. All villages included dairy and beef producers who had participated in group interviews using participatory methods (see above) and blood sampling was done in each village. Blood was collected from cattle over 6 months of age in order to avoid the maternal immune effect. Sampled animal was selected randomly from herd and accordingly to owner's prior agreement. Status of animal sampled such as vaccinated/unvaccinated within six months prior to sampling moment, present/absent clinical signs were also collected. Oesophageal fluid (probang) samples were also collected from some animals that had presented clinical signs in recent months. Collection and conservation procedures applied for sera and oesophageal fluids followed the manual collection of Pirbright (Kitching and Donaldson, 1987). Sera and oesophageal fluids were stored in ice in the field for 2-3 days and then transported to the laboratory of the Nong Lam University

Veterinary Hospital (distance of 80-180 km from field) to be stored at -80°C. Then, the samples were shipped frozen to the French Reference Laboratory for FMD for laboratory analysis.

2.5. Laboratory tests

All of the laboratory tests were performed over a three-week period in November 2014, in compliance with the ANSES laboratory manual (ANSES, 2012; Bakkali-Kassimi et al., 2012).

Serologic tests with ELISA NSP 3ABC Priocheck for serum sample

Samples were tested for the presence of antibodies against the NSP of FMD virus (FMDV) with the 3 non-structural protein ELISAs kit (PrioCHECK FMDV NSP ELISA, Prionics, Netherlands; product No: 7610450). Analyses were performed according to manufacturer's instruction. Sample with sero-positive indicated that animal was infected at least once in approximately the last 2 years (with considerable uncertainty and variability, including by confounding, age and vaccination status).

Virology tests with PCR for probang samples

All probang samples were first subject to a screening test with one-step duplex real-time reverse-transcription polymerase chain reaction (rRT-PCR) pan FMDV. The protocol of screening test was set as previously described (ANSES, 2012; Gorna et al., 2014). Positive samples were then submitted to serotype identification with a second multiplex RT-PCR and virus isolation on cell culture. For serotyping, characterisation of the serotype of the FMDV was performed using specific primers and probes that targeted the VP1 region encoding a capsid protein. These pairs of primers and probes detected only type O, type A and type Asia1. Protocol of multiplex RT-PCR was set as previously described by ANSES (2012). Cell cultures were performed as previously described by Gorna et al. (2014).

Another RT-PCR for amplification of the VP1 protein coding sequence of FMDV according to protocol that was previously described (Gorna et al., 2014) was also performed on samples that came up positive in the screening test, to collect virus genomes for sequencing. The resultant gene sequences were assembled and verified using SeqMan software (DNAStar, Lasergene 8). The evolutionary history was inferred using the Neighbor-Joining method (Saitou and Nei, 1987). The comparison and midpoint-rooted neighbour-joining trees of FMDV VP1 sequences from this study with those from South East Asia available in the NCBI was performed using the Clustal W method running with MEGA 5.05 software (Tamura et al., 2013). The optimal tree with the sum of the branch length equal to 2.53 was shown. The percentage of replicate trees in which the associated taxa clustered together in the bootstrap test (1000 replicates) was shown next to the branches (Felsenstein, 1985). The tree was drawn to scale, with branch lengths in the same units as those of the evolutionary distances used to infer the phylogenetic tree. The evolutionary distances were computed using the Kimura 2-parameter method (Kimura, 1980) and were in the units of the number of base substitutions per site. The analysis involved 139 nucleotide sequences. All ambiguous positions were removed for each sequence pair. There were a total of 597 positions in the final dataset.

2.6. Risk factor analysis

To evaluate the possible role of practices and husbandry system on the sero-prevalence in study zone, seven explanatory variables issued from 110 individual interviews in 19 villages under study were analysed with helps of logistic regression model. In this model, sero-prevalence status of each farm was related to a set of explanatory variables, namely herd scale (≤ 20 heads per farm/ >20 heads per farm), production purpose (milk, breed, meat), disease cattle reported within considering period (yes, no), protocol of vaccination (Unknown, zero, one, two, more than two times per year), vaccination status (yes, no), age of animal (7-12 months, 12-24 months, 24-36 months, 36-48 months, ≥48 months), sex (male, female), type of vaccine used in farm (unknown, monovalent, bivalent), location of farm nearly to border (yes, no).

2.7. Bayesian modelling

The Bayesian approach was used to estimate the true prevalence of FMD in the study area from two sources of data: participatory declarations of suspect cases by farmers and serological tests. The sensitivity, specificity and predictive value of the participatory approach were also taken into consideration. Two populations were distinguished in the analysis according to geographical location. Population 1 encompassed three districts (named Vinh Hung, Kien Tuong-Moc Hoa, Duc Hue) at the border of Cambodia (*a*=1), while population 2 consisted of one district (named Duc Hoa) located far away from the border (*a*=2). For each of these two populations the data consisted in the vector ya:

$$ya = (ya11, ya12, ya21, ya22) \qquad \textit{(Equation (Eq.) 1)}$$

Where $ya11$ and $ya22$ represented the number of animals that tested positive and negative in both tests, respectively; $ya12$ and $ya21$ represented the number of animals that tested positive only in the participatory approach and serological test, respectively.

ya was produced by the multinomial model described in detail by Enøe et al. (2000) for two independent tests applied to two populations:

The Bayesian model

$$ya[1\colon 2,1\colon 2] \sim dmulti(pa[1\colon 2,1\colon 2], na)$$

$$pa[1,1] < -Prev1 \times SePE \times SeAb + (1 - Prev1) \times (1 - SpPE) \times (1 - SpAb)$$

$$pa[1,2] < -Prev1 \times SePE \times (1 - SeAb) + (1 - Prev1) \times (1 - SpPE) \times SpAb$$

$$pa[2,1] < -Prev1 \times (1 - SePE) \times SeAb + (1 - Prev1) \times SpPE \times (1 - SpAb)$$

$$pa[2,2] < -1 - pa[1,1] - pa[1,2] - pa[2,1]$$

$$SePE \sim dbeta(1,1)$$

$$SpPE \sim dbeta(1,1)$$

$$SeAb \sim dbeta(67.50,6.31)$$

$$SpAb \sim dbeta(192.77,8.78)$$

$$Prev1 \sim dbeta(1,1)$$

$$Prev2 \sim dbeta(1,1)$$

The parameters of the model included the sensitivities (Se) and specificities (Sp) of the participatory and the serological approaches (SePE, SpPE and SeAb, SpAb, respectively), as well as FMD animal-level prevalence among the animals investigated (Prev).

The positive and negative predictive values (PPV and NPV) of the participatory approach at animal level in two populations (*a=1,2)* were also computed and monitored using Eq. 2 and 3 as described by (Dohoo et al., 2003):

$$PPVa = SePE \times Preva \div [SePE \times Preva + (1 - SpPE) \times (1 - Preva)] \qquad (Eq.2)$$

$$NPVa = SpPE \times (1 - Preva) \div [SpPE \times (1 - Preva) + (1 - SePE) \times Preva] \qquad (Eq.3)$$

There were no sero-prevalence estimations for the two study populations from previous studies. The only available sero-prevalence estimation was reported at the hotspots areas as 0.243 (Ci 0.21-0.27) (Nguyen et al., 2014). Because sero-prevalence in the local area considered in the present study could differ greatly from such hotspots areas estimation, the prior distributions for the two sero-prevalence parameters were set as non-informative beta (1, 1).

The beta prior distributions for the sensitivity (SeAb) and specificity (SpAb) of FMD detection with the serological test were determined using the parameters for ELISA NSP 3ABC performances reported by Brocchi et al. (2006). The beta prior distribution of SeAb and SpAb were set as dbeta (67.5, 6.31) with mode = 0.926 and dbeta (192.77, 8.78) with mode = 0.961, respectively. Prior distributions were determined with the betaExpert function in package “prevalence” in R (Devleesschauwer et al., 2015).

For SeT1 and SpT1, non-informative beta (1, 1) priors were used, as there was no previous knowledge of the sensitivity and specificity of the participatory approach at animal level.

In this model it was assumed that the two tests used in each population were independent. This was considered to be acceptable because of the different biological nature of the two tests. PE relies on the syndrome – based on observations and declarations by farmers, while ELISA NSP 3ABC is a serologic – based technique. A second assumption was that the Se and Sp of each test were similar in both populations. Finally, the model assumed that prevalence varied between the two populations. Such a variation was likely as the populations presented different risk factors. Population 1 was located on the pathway of important animal movement routes at the border with Cambodia where FMD is present and routine vaccination is practiced. It was therefore subject to vaccination twice a year with government subsidies. Population 2 was characterised by a high density of dairy cows and of slaughterhouses. Government subsidies covered only one vaccination per year although some farmers applied a second injection at their own expense.

Using the free program WinBUGS (Spiegelhalter et al., 2003), two chains comprising 100,000 iterations each were simulated. Convergence between the chains was assessed by the Gelman–Rubin convergence diagnostic. The first 20,000 iterations were discarded from the analysis as burn-in.

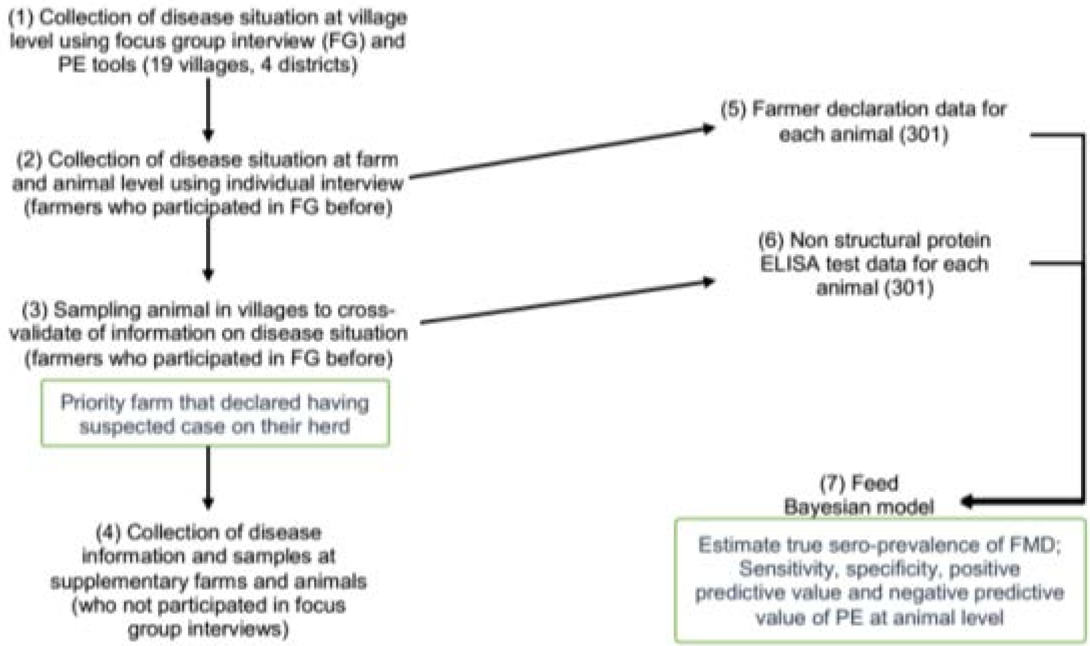
2.8. Data management

Information of each interview was recorded in the field and was stored as separated file using Microsoft Word 2007. Samples from each farm were recorded in separated form of data collection in the field and were inputted into a Microsoft Excel 2007 database. A copy of samples' data was sent to laboratory. Data analysis was performed with help of open source software R version 3.1.2 using integrated packages such as ""EpiCal" (Chongsuvivatwong, 2008), "prevalence" (Devleesschauwer et al., 2015). Bayesian model was developed and tested in WinBUGS environment (Spiegelhalter et al., 2003). The nucleotide sequences obtained in this study were deposited in the NCBI Genbank.

All ethics and principles of responsible research were observed at every step of the survey. We fully protected the privacy rights of participants by anonymising all the data. All the interviews and the sampling collection were carried out after presenting the study objectives and obtaining written informed consent in Vietnamese from all participants.

The summary of study design is presented in Figure 2.

Figure 2: Summary of study design



3. Results

3.1. Infection situation detected by participatory epidemiology methods

From the focus group interviews, suspected cases of FMD were detected in 13 villages. Through individual interviews, 75 animals from 27 farms were reported as presence of the FMD clinical signs during studied period (Table 1). 33% of suspected cases were found in the population 1 and the rest of 67% belonged to the population 2 (Table 2).

Table 1: Sero-prevalence status classification per district, village and farm level

Distribution of	Results of ELISA NSP 3ABC		Total samples (animal)
	Positive %	Negative %	
District			
+Vinh Hung	36.9	63.1	46
+ Kien Tuong-Moc Hoa	28.6		28
+ Duc Hue	5.7		37
+ Duc Hoa	32.6		190
Total	29.6		301
Farm	46.3[a]	53.7	110
Village	84.2[b]	15.8	19

ELISA NSP 3ABC: ELISA non-structural protein 3ABC
a: Percentage of farms with at least one animal having positive result with ELISA NSP 3ABC
b: Percentage of village with at least one animal having positive result with ELISA NSP 3ABC

Table 2: Observed sample test results for 2 populations, cross-classified as positive (T+) or negative (T-) for foot–and-mouth disease by participatory epidemiology approach (PE) and ELISA NSP 3ABC at animal level

PE	ELISA			
	Population 1 (near border)		Population 2 (far away from border)	
	T+	T-	T+	T-
T+	15	10	29	21
T-	12	72	33	103

3.2. Infection situation detected by serological test

Due to the field constraints and predefined criteria for the maximum number of samples taken per farm, there were 301 out of the required 360 sera collected from four districts. The number of animal sampled per farm varied from 1 to 6 to avoid cluster issue. The FMD animal-level sero-prevalence in study zone was found at 29.56% [Ci 95% (24.3-34.8)]. The average inhibition percentage of positive samples was 81.04 [min-max (50-97)]. The average sero-prevalence was recorded highest at Vinh Hung district 36.9% (17/46) (Table 1). The figures at others districts (Duc Hoa, Kien Tuong-Moc Hoa, Duc Hue) were 32.63% (62/190), 28.57% (8/28) and 5.71% (2/37), respectively. Except Duc Hue district, the sero-prevalence at the other three districts had no significant difference (p value >0.05). Risk factors were identified within two variables. Age and vaccination status were considered as confounder factors and also added into the final model even the result did not show a significant different (Table 3). Animal within farm that reported diseases one year before had an odd of 5.7 95% Ci (3.12; 10.41) being infected than farm without cases reported. Cow had an odd of 2.39 times higher than bull being infected.

Table 3: Odds ratio (OR) for each variable associated with infection situation (n=282)

Explanatory variable	Crude OR (95% Ci)	Adjusted OR (95% Ci)	p-value (Ward's test)	p-value (LR-test)
Presence of symptoms in cattle within considering period				
+No	Ref	Ref	p<0.001	p<0.001
+Yes	5.34 (3;9.52)	5.7 (3.12;10.41)		
Sex				
+Male	Ref	Ref	p>0.05	p<0.2
+Female	2.76 (0.93;8.21)	2.39 (0.73;7.88)		
Age of animal				
+7-12 months	Ref	Ref		p>0.2
+13-24 months	1.99 (0.85;4.7)	1.49 (0.58;3.8)	p>0.05	
+25-36 months	1.48 (0.63;3.46)	1.11 (0.44;2.82)	p>0.05	
+37-48 months	2.66 (1.02;6.91)	2.13 (0.74;6.11)	p>0.05	
+>48 months	1.61 (0.63;4.08)	1.29 (0.46;3.6)	p>0.05	
Vaccination status				
+Vaccinated	Ref	Ref		p>0.2
+Unvaccinated	1.46 (0.56;3.78)	1.75 (0.6;5.08)	p>0.05	

Ci: confidence interval

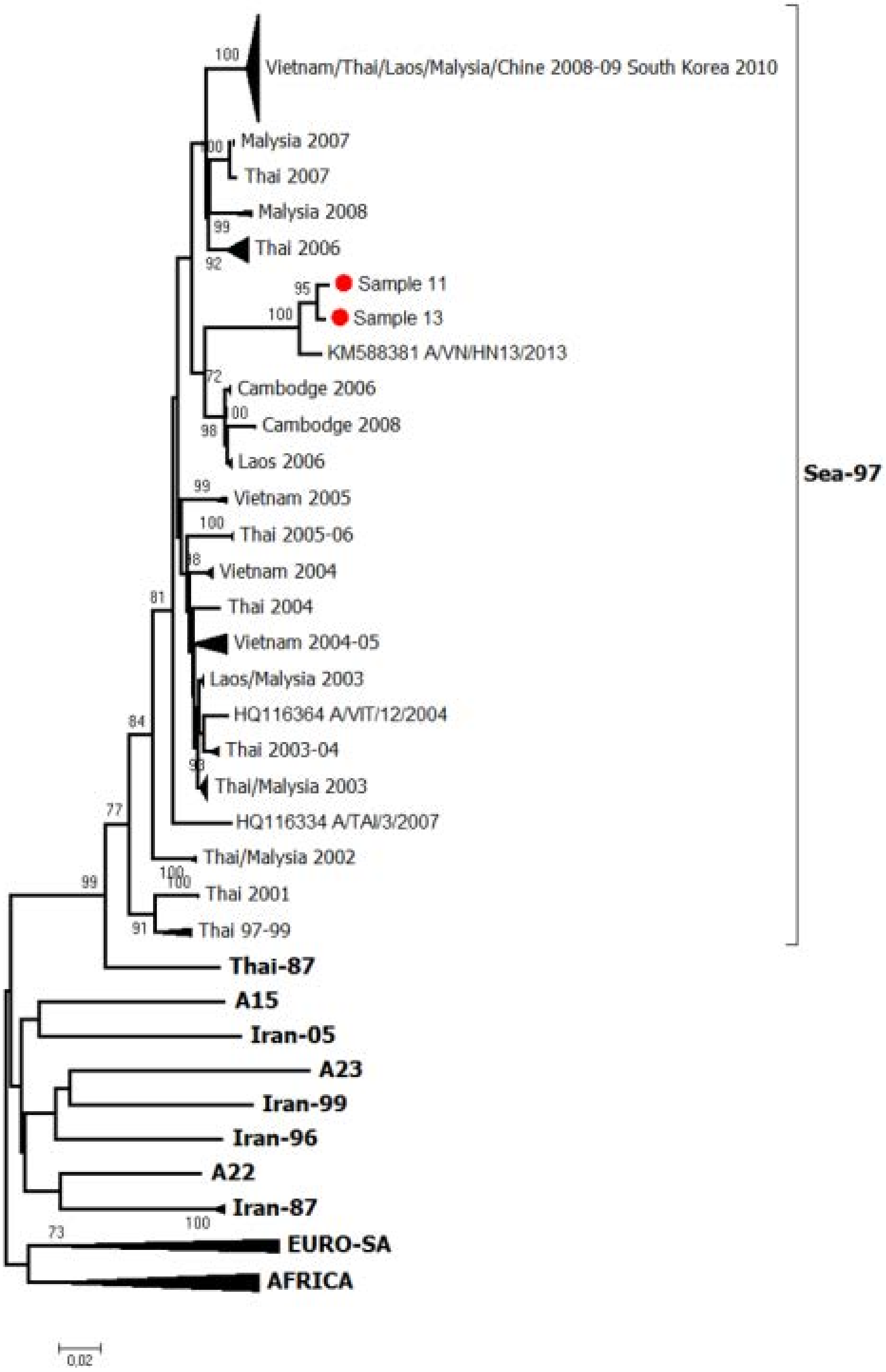
3.3. Virology findings

From 24 probang samples collected in the field, 6 tested positive after the first screening with rRT-PCR. The Ct value of positive samples varied from 32.33 to 37.98. Five out of 6 positive samples had relevant serum that also showed a positive result with the ELISA NSP 3ABC test; the serum relevant to the last one was missing. Virus isolation in cell culture was performed with these positive samples but unfortunately no live virus was detected after two passages. The second rRT-PCR for serotyping detected the serotype of 5/6 samples as positive at the first screening and the last one was concluded as undetectable. The five positive samples originated from 4 farms (sample 11 and 13 collected from one farm) that were located in 4 different villages of 5 communes of 1 district in the Long An province (Table 4). Among them, two belonged to serotype A and three belonged to serotype O. Information about those isolates such as location (i.e. commune, district), specie was detailed in table 4.The serotype A viruses belonged to lineage A/Asia/Sea-97 (Figure 3). The serotype O viruses belonged to two separate lineages, O/ME-SA/PanAsia for sample 21 and O/SEA/Mya-98 for sample 16 and 22 (Figure 4).

Table 4: Foot-and-mouth disease virus serotype O and A isolates found in Long An province

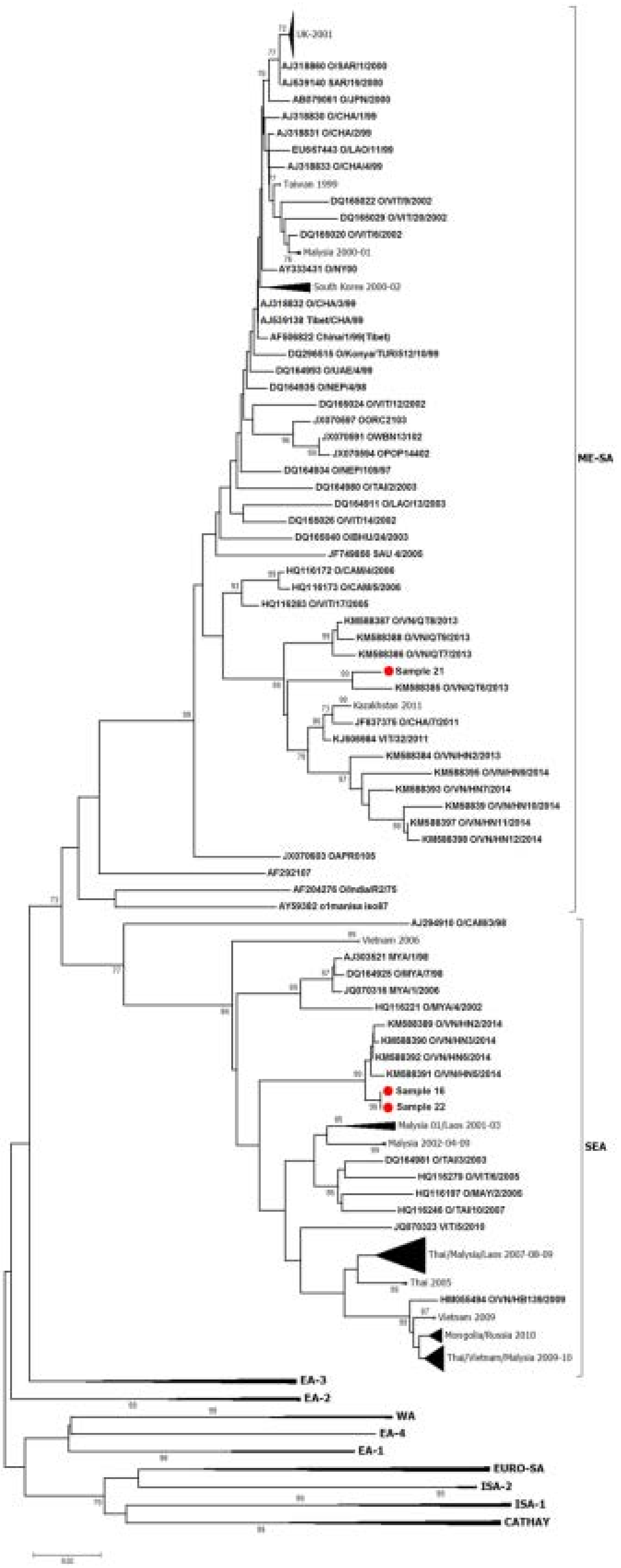
Isolate	Date of collection	Location of collection		Type	Topotype
		District level	Commune level		
Sample 11 (A/VIT/11/2014_Long An_cattle)	12/09/ 2014	Duc Hoa	Duc Lap Thuong	A	Sea_97
Sample 13 (A/VIT/13/2014_Long An_cattle)	12/09/ 2014	Duc Hoa	Duc Lap Thuong	A	Sea_97
Sample 16 (O/VIT/16/2014_Long An_cattle)	12/09/ 2014	Duc Hoa	Duc Hoa Thuong	O	SEA
Sample 21 (O/VIT/21/2014_Long An_cattle)	13/09/ 2014	Duc Hoa	Duc Lap Ha	O	ME-SA
Sample 22 (O/VIT/22/2014_Long An_cattle)	13/09/ 2014	Duc Hoa	Tan My	O	SEA

Figure 3: Phylogenetic tree of type A foot-and-mouth disease virus isolates



New serotype A isolates are marked with red dots. Information of isolates presented in Table 4.

Figure 4: Phylogenetic tree of type O foot-and-mouth disease virus isolates



New serotype O isolates are marked with red dots. Information of isolates presented in Table 4.

3.4. Estimation of true sero-prevalence at animal level and quantitative assessment of the participatory approach using the Bayesian modelling

Results of serological tests and PE methods for 109 animals in three districts near the border (Vinh Hung, Kien Tuong- Moc Hoa, Duc Hue) (population 1) and 186 animals in one district far from border (Duc Hoa) (population 2) were included in the data to fit the Bayesian model. Table 3 describes their cross-classified status according to PE methods and ELISA test. Table 5 represents the prior distributions used in the model for Prev1, Prev2, SeT1, SeT2, SpT1, SpT2. Table 6 shows a summary of the results from the Bayesian analysis, using WinBUGS for animal level sero-prevalence in the two populations (Prev1 and Prev2, respectively), the sensitivity and specificity of the participatory approach (SeT1, SpT1) and serological tests (SeT2, SpT2). The Prev1 and Prev2 was estimated at 23% [Credible Interval (CI) 95% (14-34)] and 31% [CI 95% (20-44)], respectively. SeT1 and SpT1 were found to be 59% [CI 95% (42-76)] and 81% [CI 95% (75-87)]. Similarity, SeT2 and SpT2 were estimated at 91% [CI95% (83-96)] and 95% [CI95% (92-98)]. The PPV and NPV of the participatory approach were also computed using equation 1 and 2 as described above. The PPV and NPV values were found to be 48% [CI 95% (31-65)] and 86% [CI 95% (77-94)] for population 1 and 58% [CI 95% (44-72)] and 81% [CI 95% (65-92)] for population 2.

Table 5: Distribution of the priors used in the model of Prev1, SeT2, SpT2

Prev*1*	Prev*2*	SeT1	SpT1	SeT2	SpT2
dbeta (1, 1)	dbeta (1, 1)	dbeta (1,1)	dbeta (1, 1)	dbeta (67.5, 6.31),	dbeta (192.77, 8.78),
				mode = 0.926, 95% sure > 0.845	mode = 0.961, 95% sure > 0.928

Table 6: Posterior distribution of parameters used in the Bayesian model

	Mean	Sd	MC error	2.5%	Median	97.5%
Prev1	0.23	0.04	<0.001	0.14	0.23	0.34
Prev2	0.31	0.05	<0.001	0.20	0.31	0.44
SeT1	0.59	0.09	<0.001	0.42	0.58	0.76
SpT1	0.81	0.03	<0.001	0.75	0.81	0.87
SeT2	0.91	0.04	<0.001	0.83	0.91	0.96
SpT2	0.95	0.02	<0.001	0.92	0.95	0.98
PPV1	0.48	0.08	<0.001	0.31	0.48	0.65
NPV1	0.86	0.04	<0.001	0.77	0.87	0.94
PPV2	0.58	0.07	<0.001	0.44	0.58	0.72
NPV2	0.81	0.07	<0.001	0.65	0.81	0.92

4. Discussion

4.1. The quantitative assessment of the participatory approach

In our study, sero-prevalence in the population 1 close to the Cambodian border (23%) was lower than that of the population 2 located far from the border (31%). This finding suggests that prevalence could vary between these two populations. Differences in the application of control programs may explain this pattern. In the population close to the border, it was noted that FMD vaccination in many local areas was done with government vaccines which were distributed twice per year in sufficient quantities to achieve the required vaccination coverage (MARD, 2015). There might have been insufficient vaccine coverage in the population far from the border where repeat vaccination relied on farmers' willingness. However, the difference in sero-prevalence between two populations under study was not statistically significant. Such a lack of significance was undoubtedly associated with the relatively small size of our sample. Initially, it was planned to collect 360 samples (20 villages multiply by 18 animals per village) from dairy and beef cattle. However, due to field constraints, only 301 animals could be sampled and included in our study.

The Bayesian approach allowed us to assess the performance of the participatory approach at animal level. While the specificity of PE was relatively high at 0.81, the sensitivity was estimated at only 0.59. In our study, we required farmers to detect clinical signs on animal individually in advance and those collected information were used as source for participatory approach. In an endemic situation where vaccination has been systematically applied in cattle such as Vietnam, clinical signs of infection could be hidden (Davies, 2002; Kitching, 2002) and might be undetectable by farmers. Therefore, the sensitivity of PE was computed as low value. However, the in depth discussion and ELISA result on animal present clinical signs confirmed that farmers can easily detect FMD while clinical signs present on their animals. Bellet et al. (2012) evaluated the performance of the participatory approach at village level in Cambodia. They reported the sensitivity of the approach at 0.87 at village level using Bayesian method. Their sensitivity was higher than ours finding. In addition, a village was defined as infected when an animal in this village infected with FMD. This selection criteria was considered as easier than our criteria while we focus on animal level. In other study focus on the estimation of performance of herdsmen's reports (similar to participatory approach) in prevalence estimation in the previous year at herd level, the sensitivity and specificity were estimated with help of latent class Bayesian model at 0.84 and 0.75, respectively (Morgan et al., 2014). Their estimated sensitivity was also higher than ours finding. Those information suggest that participatory approach is certainly more easy to use while having a table of specific clinical signs, applying in an unvaccinated population and being used at herd or village level. Our result would also suggest that information provided by farmers should be systematically validated. Our results once again confirmed the recommendation of previous studies (Dukpa et al., 2011; Catley et al., 2012) that the PE approach must be implemented in combination with other conventional methods in order to be effective and representative.

4.2. Discussion on the results of ELISA NSP 3ABC test

In our Bayesian model, ELISA was used as a reference test for estimating the Se and Sp of PE. This test help to differentiate the infected antibody called 3ABC NSP that theoretically did not present in animal who being vaccinated with a purified vaccine. To our knowledge, the FMD bivalent vaccine used in Vietnam was not totally purified for NSP antibodies, hereafter called vaccine with NSP trace (personal communication). An uninfected animal received several times the vaccine with NSP trace could also possess anti-NSP antibodies and lead to a false-positive in ELISA test (Brocchi et al., 2006). The older animal had more chance to become false-positive in ELISA test than the elder one. A historically infected cattle (infected before 2013) might present minor clinical signs during considering period (2013, 2014) when re-infected with other serotype (i.e. serotype A). Therefore, they might be undetectable as an infected case (Radostits and Done, 2007).

In our study, the sampling was performed to collect samples from cattle that previously reported as infected within period of 2013 and 2014. In the worst case, the serological test to cross-validate animal status was performed in more than one year. However, a field evaluation of this test on infected cattle during 3 years after infection with repeated vaccination confirmed that this test can be used as a valuable tool for detection of previous FMDV infection in cattle in endemic countries such as Vietnam several years after exposure (Elnekave et al., 2015). Therefore, the sero - positivity detected by ELISA in our case was covering the time period of detectable antibody level. In term of surveillance and control, the interval between declaration of suspected case (PE) and confirmation by laboratory test should be minimised to be able to detect early outbreak. This point need to be taken into consideration in further research focus on the application of PE in surveillance system.

4.3. Influence of confounder factors on the assessment of participatory approach

Age and vaccination status of animal variable was considered as a confounder factor that affect the detection level of PE in our analysis. Including those variables in logistic regression model changed value of the main effect (presence of symptom in animal within considering period) (Table 3). Even the model showed their effects on the NSP result was not significant, their biological sense had significant role on the changing of NSP result as mentioned before. Moreover, the vaccination record for animal lifetime could not be generated and used to give more accuracy explanation. Therefore, sero - prevalence in two populations might be over-estimated due to this limitation. Despite good coverage vaccination effectiveness also remains an important challenge under study context. A study in surrounding province (Tay Ninh) showed that despite a vaccination uptake of 85.4%, the sero-conversion in this province was only 60.6% (Nguyen et al., 2014). The imperfect application, storage and delivery can explain the relatively low effectiveness of vaccination (Alders et al., 2007). Farmers are concerned with this low effectiveness and can refuse to use it due to their past experience of vaccine failures.

4.4. Identification of serotypes circulated in the study area

The serotype A FMD virus (sample 11 and 13) formed a group with previous published sequences from Vietnam in 2013, and from Cambodia and Laos dated between 2006 and 2008. For serotype O, sample 21 formed a group with other Vietnam sequences that were reported from 2011 to 2014 in other provinces. This group also included two previously reported viruses isolated from China and Kazakhstan in 2011. The isolate most closely related to sample 21 was an isolate from Quang Tri province (central Vietnam) found in 2013. Sample 16 and 22 formed a small group with others isolated in the same period (2014) but in another location, Ha Nam province (North of Vietnam). Our finding suggested that active animal movement occurs in both the northern and southern parts of Vietnam. As previously reported by Cocks (2009) and Widders (2015), Vietnam receives cattle transported from Thailand, Myanmar, Cambodia and Laos. The results of Cocks (2009) confirmed that cattle might enter the northern part of Vietnam after passing through Laos and suggested the existence of a similar pathway in southern Vietnam, which was supported by the similar virus genome in our study. Recent studies and surveillance activities reported serotype A circulating in pigs but not in cattle in surrounding provinces (Carvalho Ferreira et al., 2015) and in other districts of Long An province in 2013 (Sub-DAH of Long An province, 2014). In addition, from focus group interview, it was mentioned by some farmers that the monovalent vaccine that given by veterinary authorities did not well protect their animal. Farmers questioned whether a new serotype of virus existed in the field but they did not have any molecular evidence except their vaccinated animals (with monovalent vaccine) got infected with FMD disease. Our findings provided the supported evidence of the circulation of serotype A in cattle within the study zone in 2014 (Long An province). Moreover, it has been reported that FMD virus in Long An province belonged only to lineage O/ME-SA/Pan Asia (Carvalho Ferreira et al., 2015). Our study found two new lineages in Vietnam (O/SEA/Mya-98 and A/Asia/Sea-97), suggesting a hypothesis that the new serotype of FMD virus was silently circulated in study zone at the end of 2013, or the beginning of 2014, via trans-boundary commercial activities. Due to limited resources, serotyping is not always being performed in also of suspected case, then information of some minor lineages might be missing.

5. Conclusion

To date, our study is one of the first experiments to apply PE to animal health in Vietnam, in particular for FMD. Even if, in our case, the sensitivity and specificity of PE was not as high as expected, the informative results obtained proved its value and cost-effectiveness as an epidemiological tool in developing countries. Further studies focused on surveillance and disease detection using framework of our study on a larger scale relative to geographical location and sample size would be recommended.

Acknowledgments

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Supporting information

```
# Bayesian model used in Winbug

model {

y1[1:2, 1:2] ~ dmulti(p1[1:2, 1:2], n1)
p1[1,1] <- Prev1*SeT1*SeT2 + (1-Prev1)*(1-SpT1)*(1-SpT2)
p1[1,2] <- Prev1*SeT1*(1-SeT2) + (1-Prev1)*(1-SpT1)*SpT2
p1[2,1] <- Prev1*(1-SeT1)*SeT2 + (1-Prev1)*SpT1*(1-SpT2)
p1[2,2] <- 1-p1[1,1] -p1[1,2] - p1[2,1]


y2[1:2, 1:2] ~ dmulti(p2[1:2, 1:2], n2)
p2[1,1] <- Prev2*SeT1*SeT2 + (1-Prev2)*(1-SpT1)*(1-SpT2)
p2[1,2] <- Prev2*SeT1*(1-SeT1) + (1-Prev2)*(1-SpT2)*SpT1
p2[2,1] <- Prev2*(1-SeT2)*SeT1 + (1-Prev2)*SpT2*(1-SpT1)
p2[2,2] <- 1-p2[1,1] -p2[1,2] - p2[2,1]


SeT1~dbeta(1,1)
SpT1~dbeta(1, 1)
SeT2~dbeta(67.50, 6.31) # mode = 0.926, 95% sure > 0.841
SpT2~dbeta(192.77,8.78)  # mode = 0.961, 95% sure > 0.924

Prev1~dbeta(1,1) #  mode = 0.243, 95% sure > 0.215
Prev2~dbeta(1,1) #  mode = 0.5, 95% sure > 0.215
# PPV and NPV of population 1
PPV1 <-SeT1*Prev1/ (SeT1*Prev1 + (1 − SpT1)*(1 − Prev1))
NPV1<-SpT1*(1 − Prev1)/(SpT1*(1 − Prev1) + (1 − SeT1)*Prev1)
# PPV and NPV of population 2
PPV2 <-SeT1*Prev2/ (SeT1*Prev2 + (1 − SpT1)*(1 – Prev2))
NPV2 <-SpT1*(1 – Prev2)/(SpT1*(1 – Prev2) + (1 − SeT1)*Prev2)

}

# data
# n1 = district near border; n2 = district far border
list(n1=109, n2=186,
y1=structure(.Data=c(15,10,12,72),.Dim=c(2,2)),y2=structure(.Data=c(29,21,33,103),.Di
m=c(2,2)))

# initials 1
list(SeT1=0.7, SpT1=0.8, SeT2=0.90, SpT2=0.95, Prev1=0.7,Prev2=0.4)

# initials 2 (alternative)
list(SeT1=0.4, SpT1=0.5, SeT2=0.7, SpT2=0.6, Prev1=0.1,Prev2=0.3)
```

CHAPTER 4

EVALUATION OF THE EFFECTIVENESS OF FOOT-AND-MOUTH DISEASE VACCINATION PROGRAM IN VIETNAM: LOCAL SOCIO-ECONOMIC CONSTRAINTS

Evaluation of the effectiveness of Foot-and-Mouth disease vaccination program in Vietnam: local socio-economic constraints

***D.B. Truong*[1,2*], *S. Bertagnolie*[3], *F.L. Goutard*[1,4], *M. Peyre*[1], *A. Binot*[1,4]**

[1] UPR AGIRs Research Unit, Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), Montpellier, France

[2] Faculty of Animal Science and Veterinary Medicine, Nong Lam University, Ho Chi Minh, Vietnam

[3] UMR INRA-ENVT IHAP, Université de Toulouse, Toulouse, France

[4] Faculty Veterinary Medicine, Kasetsart University, Bangkok, Thailand

***** dinhbao.truong@hcmuaf.edu.vn/ dinh-bao.truong @cirad.fr

Abstract

This study aimed to evaluate farmers' perception on foot-and-mouth disease (FMD) risk factors and its consequences on livelihood according to farmer's point of view, to evaluate prevention methods applied in case of FMD, to understand advantages and inconveniences of vaccination for farmers in using participatory epidemiology approach. 43 focus group interviews for dairy, beef and pig production were carried out in Long An and Tay Ninh provinces located in the South of Vietnam, bordering with Cambodia. 5 groups of risk factors related to FMD identified by farmers were: "Diseases linked to seasonal parameters", "disease transmission from location presenting infected cases", "insufficiency of vaccine coverage in population", "vectors carrying the disease" and "unsafe environment in production".

The most important consequences of FMD for dairy and beef farmers was "income loss", followed by "cost of treatment" while the importance was opposite for pig farmers. At least five principal prevention methods applied by farmers to fight against FMD were vaccination, disinfection, cleanliness, quarantine and good husbandry management practices. Vaccination was considered as the most important method for all production types, followed by disinfection and cleanness, which depended on the production type. Proportional pilling data was analysed by using principle component analysis, which allowed characterizing prevention methods according to production type. Dairy farms frequently practiced quarantine, disinfection and vaccination as prevention methods. Beef farms preferred cleanliness and good husbandry management practices while farms considered all of prevention methods equally important. The matrix of correlation between variables showed that only vaccination and disinfection had a lightly positive correlation with quarantine (r = 0.14 and 0.13, respectively). A hierarchical clustering on principle components classified farms into four clusters. Vaccination was considered as an important method for all clusters while disinfection was ranked as medium-high level. Cleanliness was ranked as medium-high in cluster 1 and 3 and quarantine method was ranked as low in cluster 1, 2 and 3. The rank of good husbandry practice as a prevention method decreased from cluster 1 to 4 and from medium to low level. The most important advantage of vaccination for all production type was "infection prevention" while the "unwillingness due to production loss caused by vaccination" and "worry that vaccination may affect the reproducibility" were highlighted as the most inconveniences factors for farmers. Further quantitative studies focused on FMD impacts and cost benefit of vaccination are required.

Keywords: foot-and-mouth disease (FMD), farmer perception, risk factors, consequences, prevention methods, principle component analysis

1. Introduction

1.1. Risk factors of foot-and-mouth disease (FMD) introduction in Vietnam

In Vietnam, nearly 70% people live in rural areas, of which almost 80% rear animal (Hoang, 2011). The total populations of pig, cattle and buffalos in 2014 are estimated at 26.8, 5.2 and 2.5 million, respectively (GSO, 2015). Pig and beef production are ranked as first and third largest industry in the livestock sub-sector (Pham et al., 2015). Among animal diseases in Vietnam, FMD is considered by animal health specialists as one of the most important diseases with outbreaks occurring every year (Madin, 2011; Nguyen et al., 2014; Carvalho Ferreira et al., 2015). Data on outbreaks in Vietnam from 2006 to 2012 showed that on average a serious epidemic occurred every 2 – 3 years, incidence risk was 5.1 [Confidence interval 95 % (4.9-5.2)] FMD infected commune per 100 commune-year. Moreover, FMD outbreaks occurred repeatedly in more than 60% of communes in hotspot areas (Nguyen et al., 2014)

Animal movement has been known to be one of the most important factors of FMD introduction (Cocks et al., 2009; Radostits et al., 2011; Windsor et al., 2015). Located in animal movement roads, Vietnam shares the same viral serotypes with others countries in the region (Le et al., 2010). Farms with unvaccinated pig, farms located near infected farms or near main streets were identified as being at more risk of being infected by FMD (Nguyen et al., 2011). Purchase of cattle from unknown source is also noted as major risk factor in introduction of the disease with the odds ratio of 5.27 when compared to cattle produced by households themselves (Nguyen et al., 2014). In a report of five-year application of national program of prevention and control, some risk factors were also mentioned such as illegal importation of animal and animal products, illegal purchase and transport of infected animals from one zone to another, lack of strict legislation and punishment for offenders. Lack of awareness with both authorities and farmers in absence of outbreaks for years, incomplete cooperation between actors during vaccination campaign and insufficient vaccination coverage which, due to field constraints (small scale farms distributed in large areas, poor accessibility to the farms, etc…) were also noted (MARD, 2011).

1.2. Prevention and control policy of FMD in Vietnam

In Vietnam, bio-security methods are applied in order to control FMD through disinfection of vehicles used for animal transportation, mandatory health certificates for animal trade and changing clothes when getting in and out of farms. Farms are required to be fenced; cleaning of buildings and equipment are advised to be done frequently, new animals should be vaccinated and quarantined for 21 days before mixing with the herd.

Besides that, herd need to be vaccinated according to the regulations of the national program of FMD control (MARD, 2006; Vietnam National Assembly, 2015). For imported animals, authorities need to verify health documents which include health certificates from exporting countries before importation to Vietnam, cleanliness and disinfection of the transportation vehicles and also monitoring residues treatment (MARD, 2006; Vietnam National Assembly, 2015). The Department of Animal Health of Vietnam also participates in regional network of surveillance of FMD in Southeast Asia (Southeast Asia and China for Foot and Mouth Disease Campaign) which aims to share outbreak information between countries, share experiences and learn new approaches to prevention and control of FMD.

1.3. Vaccination policy in Vietnam and study zone

Based on the epidemiological situation, geography, husbandry practices, socio economic factors, financial capacity and disease control targets, Vietnam has implemented FMD control program by dividing the country in three zones (control, buffer, and low risk zones) from 2006 until now (MARD, 2006, 2011, 2015; OIE Sub-Regional Representation for South East Asia, 2016). The vaccination policy and budget is different for these three zones. FMD vaccination has been applied for cattle and buffalo in control and buffer zones. For other animals, vaccination can be done at the livestock owners' expenses. In the control zone, vaccines are supplied free of cost while in the buffer zone vaccines are supplied at subsidized rate (50%) and in the low risk zones, vaccination against FMD is encouraged to the farmers but the government do not supply the vaccines. Based on the evidence from the investigation of FMD outbreak in recent years, in particular about viral serotypes circulating, monovalent vaccine (type O) or bivalent vaccine (type O and A) are used (OIE Sub-Regional Representation for South

East Asia, 2016). Vaccination is generally applied twice a year in March-April and September-October. In Long An province, five districts which border Cambodia are classified as control zones. 100% of cattle in those districts receive two injections every year which is supplied free of cost by the government subvention (national level). Cattle in two other important districts such as Duc Hoa and Chau Thanh receive one free injection per year with support of provincial budget. This policy is applied only for herds having less than 20 heads and free vaccine is supplied for the second injection of vaccination campaign (September-October). For pigs, vaccination is supplied free for one time per year in the important districts such as Chau Thanh, Duc Hoa, Ben Luc, Tan Tru, Tan An, Thu Thua (2 communes), Can Duoc (3 communes), Can Giuoc (3 communes) for farms where herd size is less than 50. These farms are encouraged to maintain immunity in their herd by not missing the second vaccination. Other farmers who are not involved in subvention policy are mobilized to practice vaccination on their expenses (DARD Long An, 2014). Vaccine types used in cattle varied from year to year. In 2013, Long An authorities used monovalent vaccines in cattle populations in all districts before using bivalent vaccines in 2014 for 5 bordering districts and monovalent for the others. The delay in the delivery of vaccines led to the delay in the vaccination program by 1 to 2 months from the planned program (DARD Long An, 2014, 2013). In Tay Ninh province, 100% of cattle are given free vaccine twice a year and pig farmers are encouraged to vaccinate their animals. Policy of vaccination in cattle is applied for all population in province. Vaccine types used in cattle is monovalent in 2013 and 2014 (DARD Tay Ninh, 2013, 2014).

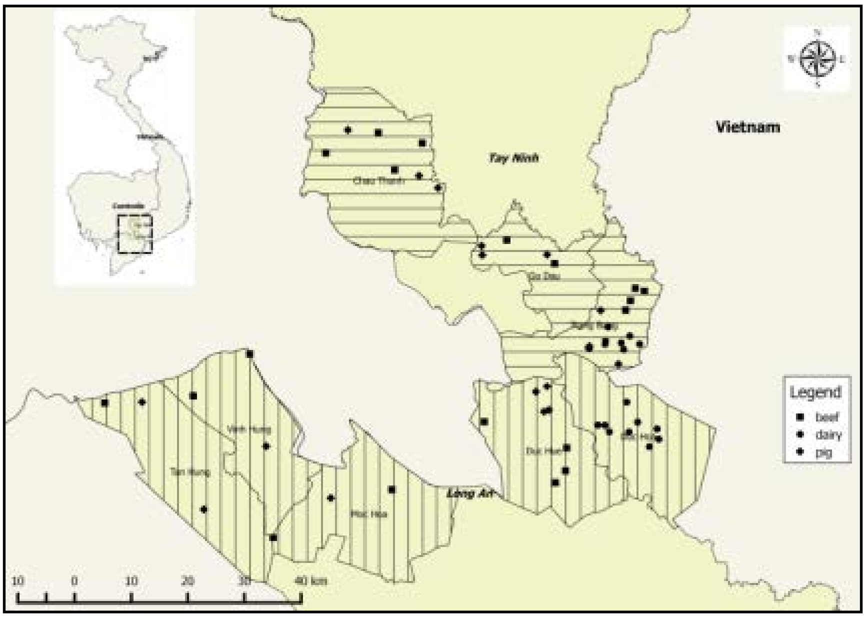
This study was done aiming at the evaluation of farmers' perception of risk factors regarding FMD introduction and its consequences on their livelihoods, in order (1) to evaluate the methods adopted by the farmers to prevent FMD as well as (2) to understand the advantages and inconveniences of vaccination as perceived by the farmers.

2. Material and method

2.1. Study area and population under study

Our study was carried out in Long An and Tay Ninh provinces as these areas are important livestock production provinces in the South of Vietnam sharing border with Cambodia, animal movements between provinces and countries are frequent in these provinces and FMD outbreaks have been reported during 2010-2013 period. At the district level, we consider five districts of Vinh Hung, Tan Hung, Kien Tuong, Duc Hoa, Duc Hoa (diagonal hatchings) located in Long An province and 3 districts of Go Dau, Chau Thanh and Trang Bang (horizontal hatchings) located in Tay Ninh province (Figure 1). Sample size is based on sample size calculation adopted in other studies that performed in parallel (see chapter 2, 7). In total, 146 villages were randomly selected in order to perform focus group interviews. The research team members included 5 trained people from faculty of Animal Science and Veterinary Science, Nong Lam University. With the help of local veterinarians, interviews were organized in a place convenient for the farmers. Efforts were made to ensure that only farmers of one production type were present for each meeting. Genders issues have been taken into consideration to avoid possible selection bias. Before the interview, each participant signed a written consent to be part of the study. Internal staff meetings were organized frequently to review daily work, to extract bias and explore ways to improve.

Figure 1: Map of the study districts (hatched) showing the location of focus group interviews targeting the 3 production types (beef cattle, dairy cattle, pig) in the 2 study provinces of Long An (diagonal hatchings) and Tay Ninh (horizontal hatchings)



2.2. Participatory epidemiologic methods

Our survey was conducted using participatory epidemiology (PE) tools that were decribed by Mariner (2000), Catley (2005) and Bagnol and Sprowles (2007). PE includes semi-structured interviews for focus groups with open-ended question, proportional pilling, problem tree and flow charts.

2.2.1. Semi-structured interviews

This tool was used throughout all the interviews to gather qualitative data with the help of a checklist of objectives prepared beforehand. Checklists included three big themes which needed to be addressed: (1) cause and consequences of FMD from farmers' viewpoint; (2) prevention methods used by farmers to prevent and control FMD; (3) advantages and inconveniences of vaccination for farmers. Effort was made to ensure that all attendants participated at least once in the discussion and actively exchanged ideas.

2.2.2.Problem trees

This tool was implemented in our survey in order to understand risks factors and consequences related to FMD in the framework of the identification of farmers' knowledge about the disease. Names of diseases were written in the middle of a A0 sized paper, divided into two parts, one for risks of introduction of FMD into farm at the bottom part and disease related consequences at the top. Participants were asked to list all of possible risks factors that might introduce FMD into their herd and its consequences. Then, a series of open and probed questions related to the methods that farmers used to deal with outbreak's causes (prevention methods) were asked.

2.2.3. Proportional pilling

This tool was performed to identify and understand prevention methods used by farmers through a ranking process. Cards of preventive methods were laid down in separated circles on a A0 paper. 100 beans was freely distributed to each farmer to be put in the circles. Probling question was then asked for the most and the least important elements (receiving the biggest and the smallest amount of beans, respectively). Because of the diversity in farmer's answers, setting up categories and standardized process were applied on data from proportional pilling about prevention methods used before analysis (AFENET, 2011). In fact, the amount of beans in each circle was used to detect rank of each prevention method mentioned, e.g. one method receiving most beans was considered as located at the first ranking. Then, results of focus groups were entered all together in an excel sheet and ranks of each method in each interview were transformed into standardized scores according to the amount of total FMD preventive methods listed by the farmers. For interview 1, prevention methods 1 that was ranked first received score of n (with n equal to the number of total prevention methods), the one that was ranked second had score of n-1, the one that was not mentioned in interview 1 received score 0.

2.2.4. Flow chart

This tool was used to understand advantages and inconveniences of vaccination according to farmers' perception. Beginning with an open question on what are the advantages and inconveniences of vaccination, each elements was listed in a A0 paper. The paper was divided into two columns, one for advantages and the other for inconveniences. Then, a discussion was performed with help of several probing questions.

2.3. Data analysis

Discussion about each interview has been recorded and transcript into electronic version. Data analysis and graphs were performed with open source software R version 3.1.2 and some specific packages in R such as ggplot2 package for visualisation **(**Wickham, 2009) and FactoMineR for Principal Component Analysis and Hierarchical Clustering (Husson et al., 2011). Frequency data from problem trees and flow charts were transformed to proportion and visualized in order to analyse differences among production types. Ranking data from proportional pilling exercise were transformed to standardized score and then were described by median, minimum and maximum to identify central tendency and dispersion. Proportional pilling data on preventive methods were also analysed with principle component analysis (PCA) to understand the correlation between individuals or between variables (prevention method). Then, a hierarchical clustering on principle components (HCPC) performed an agglomerative hierarchical clustering of prevention methods used by farmers from a factors analysis.

3. Results

3.1. Causes and consequences of FMD from farmer's viewpoints

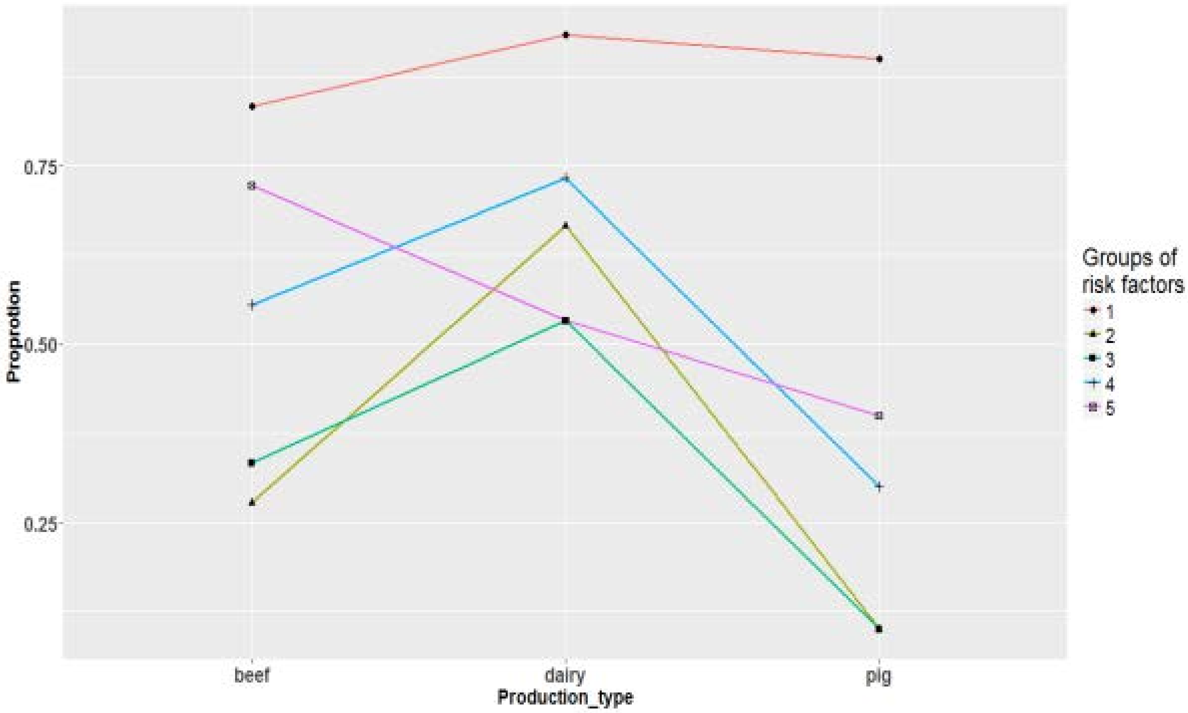
3.1.1. Evaluation of risk factors related to FMD according to farmer's viewpoints

Based on the data from 43 focus groups in our survey, five groups of risk factors related to FMD were identified by farmers in our study zone. Risk factor groups are (1) seasonal parameters, (2) disease transmission from location presenting infected cases, (3) the insufficiency of vaccine coverage in the animal population, (4) vectors carrying out the disease and (5) unsafe production environment (Table 1). Group 1 was the most important risk factor for all of the three production types as it was mentioned by 83-93% of focus groups (Figure 2). The remaining four groups of risk factors were considered important for dairy production (mentioned in 53-75% of focus groups) but negligible for pig production (mentioned in less than 30% of focus groups). For beef production, risk factors of group 1 and 5 were ranked as the 1^{st} and 2^{nd}, then group 4.

Table 1: Description of 5 groups of risk factors related to foot-and-mouth disease (FMD) according to farmers' viewpoints

Group of risk factors	**FMD risk factors in detail**
1. Seasonal parameters	Raining season, wind direction
2. Disease transmission from location presenting infected cases	Proximity to outbreak area, slaughter house, infected surrounding farms
3. Insufficiency of vaccine coverage in animal population	Unvaccinated practice, inadequate vaccine type, given vaccine for being infected animal, imported beef without unknown immunity status, imperfect vaccine practice
4. Vectors carrying out the disease	Veterinary, vehicles, imported cattle from surrounding countries (Thailand, Cambodia)
5. Unsafe production environment	Housing, drinking water, feed

Figure 2: Overall distribution of 5 groups of risk factors related to foot-and-mouth disease according to beef, dairy and pig production types

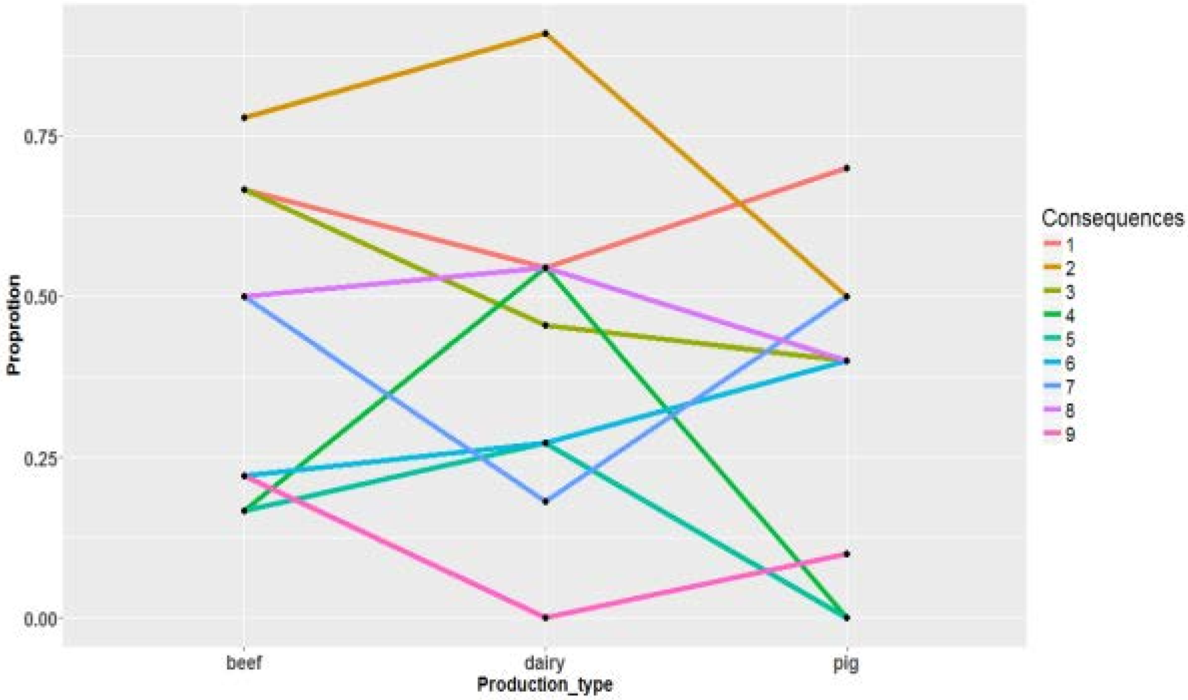


1. Seasonal parameters; 2. Disease transmission from location presenting infected cases; 3. Insufficiency of vaccine coverage in population; 4. Vectors carrying out the disease; 5. Unsafe production environment

3.1.2. Evaluation of consequences of FMD according to farmer's viewpoints

From the collected information from 39 focus groups, 9 consequences due to FMD were identified. They were "cost of treatment", "income loss" (due to milking loss, decrease of milk's quantity and quality or decrease of selling price), "capital loss", "reduced reproduction capacities" (abortion, artificial insemination failure), "transmission of disease to surrounding farms'", "social impacts" (i.e. anxiety, anger from neighbours, losing friend), "time consumption for treatment", "reduced productivities" and "debt" (Figure 3). "Income loss" was the most important consequence of FMD to dairy and beef farmers while "cost of treatment" was the most important for pig production. For beef farmers, "cost of treatment" and "capital loss" were ranked as second place, followed by "reduced reproduction" and "time consumption for treatment" while for dairy farmers, “cost of treatment”, “reduced productivities” and “reproduction capacities” were ranked second followed by “capital loss” in third. “Income loss” and “time consumption for treatment” were considered as second important consequences of FMD by pig farmers, followed by “capital loss”, “social impacts” and “reduction productivities”.

Figure 3: Consequences of foot-and-mouth disease on livelihoods according to beef, dairy and pig production types

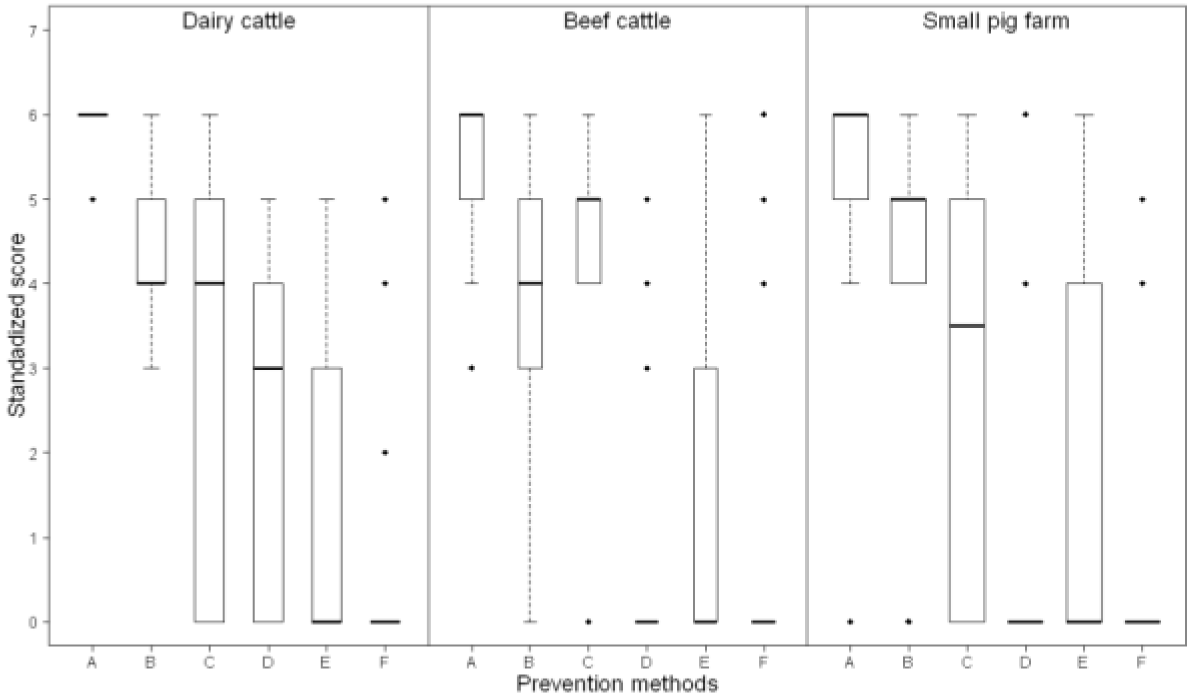


1. cost of treatment; 2. income loss; 3. capital loss; 4. reduction reproduction capacities; 5. transmission of disease to surrounding farms; 6. social impacts; 7. time consumption for treatment; 8. reduction productivity; 9. debt

3.2. Description of prevention methods used by farmers to control FMD

Our survey showed that farmers used at least five principal prevention methods (vaccination, disinfection, cleanliness, quarantine, good husbandry management practices) and other methods (less important) to prevent introduction of disease to their farm (Figure 4). The four most important methods for dairy were vaccination (median score (Md): 6), disinfection (Md: 4), cleanliness (Md: 4) and quarantine (Md: 3) while good husbandry management practices and other methods were negligible (Md: 0). Vaccination, cleanliness and disinfection were the most important methods for beef farmers. Pig farmers ranked vaccination, disinfection and cleanliness as the most important methods. Quarantine, good husbandry management practices and other methods had minor role for preventing FMD in beef and pig production (Md: 0). The importance of each prevention method was significantly differently within a production type according to result of Kruskal-Wallis chi-squared with $p < 0.05$ (data not showed). Regarding the importance of prevention methods used by each production type, dairy farms preferred vaccination and quarantine while cleanliness and disinfection were considered most important for beef and pig farms, respectively ($p < 0.05$). There was no significant difference of using good husbandry management practices and other methods between these three production types.

Figure 4: Prioritisation of prevention methods used in case of foot-and-mouth disease according to dairy, beef and pig production types



A: Vaccination, B: Disinfection, C: Cleanliness, D: Quarantine, E: Good husbandry management practices, F: other methods

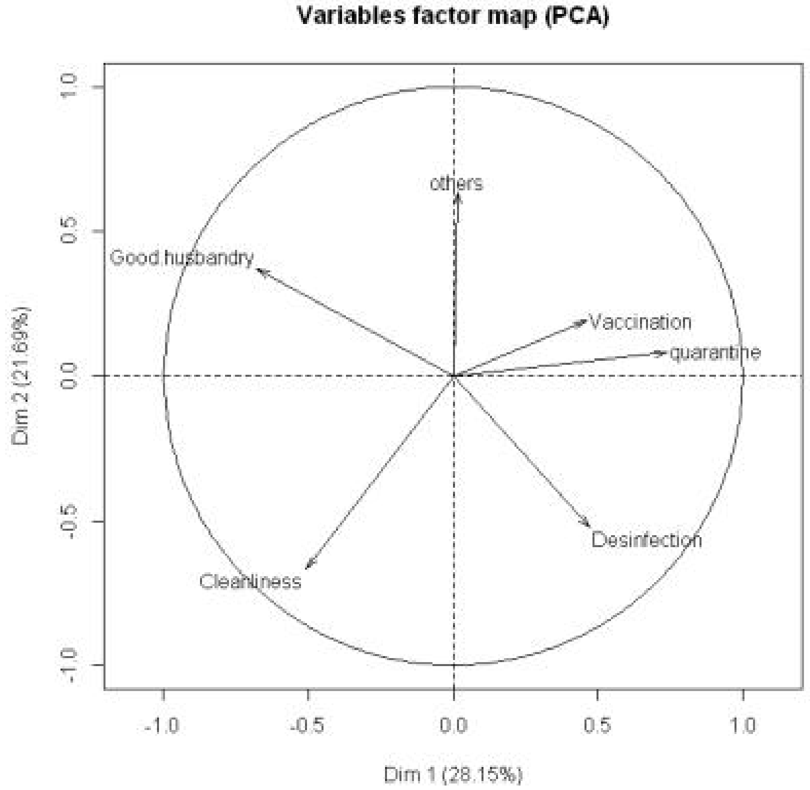
3.3. Multivariable analysis of Foot-and-mouth disease prevention method used

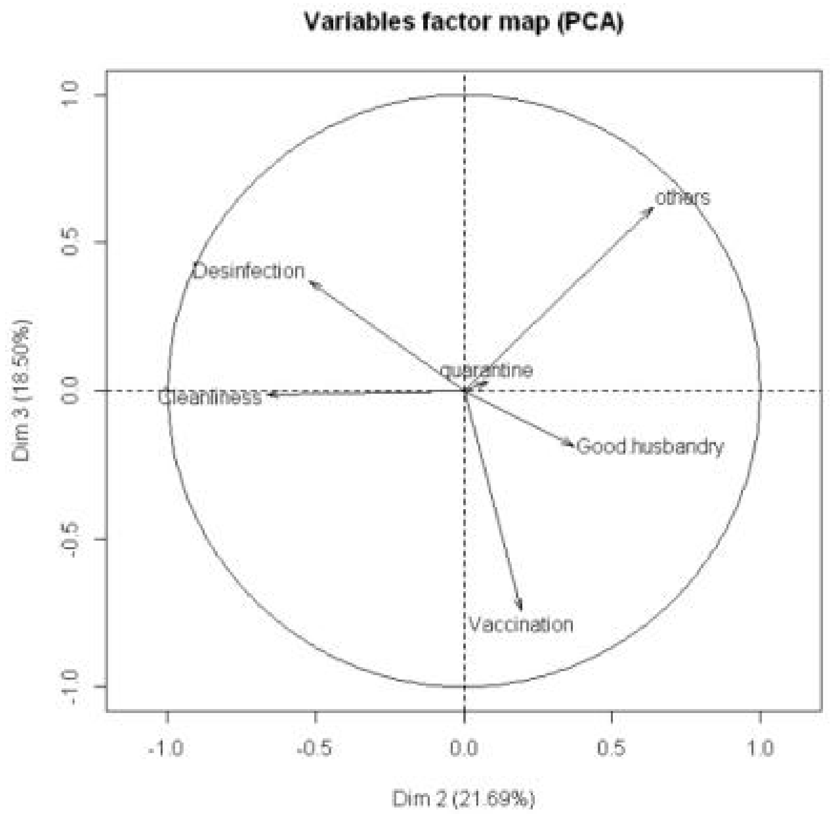
3.3.1. Overall description of principal component analysis

This analysis is based on the data produced from 116 focus groups, which included six actives variables related to prevention methods and one supplementary variables related to production types. The three first components had an eigenvalue superior than one that accounted for 68.3% (28.2%, 21.7% and 18.4%, respectively) of the total cumulative percentage of explained variance, and were retained for analysis.

In the first component (Figure 5A, axis X), active variables had two coordinates of both signs. Vaccination, quarantine and disinfection were positively correlated while good husbandry management practices and cleanliness were negatively correlated. It was noted that quarantine was positively and more closely linked to this component than others with a correlation coefficient (r) of 0.74 while good husbandry management practices were negatively linked (r: -0.68). For the second component, vaccination, good husbandry management practices and other methods had positive correlation while disinfection and cleanliness had negative correlation (Figure 6A, axis Y; 6B, axis X). Other methods had close positive association to this second component (r: 0.63) while cleanliness had a close negative correlation (r: -0.66). Regarding the third component (Figure 5B, axis Y), other methods and disinfection were positively correlated while good husbandry and vaccination were negatively correlated. Others methods had a close positive correlation (r: 0.62) with component 3 while vaccination had a close negative correlation (r: -0.74).

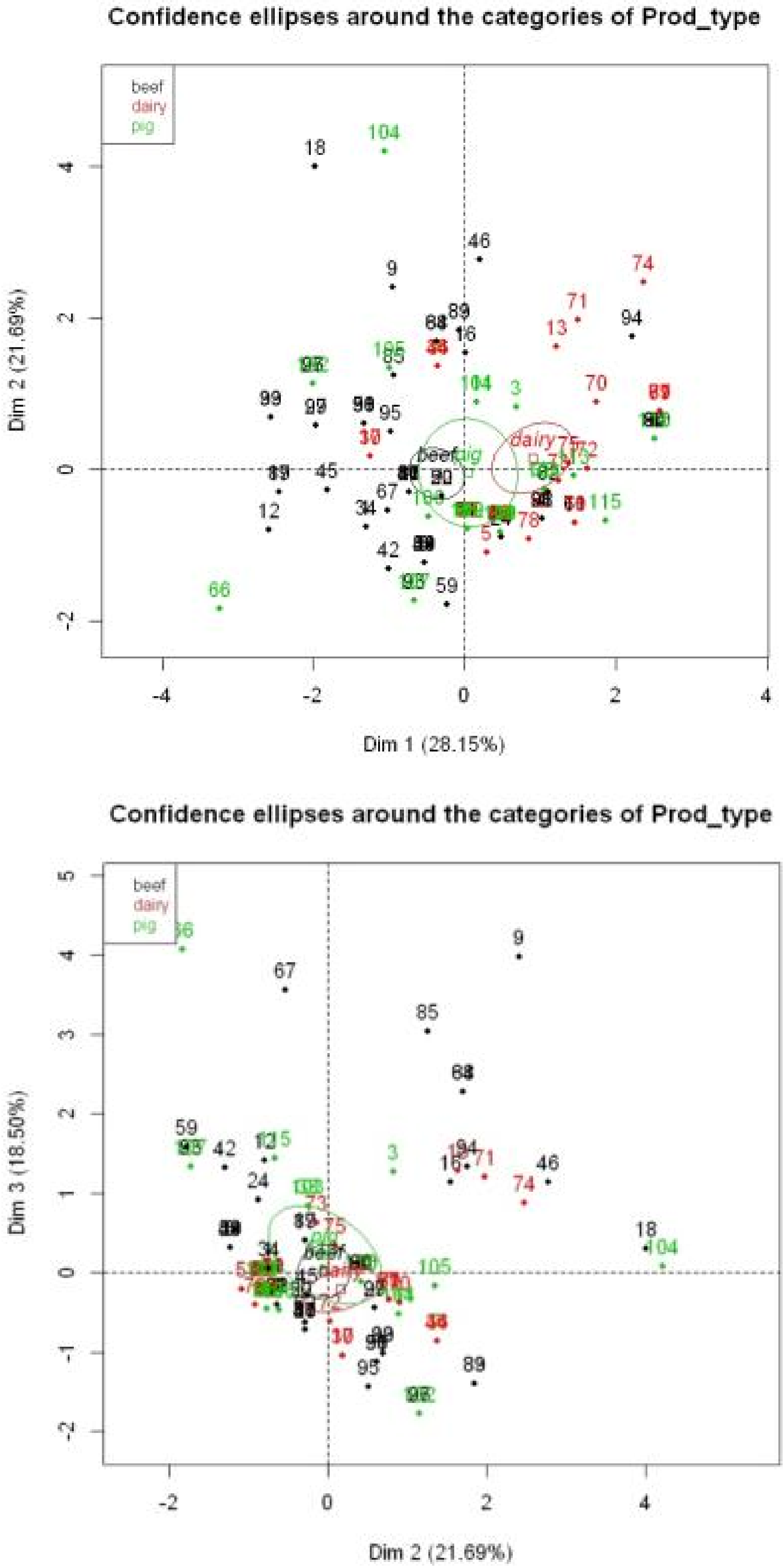
Figure 5: Variable factor map on axes 1-2 (A) and on axes 2-3 (B) of foot-and-mouth disease prevention methods used (i.e. vaccination, disinfection, cleanliness, quarantine, good husbandry management practices, and other methods)





Production type, supplement qualitative variable, within three modalities such as dairy, beef and small pig production allowed us to characterize the first component. Modalities of dairy and beef production had respectively significantly positive and negative coordinates on the first component (Figure 6A and 6B). By grouping farms close to the first component respecting to type of production, the following typologies could be suggested. Dairy farms frequently applied quarantine, disinfection and vaccination as prevention methods. Beef farms preferred cleanliness and good husbandry management practices. Pig farms considered that all prevention methods had the same importance. The supplement qualitative variables did not allow us to characterize the second and the third components, as well as to demonstrate links between variables and individuals that can be used for setting up a typology.

Figure 6: Individual factor map with confidence ellipses around the categories of beef, dairy and pig production type on axes 1-2 (A) and on axes 2-3 (B) of foot-and-mouth disease prevention methods used



The matrix of correlation between variables showed that only vaccination and disinfection had a lightly positive correlation with quarantine (r= 0.14 and 0.13, respectively) (Table 2). It means that farmers combined vaccination (or disinfection) with quarantine as preventive methods. Otherwise, all methods had negative correlation together. Strongest negative correlation was found between cleanliness and vaccination (r= -0.25) or other methods (r= -0.25), good husbandry management practices and disinfection (r= -0.33) or quarantine (r= -0.34), cleanliness and quarantine (r= -0.3). These methods seemed not being implemented together.

Table 2: Correlation matrix between foot-and-mouth disease prevention methods used by farmers

	Vaccination	Disinfection	Cleanliness	Quarantine	Good husbandry management practices	Other methods
Vaccination	1.00	-0.09	-0.25	0.14	-0.20	-0.15
Disinfection	-0.09	1.00	-0.10	0.13	-0.33	-0.15
Cleanliness	-0.25	-0.10	1.00	-0.30	-0.06	-0.25
Quarantine	0.14	0.13	-0.30	1.00	-0.34	-0.02
Good husbandry management practices	-0.20	-0.33	-0.06	-0.34	1.00	-0.05
Other methods	-0.15	-0.15	-0.25	-0.02	-0.05	1.00

3.3.2. Hierarchical classification of farmers according to their opinion on prevention methods used

From HCPC result, s in the study zone could be classified into four clusters. Cluster 1, 2, 3, 4 composed of 35, 13, 42 and 26 individuals, respectively. Farms from cluster 1 are characterized by a lower score of quarantine (0), disinfection (2.89) and other methods (0) than average score of all farms (0.94; 3.91; 0.60, respectively) (Table 3). Only good husbandry management practices scores (3.83) were higher than the average score (1.48). Farms in cluster 2 had other methods score (4.92) much higher than the average of the other farms (0.60). None of the variables characterized the farms in cluster 1 and 2. Farms in cluster 3 had disinfection and cleanliness scores (4.69 and 4.50) higher than the average score of other farms (3.90 and 3.70, respectively). Similar to cluster 1, quarantine and other methods were not practiced in this cluster with score around 0. For farms of cluster 3, good husbandry management practice score (0.35) was lower than the average for all farms (1.48). Farms in cluster 4 had quarantine score (3.90) which is higher than the average score (0.93). Cleanliness and good husbandry score (2.80 and 0.20) in this cluster were lower than the average of all farms (3.70 and 1.40, respectively). Cluster 4 is characterized by categories dairy – beef of the categorical variable "production type". The number of farms with those categories in this cluster was higher than in the others. In fact, 53.8% and 38.4% of the farms in cluster 4 are dairy and beef's farms, respectively.

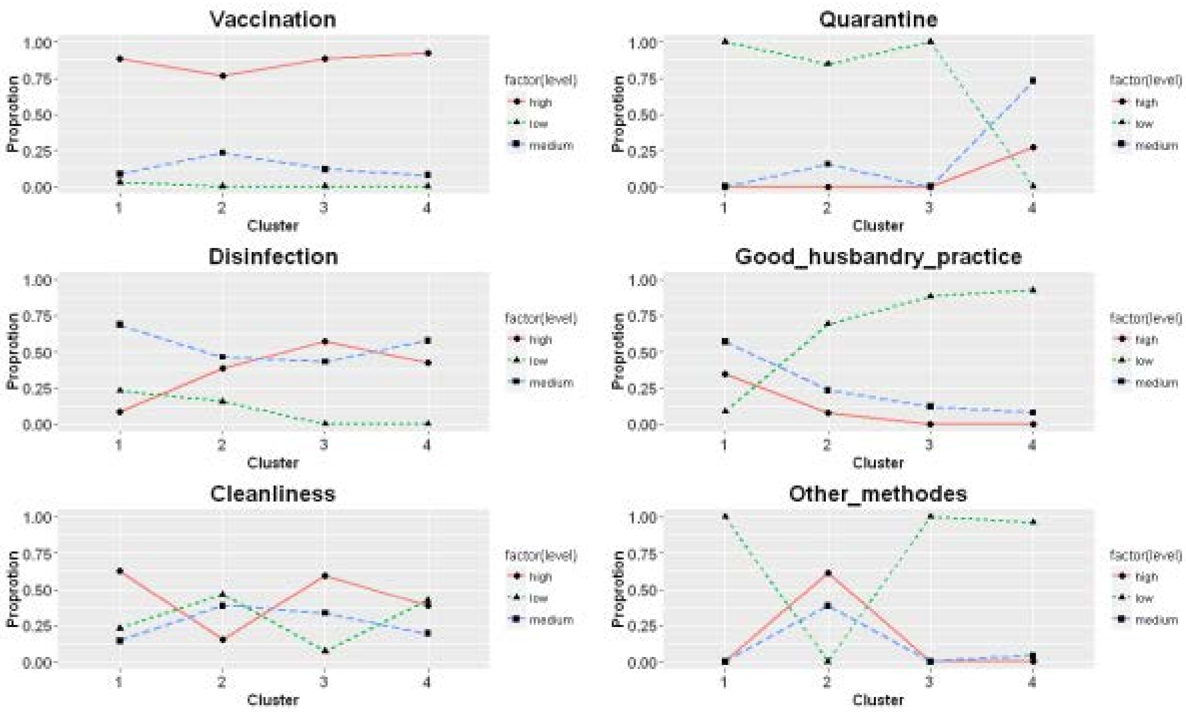
Table 3: Definition of foot-and-mouth disease prevention methods' clusters by actives variables

Cluster	Prevention method	v.test	Mean in category	Overall mean	Standard deviation in category	Overall standard deviation	p.value
1	Good husbandry management practice	8.17	3.83	1.48	1.48	2.02	0.00
	Others	-2.64	0.00	0.60	0.00	1.61	0.01
	Quarantine	-3.85	0.00	0.94	0.00	1.72	0.00
	Disinfection	-5.05	2.89	3.91	1.67	1.44	0.00
2	Others	10.20	4.92	0.60	0.83	1.61	0.00
	Cleanliness	-2.59	2.23	3.71	2.19	2.17	0.01
3	Disinfection	4.37	4.69	3.91	0.67	1.44	0.00
	Cleanliness	2.95	4.50	3.71	1.44	2.17	0.00
	Others	-3.02	0.00	0.60	0.00	1.61	0.00
	Quarantine	-4.42	0.00	0.94	0.00	1.72	0.00
	Good husbandry management practice	-4.49	0.36	1.48	0.97	2.02	0.00
4	Quarantine	10.01	3.92	0.94	0.87	1.72	0.00
	Cleanliness	-2.38	2.81	3.71	2.35	2.17	0.02
	Good husbandry management practice	-3.57	0.23	1.48	0.80	2.02	0.00

Cluster 1 included 35 individuals from 116 that were divided into 24, 6 and 5 individuals for beef, pig and dairy, respectively. Cluster 2 composed of 13 individuals, in which divided into 9 beef, 2 dairy and 2 pigs. Cluster 3 included 24, 6 and 12 individuals of beef, dairy and pig, respectively. Finally, cluster 4 composed 14 dairy, 10 beef and 2 pig individuals.

The distribution of individuals in each cluster according to prevention methods was presented in Figure 7. Vaccination was considered as an important method for all clusters. Among them, individuals in cluster 4 considered this method as highly important, and people from cluster 2 considered it as medium to high level of importance. Disinfection was mainly ranked as medium-high level of importance. Role of disinfection was the lowest in cluster 1. The importance of quarantine methods was considered as low in cluster 1, 2, 3 and medium - high in cluster 4. Cleanliness role was ranked as medium-high in cluster 1 and 3. Its value decreased to medium in cluster 4 and lowest in cluster 2. The importance of good husbandry practice decreased from cluster 1 to 4 and from medium to low level. Other methods were considered as less important for cluster 1, 3, 4 and the value was medium-high in cluster 2.

Figure 7: Distribution of clusters' opinion focused on the level of importance of foot-and-mouth disease prevention methods applied by farmers

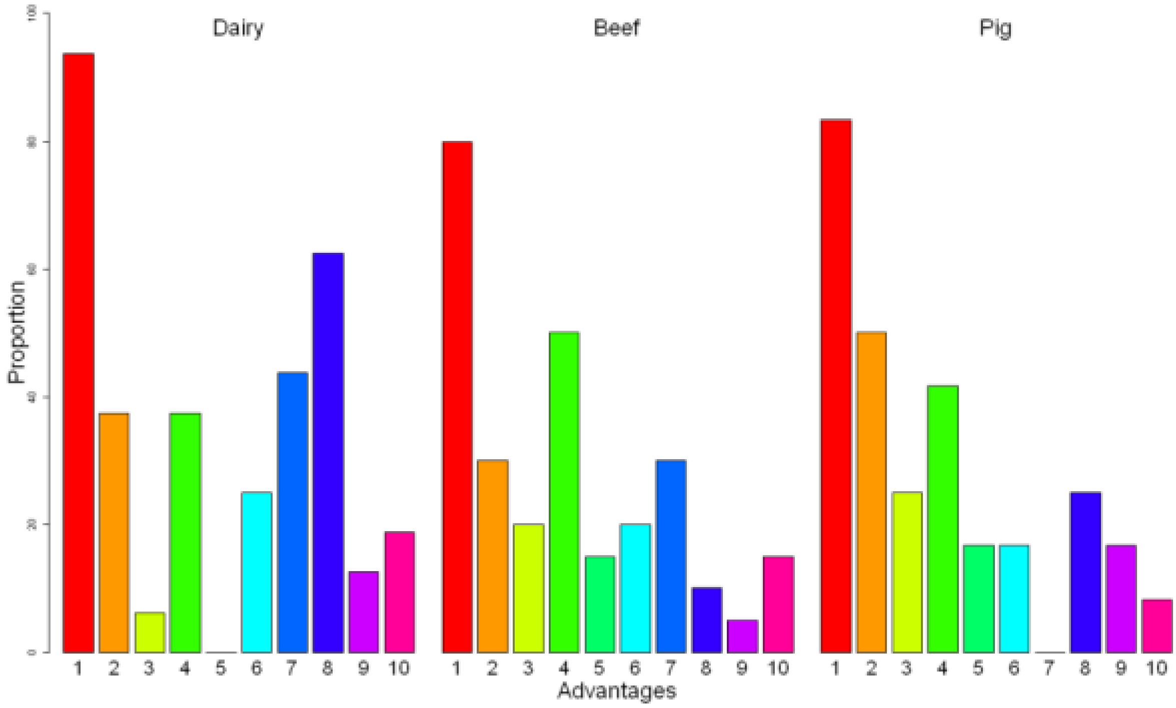


3. 3. Advantages and inconveniences of FMD vaccination for farmers

3.3.1. Advantages of FMD vaccination

Ten advantages of vaccination were listed by farmers : "infection prevention", "ease in treatment or short duration of treatment", "decreasing treatment cost", "reducing anxiety amongst farmers", "aid in maintaining a high selling price for product or increase income", "avoidance of income loss", "having support from government", "ease in trading (milk selling, transport)", "reducing propagation of disease" and "capital protection" (Figure 8). The infection prevention was considered as the most important advantage of vaccination for all of three production types. In fact 67% of farms (41/48) appreciated the overall effectiveness of vaccination (100% of vaccinated animal free of infection), then 19% of them declared a good protection rate of vaccination (only 5 – 20% of animal infected after vaccination). "Ease in trading (milk selling, transport)" and “reduce anxiety amongst farmers” were respectively considered as the second important advantages for dairy and beef farmers, respectively. “Receive support from government” was mentioned as the third important element for dairy and beef farmers. Pig farmers were not benefitting from this support. For pig production, “ease in treatment or short duration of treatment” and “reduce anxiety amongst farmers” were ranked as second and third important advantages of vaccination.

Figure 8: Overall of advantages from foot-and-mouth disease vaccination for farmers according to dairy, beef and pig production type

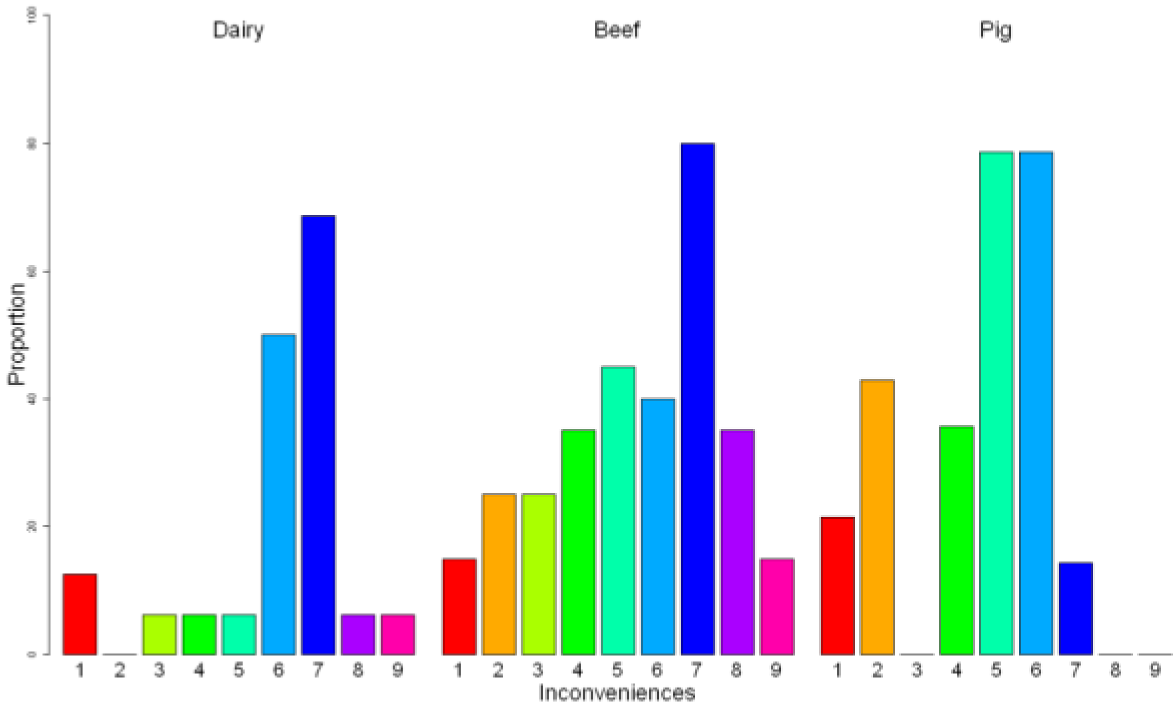


1: infection prevention; 2: ease in treatment or short duration of treatment; 3: decreasing treatment cost; 4: reducing anxiety amongst farmers; 5: aid in maintaining a high selling price for product or increase income; 6: avoidance of income loss; 7: receiving support from government; 8: ease in trading (milk selling, transport); 9: reducing propagation of disease; 10: capital protection.

3.3.2. Inconveniences of vaccination

Regarding vaccination against FMD, nine principal problems described by farmers were “vaccine delivery” (not enough doses to be distributed or to be sold, delayed delivery); “high cost of vaccine” (an uncorrelated phenomenon between amount of doses in a vial sold and minimum requirement of farmers); “information lacking about timing and schedule of the vaccination campaign"; "practice totally depending on veterinary"; "perception of uselessness" (vaccination cannot protect animal); "unwillingness due to production loss caused by vaccination"; "worry about side effect of vaccination on animal's reproducibility, i.e. abortion"; "worry about side effect of vaccination on animal behaviour"; "fear of infections to animals from unhygienic vaccination equipment" (Figure 9). "Unwillingness due to production loss caused by vaccination" and "worry about side effect of vaccination on animal' reproducibility" had been respectively highlighted as major inconveniences for dairy farmers. For beef production, "worry about side effect of vaccination on animal' reproducibility" was considered as the most important inconvenience caused by vaccination, then the "perception of uselessness" hampered its practice. "Unwillingness due to production loss caused by vaccination" ranked as the third important element. "Worry about side effect of vaccination on animal' reproducibility" and "perception of uselessness" were considered as the two most important inconveniences that hindered its practice in pig production. Ranking as the second important element was "high cost of vaccine".

Figure 9: Overall of farmers' perception on inconveniences of foot-and-mouth vaccination according to dairy, beef and pig production type



1: vaccine delivery; 2: high cost of vaccine; 3: information lacking about timing and schedule of the vaccination campaign; 4: practice totally depending on veterinary; 5: perception of uselessness; 6: unwillingness due to production loss caused by vaccination; 7: worry about side effect of vaccination on animal's reproducibility; 8: worry about side effect of vaccination on the animal behaviour; 9: fear of infection to animals from unhygienic vaccination equipment.

4. Discussion

4.1. Causes of introduction FMD and its consequences on livelihood from farmers' viewpoints

Farmers mentioned that FMD prevalence has to be often linked to seasonal factors, frequently happening with season's change, due to an increase in humidity and a decrease in animal's immunity. In Long An, in floating season (July and August) animals are being kept all day in a simple building located on a small hill and surrounded by water and stall fed instead of grazing in fields, as during other seasons. This husbandry practice made animal more susceptible to diseases, including FMD.

Several elements can have a role as vehicles for disease transmission. According to farmer's opinion, vaccinators and vaccination equipment can transmit the disease if proper hygienic measures during farm visits are not considered and if they do not change syringe during vaccination. The risk of introduction of disease into the farm increases due to the easy access into farm without any bio-security measures (Unger, 2015). Importation of cattle with unknown immunity status from Thailand and Cambodia was considered as a risk of FMD introduction by farmers. The risk of transmission of FMD on animal movement route was previously reported by Forman et al. (2009), Polly et al. (2009) and Widders (2015). It is suggested that local veterinarians need to improve their control measures at the boundary to make it more effective through strict control methods and legislations for imported animals and applying punishment methods as mentioned in veterinary law. In fact, Vietnamese regulations requires imported animals to be vaccinated at least once, being quarantined during two weeks at a quarantine station at the boundary (DARD Long An, 2014; Vietnam National Assembly, 2015) and being attached an ear-tag for identification. However, the majority of traders did not implement these measures. They explained that quarantine duration was long and expensive as their animals lose weight in quarantine. Therefore, animals were moved on foot to cross the boundary by local people from Cambodia to Vietnam as normally Cambodian herds. In this case, veterinary services did not know that the animals were being imported to check for health status. Secondly, traders can act as farmers who raise two herds in both countries. Animals from two herds can be exchanged and new animals from Cambodia can be added to Cambodia herd for fattening in a short period and go through boundary as part of Vietnamese herd. Catley et al. (2002) performed study in 12 farmers groups and reported that importation of infected animals (especially sick buffalos) into herds was the major risk factor related to disease introduction in cattle. Thai et al. (2008) also indicated that buying animals from unknown place was also a risk of disease introduction. Disease transmission from infected zone was related to characterization of husbandry and commercial patterns in study zone. Farmers living in boundary zones (at the edge of two countries) always left their animals in grazing zones at border's location. Trans-boundary trade of cattle took place in live market located normally near boundaries where many of traders, vehicles and animals from different zones concentrated. Moreover, some pig slaughterhouses in this area bought FMD infected animals because of its cheaper price (personal communication with commune veterinarian). Meanwhile, infected cattle in this area could be bought alive and then they were transported to other areas for slaughter. These activities played an important role in diseases transmission (Thai, 2008).

Farmer's perception on risk factors related to unsafe environment (e.g. cage hygiene) is still limited. Dirty cage is a possible route of transmission, especially through manure. Animals with FMD were rarely quarantined strictly. In fact, they were kept together with normal ones or a little bit far from the others but still in the same cage sharing the same feeder and drinker which lead to transmission of disease from one to another (Ellis-Iversen et al., 2011; Nguyen et al., 2011).

Income loss and cost of treatment were ranked as the two most important consequences of FMD on farmer livelihoods. Their rankings linked to characterisation of this disease. Introduction of FMD could infect all the animals in a herd due to its high morbidity but the mortality of adult cattle was only 2%. The mortality of FMD in young animal was much more important, possibly increasing up to 100% (Radostits and Done, 2007). Other consequences of FMD listed by farmers were relevant and in lines with the literature about the consequences of this disease (Radostits and Done, 2007; OIE and FAO, 2012). It was highlighted that FMD affected not only on economic aspects but also influenced on sociological aspects. The later aspects needed to be taken into account to understand farmers' reaction of prevention and control of an FMD outbreak such as disease information sharing behaviour and decision of vaccination.

4.2. Identification and ranking of prevention methods in case of FMD

Vaccination was considered as the most important preventive methods by farmers because its effectiveness can achieve 70-80% (result from farmer's interviews). This ratio was similar with study's result of Nguyen (2005) on dairy calf and pigs (5 months post vaccinated) in 3 districts of Ho Chi Minh city with average immunity coverage are 87% and 80%, respectively. Moreover, vaccination also gave some advantages for them as mentioned above such as relax, support from government, decrease cost and time consumption for treatment. Farmers' choice are relevant with Vietnam's policy (MARD, 2011, 2015) and strategic framework to prevent and eradicate FMD in Southeast Asia and China (OIE Sub-Regional Representation for South East Asia, 2016) . Disinfection and cleanliness were classified as second and third most important methods for prevention. Farmers explained that pathogenic agents thriving within the cage might contact with animal every day. Cleanliness would help to decrease pathogens in cages. In fact, 47 % of farmers (of all production types) in study zone clean animal cages (Nguyen et al., 2014) and 100% of pig farmers clean their animal cages every day (Le, 2009). Moreover, farmers realized that cleaning cages with fresh water is not enough to get rid of pathogens in cages and they need to apply disinfectants with some chemical ingredients in order to prevent disease's propagation. Farms located close to infected farms had a higher risk of infection than other farms located far from infected farms because of aerosol transmission capacity of this virus (Radostits et al., 2011) and disinfection in infected zone helps to reduce virus propagation while decreased volume of exposed virus (Radostits et al., 2011). Dairy farmers considered that vaccination and disinfection had a same importance and they practiced these methods in parallel and regularly. Beef farmers considered cleanliness more important than disinfection because their buildings were used only for animals to sleep at night. Cleaning cages was enough and disinfection was applied only two or three times per year with government's support. In pig production farms, disinfection was considered as more important than cleanliness as animals always stay in cages. Farmers disinfected animal weekly or monthly.

Quarantine is considered as one of the important prevention methods by dairy farmers because of high density of population in zone, which facilitates disease transmission. Quarantine was applied not only on animal but also on visitors (traders, veterinary). Visitors played an important role in disease transmission when they travel from one farm to another. The infection risk in farms having visitors was higher (from 5 to 11 times) than the others (Nguyen et al., 2015b). However, beef and pig farmers did not apply quarantine. Easy access for visitors to cages was one characteristic of pig farms in Vietnam (Unger et al., 2015). Pig were chosen and bought from well-known farms or produced so quarantine was considered unnecessary (Le, 2009). Applying an effective quarantine method at small scale is challenging in Vietnamese condition. Animal cage is normally located aside the house in a limited surface. A strict quarantine could not be achieved while visitors can easy access to cage in a few steps and infected animal were isolated far from the healthy ones in a distance of several meters.

Beside quarantine, vaccination was applied alone by farmers and it was not correlated with any other methods. Based on bio-security principles, the perfect and most effective way of prevention is a combination of all those methods (Radostits et al., 2011). Separately utilization of each method cannot be useful to protect animal. The ideal condition is not easy to access in smallholder farms with limited resources and the choice of prevention methods strictly depends on the capacity of each farm. From the PCA result, we noted that several dairy farmers used vaccination, disinfection and quarantine together. They accepted to invest money in expensive methods for their valuable animals because of high prevalence in dairy farms (nearly 30%) (Carvalho Ferreira et al., 2015; Nguyen et al., 2015) and severe consequences of this disease (OIE and FAO, 2012) on their livelihoods. Beef farmers preferred cleanliness and good husbandry management practices because of its simplicity and easiness to apply. Cage cleanliness was easy because animals just stayed during the night with enough grass and fresh water. Pig farmers did not prefer any preventive methods so they applied whatever necessary for their animal and adapted to their financial capacities.

4.3. Advantages and inconveniences of vaccination for farmers

"Infection prevention", the most important advantage of vaccination recognized by farmers is also seen by other actors such as veterinary authorities and researchers. Veterinary authorities appreciated this method during a long period throughout implementing and maintaining national plan of FMD prevention and control in Vietnam based on vaccination. Researchers and organizations highly recommended vaccination as the first choice for eradicating this disease at a global scale (OIE Sub-Regional Representation for South East Asia, 2011; OIE and FAO, 2012). This perception might be the result of long process of utilization and public awareness provided by extension services such as district veterinary, and veterinary milking collector companies and drug companies. "Ease of trading (milk, selling, and transport)" was considered as second important advantage of vaccination for dairy farmers. In Vietnamese context, having a good vaccination certificate of infectious diseases (haemorrhagic septicaemia, FMD, etc.) which was well indicated in selling contract was a condition for farmers to be able to sell milk to milking collectors. However, it was not a condition to increase milk-selling price, which depended on milk's quality (e.g. raw material, protein, fat indicators). In addition, while majority of dairy farmers appreciated the necessary of vaccination certificate, only 10% of beefs farmers and 25% of pig farmers mentioned about it. This finding suggests that animal movement were not well controlled as needed and vaccination do not contribute to value of final product used for meat purpose. Each animal needs a certificate when it is transported to another province or to slaughterhouse. Indeed, selling animals without certificate from origin (at farm level) was observed in the field. "Receive support from government" was mentioned as the third important element for dairy and beef production but not in pig production highlighted the fact that pig farmers were not targeted actors in national plan for prevention and control of FMD. Throughout three phases of this plan from 2006 up to now, prevention methods applied in pigs were not well documented which suggested that pigs production had a minor role in transmission of FMD. Pig farmers are only encouraged to vaccinate their animals. Other advantages of vaccination in pig production were "ease in treatment or short duration of treatment". The severity of disease in a vaccinated animal was less important than unvaccinated one as well as the presence of clinical signs on animal (Radostits et al., 2011; Thomson, 1994). In fact, vaccinated pigs presenting minor clinical signs were rapidly treated with medicaments. An animal being treated its clinical signs could be considered as "cured" by farmers. "Reduce anxiety among farmers" was a common perception of farmers after vaccination, which highlighted a strong belief on vaccination effectiveness.

"Worry that vaccination may affect the reproducibility", the most important inconvenience in dairy and beef herd which mainly link to veterinary practice. Veterinary applied vaccination as fast as possible because of the large number of farms to be visited per working day. The condition of not causing stress during vaccination for animals according to the manual of vaccination is not satisfied (Merial, 2013). It is noted that a suddenly injection might startle animals. They can fall down in cage and an abortion might occur. The abortion directly links to stress caused by bad practice, not by vaccine nature itself. “Unwillingness due to production loss caused by vaccination”, one of the most important inconveniences of vaccination (1st rank for pig, 2nd rank for dairy and 3rd rank for beef) linked to fever reaction, reduction in milk production and growth capacity due to immunological reactions of vaccination. Even this reactions is normal from immunity point of view, farmers’ perceive it as an inconvenience as well. Some participants informed that after vaccination, volume of milk could decrease from two to seven days. Others thought that vaccine in piglets could cause a side effect on their animal. Finally, pig farmers considered that it exist other diseases must be more important to prevent than FMD (perception of uselessness) and omitting one type of vaccine could help them save a part of production cost. Production costs of smallholders were often higher than in industrial farms. In order to get more revenue, farmers normally applied some preventive methods for the most important diseases that could cause significant economic loss in a short time.

Some farmers refused to vaccinate their animals because it was not considered as a critical method to protect them. Others declared that vaccine monovalent O used in beefs and pigs, supported by the government, was not enough to protect their animals in this dynamic zone because their animals can be also infected with new serotypes from other countries throughout animal movements. Recent studies and reports on circulation of serotypes in the field confirmed the presence of two serotypes O and A which caused outbreaks in Vietnam (Carvalho Ferreira et al., 2015; MARD, 2015). To date, it was confirmed the presence of serotype A in our study zone (see detail in chapter 3). The presence of serotype A in cattle was reasonable while the study zone was characterized with high concentration of animal, presence of numerous important slaughterhouses, and presence of routes of animal movement, which facilitates introduction of animal carrying new virus. In this situation, farmers' requirement of bivalent or trivalent vaccine is acceptable. However, with limited government budget, bivalent or trivalent vaccine would not be supplied within free of charge for all farmers at any moment. It is recommended that farmers should use bivalent vaccine within the support from government or their private budget to ensure effectiveness of vaccine on their animal as expected. Using same syringe and needle for healthy and infected animal was also considered as a risk factor for the presence of disease in the study zone. This aspect mainly links to hygienic practices while vaccinating. Regular training on vaccination practice for communal veterinarian (e.g. role-playing game, participatory game) at the beginning of vaccination campaign might aid in maintaining a good level of vaccination's practice.

5. Conclusion

This paper demonstrated a multivariate perception of risk factors of FMD introduction into farms, the variation in socio-economic impacts on livelihood of this disease for each production type and variation in prevention methods used by farmers. Estimation and perception of how important of combination of different methods based on farmers' viewpoints were also demonstrated. Advantages and inconveniences of vaccination used were discussed in this paper. Everything examined in this paper focuses on FMD but in fact the means allocated by the farmers depend on trade-offs they make between the different risks that weigh on their flocks. It is suggested that the FMD is not necessarily the worst risk for them. Therefore, the FMD control strategy proposed by Vietnamese authorities might not be always the first choice for farmers. The finding from this study can serve as priors' information for further sociological study about farmers perception of vaccination used or further quantitative studies focused on FMD impacts and cost benefit of vaccination.

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CHAPTER 5

A Q-METHOD APPROACH TO EVALUATING FARMERS' PERCEPTIONS OF FOOT-AND-MOUTH DISEASE VACCINATION IN VIETNAM

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A Q-method approach to evaluating farmers' perceptions of Foot-and-mouth disease vaccination in Vietnam

Dinh Bao Truong[1,2*], Aurélie Binot[1,3], Marisa Peyre[1], Ngoc Hai Nguyen[2], Stéphane Bertagnoli[4], Flavie Luce Goutard[1,3]

[1] UPR AGIRs Research Unit, Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), Montpellier, France

[2] Faculty of Animal Science and Veterinary Medicine, Nong Lam University, Ho Chi Minh, Vietnam

[3] Faculty Veterinary Medicine, Kasetsart University, Bangkok, Thailand

[4] UMR INRA-ENVT IHAP, Université de Toulouse, Toulouse, France

***** dinhbao.truong@hcmuaf.edu.vn/ dinh-bao.truong @cirad.fr

Abstract

This study aims to explore the farmers' perceptions of foot-and-mouth disease (FMD) vaccination using a reflexive research method called Q methodology. A structured sample was composed including 46 farmers selected according to gender, farming experience, level of education and production type. Statements (stat.) relevant to the farmers' perceptions of and attitudes towards FMD vaccination, related to confidence, logistics, costs and impacts of vaccination, were developed. Results were analysed by principal component analysis and factor analysis. Influence of demographics and characterized variables on the respondent's contribution to each factor were also tested.

Regarding the different beliefs and behaviour towards vaccination against FMD, common perceptions of Vietnamese cattle and pig farmers was divided into three discourses named Confidence (24 subjects), Belief (12 subjects) and Challenge (6 subjects). The identified discourses represented 57.3% of the variances. Consensus points were found such as: the feeling of being more secure after FMD vaccination campaigns; the fact that farmers take vaccination decisions themselves without being influenced by other stakeholders; the opinion that FMD vaccination is cheaper than the costs of treating a sick animal; and that vaccines provided by governmental authorities are of high quality. Part of the studied population did not consider vaccination to be the first choice strategy in prevention. This raises the question of how to improve the active participation of farmers in the FMD vaccine strategy. Taking into consideration farmers' perceptions can help to implement feasible vaccination strategies at local level.

Keywords: Vaccination; farmers' perceptions; foot-and-mouth disease; participatory methods; Q methodology; discourse

1. Introduction

Foot-and-mouth disease (FMD) is among the most widespread infectious diseases that harm the development of the world's livestock sector (OIE and FAO, 2012). In order to tackle FMD outbreaks, various disease management approaches have been implemented in South-East Asia (SEA) including risk analysis, vaccination, surveillance networks, laboratory support, animal movement control, policy advocacy, support of private sector and other stakeholders, communication improvement between country members throughout workshops, meetings, and public awareness (OIE Sub-Regional Representation for South East Asia, 2011). Surveillance networks have been developed at national and also regional levels (e.g. South-East Asia and China Foot-and-Mouth Disease (SEACFMD) program, http://www.rr-asia.oie.int/activities/sub-regional-programme/stanz/seacfmd/). The efficiency of FMD surveillance and control programs in developing countries is often challenged by the issue of under-reporting (Bellet et al., 2012; Madin, 2011). Owing to the low mortality rate, farmers often consider FMD as the second priority to control after Haemorrhagic Septicaemia, despite its potential negative impact on production yield (Bellet et al., 2012). However, FMD is known to cause significant financial losses for small producers and therefore to threaten the livelihood and food security of the poorest communities worldwide (Madin, 2011). For example, in Laos, it was estimated (in 3 provinces under study) that losses due to FMD varied from 381 US Dollar (USD) to 1,124 USD per household, per year, representing 16% to 60% of annual household income (Nampanya et al., 2013). In Vietnam, the annual average economic loss for each affected farm was estimated to be 84 USD for highland areas with low livestock density, and up to 930 USD per farm for lowland areas with high livestock density (Forman et al., 2009). Moreover, a recent study on the financial impacts of swine diseases reported that the total cost of FMD was estimated to be 21.3, 23.8 and 27.8 USD per pig for a large farm, a fattening farm, and a smallholder, respectively (Pham et al., 2016). The financial impact of FMD on smallholder cattle farmers in southern Cambodia was estimated to range from 216 to 371 USD per animal, with an outbreak reducing annual household income by more than 11% (Young et al., 2013). FMD also represents a major obstacle to international trade and a permanent risk to countries with an FMD-free status. For these reasons, FMD has been targeted by The World Organisation for Animal Health (OIE) and Food and Agriculture Organization (FAO) as a priority for disease control worldwide throughout a global strategy (OIE and FAO, 2012). Despite the availability of effective vaccines, the successful control of FMD remains very limited. The investments required to control the disease are substantial regarding financial and logistical resources (OIE and FAO, 2012).

In Vietnam, FMD is endemic with outbreaks occurring every year (Madin, 2011; Phan, 2014; Carvalho Ferreira et al., 2015). Considering the importance of the disease, the Vietnam Ministry of Agriculture and Rural Development (MARD) has been implementing a national prevention and control program since 2006. This program is renewed every five years by the Department of Animal Health (DAH, subordinate of MARD) – which is in charge of disease surveillance at the central level. Some technical solutions are currently proposed in this program, such as the implementation of epidemiological and serological surveys, disease surveillance, animal movement control, vaccination, disinfection, awareness raising and training workshops. Among these strategies, mass vaccination against FMD for all cattle and buffaloes within specific targeted areas is considered to be a valuable tool. According to the epidemiological situation, provinces of Vietnam are classified into two zones: high risk (subdivided into control and buffer) and low-risk zones (MARD, 2011). The control zone (high risk) consists of eight provinces along the northern border, six provinces along the southwest border, between Vietnam and Cambodia, and five provinces located on the border with Laos and the Central Highlands region. The buffer zone (high risk) consists of ninety provinces adjacent to the control zone. The low-risk zone consists of nine provinces in the Red River Delta region, four important export provinces along the North Central Coast (Nghe An, Thanh Hoa) in the Red River delta region (Ninh Binh, Vinh Phuc), nine provinces in the Mekong Delta region and three provinces in the South East region and Ho Chi Minh City (MARD, 2011).

The surveillance and reporting system is mainly organised into three levels: i) Epidemiological unit of DAH at central level, ii) Epidemiological unit of Regional Office of Animal Health at region scale, epidemiological unit of sub-Department of Animal Health (sub-DAH) at province scale, employees of the district office of animal health at intermediate level and slaughters houses located in districts, iii) farmer, veterinary commune at local level (To, 2013). Three serotypes O, A and Asia 1 have been detected in Vietnam (Le et al., 2011; WRLFMD, 2017). According to information on the serotypes currently circulating in Vietnam, vaccines used in the field may be monovalent (serotype O) or bivalent (serotype O and A) (MARD, 2011, 2015). The type of vaccine used varies every year according to the epidemiological situation of each location. For example, the sub-DAH of Long An province used a monovalent vaccine for pigs and cattle in 2012, but they had to switch to a bivalent vaccine in 2013 for cattle as serotype A was circulating at this time. The objective of the national program is to vaccinate 85 to 100% of the cattle and buffalo populations within the high-risk zones. In the low-risk zones, vaccination is only implemented in locations where an outbreak has been recorded by the provincial authority over the last five years. The main target animals for this program are cattle and buffaloes. The vaccination of pigs and other susceptible animals is not well-detailed in the program, and the decision is left to the sub-DAH. Vaccination is usually done twice yearly (March-April and September-October). Vaccination budgets for each zone are also different. In control and buffer zones, vaccine fees are financed up to 100% and 50% of their costs respectively by the national budget, while the labour cost of the commune's veterinarian is paid for by the local authorities. In low-risk zones, these fees are paid for by the local authorities (MARD, 2011). The total estimated cost for the national program (national and local budget) for FMD prevention and control in Vietnam has recently been estimated at 36 million USD for the period of 2006-2010 and 32 million USD for the period of 2011-2015 (MARD, 2011). The following phase of the National Plan, from 2016 to 2020, is already implemented in the field, and contains some changes about the vaccination strategy for each zone and the setting up of an animal identification system (MARD, 2015).

As previously described, the primary FMD prevention and control strategy in Vietnam is, therefore, to concentrate vaccination efforts within the "hot spots", which are the zones identified with a higher risk of outbreaks. However this strategy comes up against many logistic and economic constraints, and its effectiveness has yet to be proven regarding vaccine coverage and disease control (MARD, 2011, 2015). The location of hot spots is not easy to estimate because the surveillance database is incomplete and there is high uncertainty as to the real prevalence of disease due to the problem of under-reporting by farmers (Madin, 2011; Bellet et al., 2012). Furthermore, the farmers' awareness of sanitary risk and the way in which they make animal health decisions are often associated with other multiple constraints of an economic, sociological or cultural nature that do not always favour vaccination as a priority strategy (Chilonda and Van Huylenbroeck, 2001). Some authors also mention that studies concerning the farmer's perception of the socio–

economic impacts of animal diseases are highly relevant in the implementation of disease control strategies (Nampanya et al., 2013; Young et al., 2013; Pham et al., 2015).

This study aims to use a qualitative method to describe the perception of farmers from South Vietnam regarding vaccination strategies to control FMD. Decision toward a given subject is often influenced by socio-economic factors. The decision is always made based on how they perceive the subject (Chilonda and Van Huylenbroeck, 2001). Therefore, understanding the perception of farmers is considered critical to feasible vaccination strategy. The Q-methodology – a sociological approach - is a qualitative method used to analyse the subjectivity of individuals faced with a common situation (Brown, 1980). It helps to identify trends and convergences of opinions and patterns within social groups and can be very useful for operators that intend to explore and describe subjective opinions about a particular phenomenon. This method is used in research areas such as policy (Brown, 1980), public health (Farrimond et al., 2010; Garner, 2011; Chiffot et al., 2014) and rural sociology (Danielson et al., 2009).

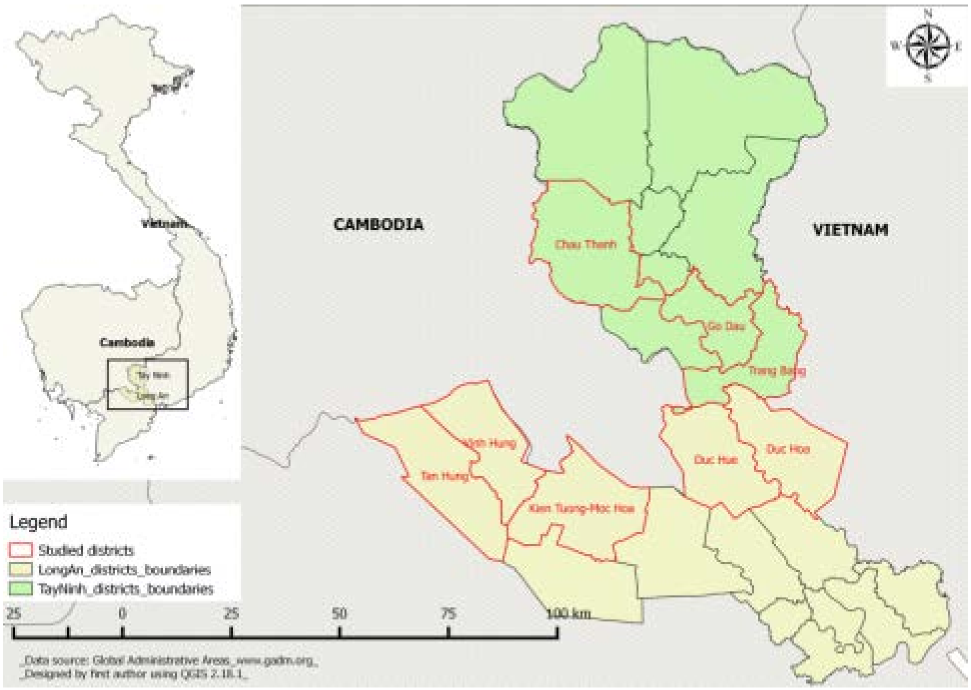
2. Materials and Methods

2.1. Study zone and population

This study was conducted in Long An and Tay Ninh provinces, in South Vietnam at the border with Cambodia, from June to October 2014. The geographical choice was based on three criteria: the importance of livestock production, proximity to the Cambodian border and the importance of animal movements between provinces and countries. These provinces were also selected in agreement with the DAH and the sub-DAH of the two provinces under study.

The first step of our survey was to meet farmers and to record their position on the FMD prevention and control strategy to prepare the Q participatory method. This was performed in five districts of Long An province (Vinh Hung, Tan Hung, Kien Tuong, Duc Hue and Duc Hoa) and was repeated in three districts of Tay Ninh province (Trang Bang, Go Dau, Chau Thanh). These districts of the two provinces are classified as high-risk zones (MARD, 2011). To record the opinions of different farmers, this study focused on three types of production; dairy cattle, beef cattle and small pig farms. The number of villages to be visited was calculated for another study done on the same location. The sample size calculations were based on an individual animal prevalence of 30% (Phan, 2014). First, one focus group interviews were performed in each selected village. Then, farmers of each production type who displayed willingness to participate in individual interview were asked for Q sorting game. Our required sample was 30 villages in each province, i.e. ten villages in each production type, and at least ten farmers in each village. Those villages were selected from at least three districts in each province to ensure the study's representativeness. The number of villages selected from each district was proportional to the districts' animal population. However, only 54 villages, 27 in each province, contributed to this study due to either incomplete data or low degree of farmers' participation. Each interview was done in the most convenient place for the interviewee (usually at their house) with the participation of two members of the research team. The average duration of interviews was about one hour. The research team included five people from the Faculty of Animal Science and Veterinary Medicine of Nong Lam University: one veterinary student, two Master's students, and two professors. The research team members had been trained in participatory methodology by certified trainers one month before the start of the field study. Ethical considerations were properly taken into account, as for each interview, each participant signed a written consent to be part of this study. The second step of the survey was to apply the Q method, and this was done in three districts of Tay Ninh province. The study areas are described in Figure 1.

Figure 1: Map of study areas in Long An and Tay Ninh provinces



Yellow: Long An districts; green: Tay Ninh districts; red lines: limited study areas in Long An (Tay Ninh) province

2.2. The Q methodology

Our survey was conducted in five steps: i) generation of opinion statements; ii) selection of the Q-set (set of opinion statements); iii) selection of participants; iv) Q - sorting (sorting of statements by participants) and participant interviews; v) statistical analysis of each Q-sorting (Webler et al., 2009).

2.2.1. Generation of opinion statements

Participatory epidemiology (PE) is an emerging field that is based on the use of participatory methods to collect qualitative epidemiological intelligence from community observations, existing veterinary knowledge and traditional oral history (Mariner, 2000). In our survey, PE tools were used to collect initial information from farmers, on their priorities, on FMD prevention and control methods, and on the advantages and limits of vaccination. PE tools used in this study involved semi-structured interviews using checklists and open questions with focus groups and individual interviews, pair-wise ranking and flow charts. Further details on the practical aspects of the method's implementation are described by Mariner et al. (2000). The number of participants in each of the 27 focus group interviews varied from 10 to 15 participants. Based on the information collected in the field, an initial list of farmers' opinions regarding their reasons for vaccinating their animals against FMD, on the perceived advantages and disadvantages of vaccination and other issues related to vaccination in general, was generated. Thanks to the use of PE tools, which allow respondents to express their opinions actively (Mariner, 2000), we assumed that relevant information related to farmer's postures and perceptions was collected.

2.2.2. Selection of the Q-set

Based on this list of farmers' opinions, 46 final statements were produced, representing the spectrum of opinions on vaccination within our population. Four different topics were addressed: i) farmers' confidence in vaccination as a preventive method (sense of safety given by the vaccination; control of vaccine production; confidence in suppliers; perception of disease management based on vaccination), ii) logistics/organisation of vaccination in the field (possible constraints due to vaccine practice, type of preferred vaccine, actors delivering the vaccination), iii) cost of vaccination (farmer's affordability to vaccinate their animal; cost comparison of vaccination with other measures such as treatment, emergency selling) and iv) impacts of vaccination (on animal productivity and on already infected animal). Detailed statements used in this study are described in the Supplementary table S1.

2.2.3. Participant selection and statement sorting

As mentioned by Brown (1980), a Q study requires only a limited number of respondents that is less or equal to the number of statements (Brown, 1980). Based on this concept, a structured sample of respondents, who were relevant to the investigation of FMD vaccination issues, was chosen. Respondents were selected to form a heterogeneous group based on gender (male, female), age (less than or equal to 30 year olds, between 30 and 40 years old, between 40 and 50 years old and more than 50 years old), experience with livestock (less than or equal to 10 years, between 10 and 20 years, more than 20 years), academic level (no school, unknown, primary school, middle school, secondary school and post-secondary school), production type (beef cattle, dairy cattle and small pig farm), and location at district level (Trang Bang, Go Dau and Chau Thanh) in order to capture the points of view of various types of stakeholders. They were contacted individually, several days after their participation in the focus group. We invited 60 individuals to participate in the study. Each respondent was then personally asked to do the Q-sorting game. Forty-six (46) cards, representing statements on vaccination were given to the participant while one member of the research team explained the game instructions. The sorting was divided into two phases. First, the farmer was invited to affirm or deny the proposal by freely placing the card on three piles: agree, neutral/ambivalent and disagree. Then, they continued to put the cards into a quasi-normal grid of 46 boxes. The score given to the statements was proportional to how strongly they agreed or disagreed with them, - 3 for strongly in disagreement and +3 for strongly in agreement. When the grid was completed, a discussion with open questions was held, using sentences such as "*you strongly agreed/disagreed with statement n°..., why?*".

2.2.4. Data analysis

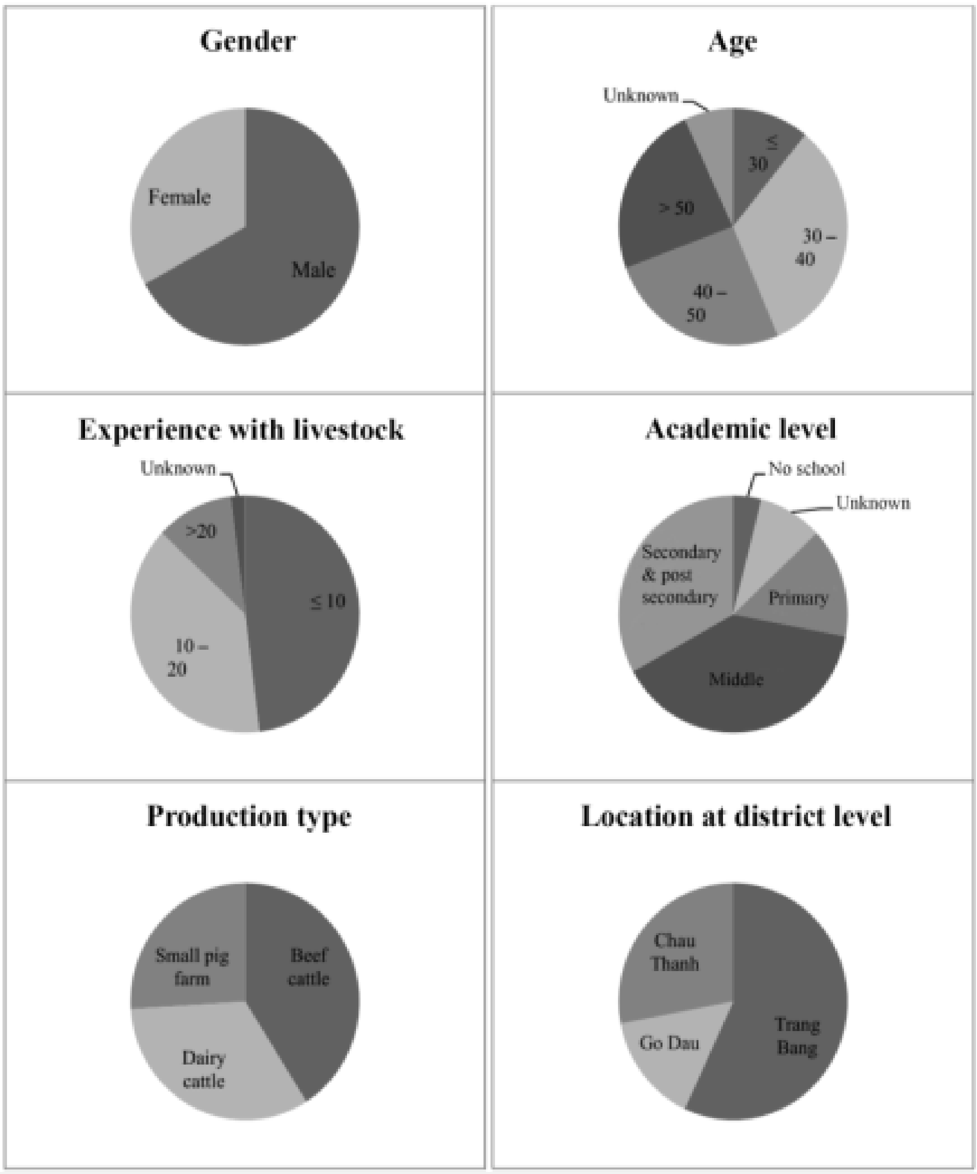
From the value attributed by the respondents (variables) to the statements (individuals), we created a 46x46 matrix. In this matrix where statements were set as row and respondents as column, cell values were the score given by each respondent (Zabala, 2014). This first inter-correlation matrix represented the relationship of each Q-sort to the other Q-sorts (by person), rather than the relationship between statements (Farrimond et al., 2010). This correlation matrix was reduced into factors (components) using Principal Component Analysis (PCA) tool in “FactoMineR” package (Lê et al., 2008). Note that the respondents were integrated as variables in the PCA analysis. The first few factors were selected and rotated to obtain a clearer and simpler structure of the data. The usual criteria by which the number of factors was selected include the total amount of variability explained, eigenvalues higher than one and a compromised solution between complexity and interpretability (Zabala, 2014). In our study, factor analysis was done using “qmethod” (Zabala, 2014) package for R. In this step, the three first factors (components) were selected based on criteria mentioned above and were rotated with varimax option (maximize of variable) to select the best combination of factors with a cumulative percentage of explained variation over a 40% level-off. Then, the most representative Q-sorts for each factor were flagged to select the final combination of factors (most distinguishable perspectives). The criteria for automatic flagging were that 5% of the total Q-sort should load distinctly and significantly on each factor with a level of significance set at 99% ($p< 0.01$), which meant that the correlation level was more than 0.38 ($2.58*(1/\sqrt{N})$ with $N = 46$ (Brown, 1980; Watts and Stenner, 2005). Some Q-sort may be considered as confounding because they loaded highly on more than one factor and thus were not flagged. The normalised z-scores that indicate the relationship between statements and factors was a weighted average of the scores given by the flagged Q-scores to that statement. The factor scores were calculated by rounding the z-scores towards the array of discrete values in the grid. The outcome was three perspectives which were represented by three selected factors at the beginning. These perspectives are a hypothetical Q-sort that has been reconstructed from the factor scores (Zabala, 2014). Some statements are considered distinguishing points when the difference between the z-scores of a statement in two factors, is statistically significant (based on the standard error of differences) (Watts and Stenner, 2005). When none of the differences between any pair of factors are significant, then the statement is considered a consensus. Automatic flags, statement z –scores and statement factor scores were analysed using the qmethod package with qflag, qzscores, respectively (Zabala, 2014). A Kruskal-Wallis test for non-parametric data was also performed to understand the influence of demographics and characterised variables on the respondent's contribution to each factor. Interpretation of the results was performed using the ABC model in sociological science (Hogg and Vaughan, 2011). According to this model, the attitude of using vaccination as preventive method can be described according to three main components: an affective component (farmer's feelings about or valuing of the vaccination), a behavioural component (how the farmers behave towards the vaccination or special tendency or action of farmers that adapt to their attitudes about vaccination) and a cognitive component (the beliefs about the attitude of using vaccination).

3. Results

3.1. Studied population

From the 60 farmers invited to the meetings held in the 27 villages of the three districts of Tay Ninh province, we were able to identify 46 respondents who fully took part of this study (performed Q sorting game) and included them in our final analysis, in order to match the 46 statements as mentioned by Brown (1980). Some of them refused to participate (declined the invitation, too busy, misunderstood the game's instruction) and others did not follow the game instructions correctly (refused to review their primary results, not providing an explanation for their sorting, and misunderstanding instructions or statements). The studied population is described in Figure 2.

Figure 2: Characterisation of the 46 farmers who participated in Q sorting according to variables such as gender, age, experience with livestock, academic level, production type and location at district level



3.2. Q-sorts analysis

From the PCA results, ten factors (components) that had an eigenvalue of more than 1.00 were retained. Nevertheless, a full interpretation of the three out of ten factors was carried out in this study, based on the criteria mentioned above (data analysis section) as well as their interpretable nature and the verbatim comments made by the participants. All these factors had an eigenvalue greater than 1.00 and were loaded with at least 5% of the participants. Each factor represented a group of participants who ranked the statements similarly as an indication of a commonly held perception of the issues. The first factor represented 46.2% of the total explained variance. The second and the third factors represented 5.8% and 5.3% of explained variance, respectively. In our analysis, 4 Q-sorts were considered as confounders because they loaded highly on more than one factor and thus they were not flagged or not being used in final results. Anyhow the three factors selected at the beginning of the analysis were obtained from PCA calculated with 46 respondents, and so the percentage of variance explained (57.3%) is as well calculated for 46 respondents. The remaining 42.7% of the total variance could not be explained by a single factor using the verbatim comments made by the participants, implying that some participants have individual perceptions that cannot be grouped into a single factor.

3.3. Factor array

Factor analysis was performed on the three selected factors mentioned above, named discourse A, B, and C respectively. The factor scores (normalised z-scores) indicate the pattern of statements that is common to the persons loading on the factor. The most positive values are the statements that the groups strongly agreed with and the most negative values are the statements that the group strongly disagreed with. The summary of statements, scoring for the three factors A, B, C is presented in Table 1 and Table S1.

Table 1 summarises the perspective of three different groups in grid form where each statement was classified according to their score for each factor. In fact, the result of forty six Q-sort of forty six individuals were generated into three Q-sort of three groups for interpretation. The grid also demonstrated the point of interests for each group through the computed score given by respondents (statements having the scores of ± 2 or ± 3). Some areas of consensus and disagreement were identified among all the factors, and some statements were identified as distinguishing elements. The list of 46 statements used in this study which was available in Table S1 helped to interpret Table 1. In the description of the different factors, the two numbers in brackets indicate the statement's number and its score. For example, (stat.19: +3) meaning that statement 19 obtained a positive score of 3.

Table 1: Summary of statement scoring for three discourses Confidence, Belief, and Challenge according to the factor analysis

Discourse Confidence							Discourse Belief							Discourse Challenge						
-3	*-2*	*-1*	*0*	*1*	*2*	*3*	*-3*	*-2*	*-1*	*0*	*1*	*2*	*3*	*-3*	*-2*	*-1*	*0*	*1*	*2*	*3*
20	7	8	4	***6***	**5**	**1**	8	17	**7**	**13**	4	2	**1**	4	8	**7**	2	15	**5**	**1**
32	***21***	17	11	9	12	2	18	***20***	11	**16**	***6***	10	3	18	11	**13**	9	***20***	***6***	3
41	23	18	**13**	10	**14**	3	23	***21***	22	***25***	9	**14**	**5**	41	17	19	12	22	10	23
42	27	***25***	15	22	**24**	19	32	33	27	**34**	12	15	19	42	***25***	27	**16**	28	**14**	**24**
	31	**34**	**16**	30	**29**			40	30	35	26	**24**			31	30	26	33	***21***	
	33	35	26	***37***	44			41	39	36	28	**29**			***38***	**34**	32	***37***	**29**	
		39	28	***38***					43	***37***	31					35	36	44		
		43	36	45					46	***38***	45					46	39	45		
			40							42							40			
			46							44							43			

Italic numbers: score number (with statistically different score values (p<0,05) in one factor compared to the two others); Bold and underlined numbers: consensus statements; Bold italic numbers: distinguishing statements.

3.4. Definition of three factors

Three main opinions (i.e. attitudes) belonging to three factors, hereafter, called discourses, as it usually is in the literature. Discourse A represents the type of farmers who frequently use vaccination because they think that vaccination is an effective tool in disease prevention. We decided to label this discourse “Confidence”. Discourse B includes farmers that also consider vaccination to be a very effective prevention measure but who have different opinion on vaccination practice (link to the trust given to the veterinarian) comparing with the group represented within discourse A. Thus, we decided to label this discourse “Belief”. Discourse C highlights a distinguished opinion on disease management. We decided to label this discourse “Challenge”.

3.5. Discourse A - Confidence

Twenty-four participants contributed to discourse A. According to the results of the Kruskall – Wallis test, no variable (gender, age, experience with livestock, academic level, production type and location at district level) shows a significant difference in this discourse (Table 2). This means that discourse A is the point of view of a heterogeneous group. Certain main perceptions dominate discourse A. First, the participants appreciate the vaccination because it helps to reduce the farmers’ stress. In fact, they feel that they would suffer from stress if their animals were not vaccinated (stat. 2: +3). In this discourse farmers consistently declare that they choose to use the FMD vaccine (stat. 19: +3; 20:-3). Their active involvement in the vaccination program is also demonstrated by the fact that the farmers’ decision to vaccinate is not usually influenced by traders (stat. 27:-2) and they have a good comprehension of vaccination process (sourcing the good quality vaccines, administering vaccine to their animals) (stat. 12:+2). Along the same lines, farmers consider that vaccination is an important method of prevention as compared to other husbandry practices (feeding, accommodation) (stat. 32:-3), although they also highlight the need for alternative methods such as disinfection or quarantine (stat. 31: -2). Finally, in this discourse farmers are aware of the impact of vaccination on animal productivity (stat. 44:+2).

Table 2: Summary of Kruskall-Wallis test for variable analysis

Variable	Discourse Confidence	Discourse Belief	Discourse Challenge
Gender	ns	ns	*
Age	ns	ns	ns
Experience with livestock	ns	*	ns
Academic level	ns	ns	*
Production type	ns	**	*
Location at district level	ns	ns	ns

p-value, ns: non-significant (p> 0,05); *: significant at 95% (p< 0,05);**: significant at 99% (p<0,01)

3.6. Discourse B - Belief

Discourse B clearly outlines certain perceptions that differ from discourse A and presents the points of view voiced by 12 participants. The discourse B group of participants is influenced by two variables: livestock experience in years and the production types (Table 2). Participants within this discourse are mainly cattle farmers (including dairy cow and beef) and have more than ten years of experience in livestock production. Similarly to discourse A, farmers in discourse B consider that adequate vaccination practices are needed to achieve a good level of protection (stat. 3:+3). They think that vaccines and services delivered by the governmental veterinary services are always very efficient in controlling diseases (stat. 10: +2; 14:+2) and that the quality of a vaccine is subject to its price (stat. 15:+2). Finally, these participants share the same approach: they systematically decide to vaccinate their animals against FMD, even if there is no outbreak close to their village (stat. 23: -3) because they are located in a high-risk zone. However, these farmers unlike the ones from the discourse A preferred to have their animal vaccinated with the help of a veterinarian than doing it by themselves (stat.40 -2).

3.7. Discourse C - Challenge

Discourse C represents the perception of 6 participants. They comprise of five females and one male, backyard farmers who keep in average 23 pigs (4 pig farmers) or 16 beef cattle in farm (2 cattle farmers) with 15 years of experiences with livestock in average (Table S2). Statistically, the discourse C is influenced by the three following variables: female gender, pig production and primary school academic level (Table 2). The first perception dominating discourse C is illustrated by their perception on the vaccine's effectiveness. They claim to vaccinate their animals to protect them from surrounding herds (stat. 6:+2), and at the same time they refuse to introduce a new animal if they do not know its vaccination status (stat. 4:-3). For them, vaccination is not 100% effective, so they need to combine the two control measures to minimise the probability of introducing the disease in the herd. In this discourse, participants consider that the vaccines proposed by the veterinarians are well-conserved (stat. 17: -2) and they have more confidence in these vaccines than in the ones they can buy elsewhere (stat. 11:-2). One of the most important perceptions distinguishing this discourse relates to the participants' opinions on disease management. According to their discourse, they do not always vaccinate their animals (stat. 21:+2). They only vaccinate when there is an outbreak close to their village (stat. 23:+3). Moreover, their decision is not influenced by their neighbours' behaviour (stat. 25:-2) or by the cost of vaccination (stat. 41:-3). Finally, they do not like to buy multi-dose vials as these are not suited to their production scale (stat. 38:-2).

3.8. Consensus and distinguishing points

Several consensual points were found across the three discourses. All of the farmers in the study zone felt more secure after taking part in the vaccination campaign (stat. 1 and 5); they make vaccination decisions themselves without being influenced by their neighbour's decisions or by traders (stat. 24); they believe in the veterinary information that they receive on disease risk (stat. 29); they also perceive that vaccination is cheaper than treatment (stat. 41) and vaccines provided by governmental authorities are of good quality (stat. 7 and 14). However, there were several points of disagreement between the discourses. Some farmers (discourse "Challenge") believe that they do not need to vaccinate their animals every year (stat.21) if the housing and feeding conditions are right (stat.32, 33) or if there is no outbreak in neighbouring villages (stat 23). Also, some participants of this discourse claim that they have never used vaccines in their herd (stat 20) because they have never experienced this disease before. The preferred type of vaccine to purchase (individually or multi-dose) differs between discourses (stat. 37, 38).

4. Discussion

4.1. The farmer's perception of FMD vaccination

4.1.1. Effectiveness of vaccination

Some advantages of vaccination are recognised by the farmers, such as the contribution to stress management, savings made thanks to the vaccination rather than the more costly treatment option and the compensation received in the case of infection within a vaccinated herd. These benefits are also clearly justified by some participants who had the experience of affected herds before using vaccination. The farmers' strong belief in governmental vaccination programmes was clearly demonstrated. This can be explained firstly by the vaccine quality control implemented by governmental authorities.

Secondly, by the fact that the epidemiological situation of FMD is supervised throughout surveillance (serologic status, outbreak investigation, post-vaccination monitoring, vaccine matching with the help of regional and worldwide FMD reference laboratories) (MARD, 2011, 2015) that provide regular recommendations on the strains of vaccine to be used for each province. Therefore, during 2011–2014, thanks to the help of the vaccination program, only two outbreaks were recorded in Tay Ninh province (MARD, 2015).

All of the farmers in the study zone perceive that the cost of vaccination is cheaper than that of treatment, for some reasons. Firstly, the vaccines used by farmers who participate in vaccination campaigns are provided by the government free of charge. Participants only pay for the cost of veterinary work, from 0.09 to 0.18 USD per injection in pigs and cattle (MARD, 2011). Otherwise, they can buy the vaccine themselves at the price of 0.76 USD for a monovalent dose and 1.08 USD for a bivalent vaccine (official vaccination price from Sub-DAH of Long An province). For example, for each head of cattle that is vaccinated twice yearly, the farmer must pay around 0.36 to 2.16 USD per head of cattle. Whereas, for the treatment of FMD, veterinary services (disinfection, consultation, medicines) are required over a duration of at least 3 to 5 days and can cost around 13.5 to 15.5 USD per head of cattle (personal communication).

4.1.2. Choice of vaccine type

The preferred type of vaccine doses (individually or multi-dose) depends on the discourse (stat. 37, 38). Some prefer individual doses for immediate use because of their small herds and difficulties regarding preservation. Others like to use multi-dose vials because they have big herds and vaccine preservation is not an issue for them. Then there is a share of the population that uses neither individual doses, due to traceability problems, nor multi-doses due to the cost of the vaccine; they opt for other prevention methods (hygiene, disinfection, good husbandry) instead. Only vials containing 25 doses are available; however, farmers can order individual doses from private veterinary practitioners if needed. Each dose is contained in a single syringe and must be used immediately after purchasing.

4.1.3. Decision-making and trends

The fact that the farmer's vaccination decision is not influenced by other stakeholders (stat. 24) illustrates one of the psychological traits of Vietnamese farmers. According to (Cao, 2015), their production is small-scale and scattered, they have a traditional lifestyle, tend to rely on experience and are reluctant to innovate. As they are influenced by small-scale production, they tend to rely on their accumulated experiences to guide their decisions on significant concerns. Our findings differ to those reported by Young et al. (2015) in Lao, where traders indicated that they prefer to buy vaccinated animals to protect their investment (Young et al., 2015) and might be influenced by other farmers' decisions. Our findings raise a question as to the sustainability of farmers' vaccination practices if they no longer receive governmental support. Dairy cow farmers will certainly continue to buy and use vaccines as the disease is a direct threat to their daily income from milk. However, for beef cattle and pig farmers, the maintenance of FMD vaccination is uncertain, as they can sell incubated or recovered animals, that are free of clinical signs, to traders since there is no stamp-out method for affected animals (MARD, 2015). This trend may be confirmed by the vaccination approach adopted by discourse Challenge farmers; the latter think that they do not need to vaccinate their animals every year (stat. 21) if the housing and feeding conditions are good or if there is no presence of outbreak in surrounding farms (stat. 23). Also, a minority share of participants indicated that they never use vaccines in their herd (stat. 20) because they had never been affected by FMD. Therefore, some farmers do not consider vaccination to be the first choice among prevention methods.

Farmers from discourse Confidence and Belief fully vaccinate their animals, either themselves (Confidence) or with the help of a veterinarian (Belief). This difference mainly lies in the trust given to the veterinarian depending on the different types of farmers. It seems that dairy farmers strongly believe that veterinarians can contaminate their herds through their visit, while beef cattle farmers place more trust in the veterinarians. Therefore, dairy farmers prefer to organise the vaccination by themselves, i.e. sourcing the good quality vaccine and administering it to animals, to ensure the vaccination's effectiveness (stat. 12 +2). In contrast, beef farmers prefer to have their animals vaccinated by the veterinarian (stat. 40 -2). When there are some difficulties linked to the delivery of the vaccine, dairy farmer are more motivated in finding out other sources of vaccine than beef cattle one. It is because the vaccination for the latter group (supply product and practice) is mainly done with the help of a veterinarian (direct observation and in-depth discussion).

Rational-choice and risk analysis theories can provide a valuable contribution to understanding the vaccination choices made by farmers. The rational-choice theory, derived from the fields of philosophy, anthropology, and economics, explains that an individual always acts intentionally, evaluating options and seeking to use resources rationally to achieve the highest possible cost/benefit ratio (Hedström and Stern, 2008). This means that before deciding on a certain action, individuals always weigh up the balance between cost and benefits, if the cost is equal to or less than the benefits they will engage in the action (as did discourse Confidence and Belief farmers), but if the cost of the action outweighs its benefits, they will not engage in the action (discourse Challenge).

Although the cost of vaccination is considered to be inexpensive, farmers who are classified as having medium or low incomes (Bui and Le, 2010; Le et al., 2014) feel that avoiding this expense will benefit them, especially for pig farmers who do not receive government compensation for vaccination. Moreover, low mortality of affected animals supports their decision to refuse vaccination.

The risk analysis theory can also be used to explain farmers' choices. According to this theory, farmers consider two elements when evaluating the risk of infection: the probability of being infected and the consequences of infection (Yoe, 2012). For cattle farmers, the likelihood of infection is high, since sero-prevalence in cattle in hotspot areas (including our study side) is nearly 30% (Phan, 2014). Moreover, the different consequences can be an interesting variable to explain the distinction between a dairy cow and beef cattle farmers´ motivation to vaccinate. For dairy cow farmers, their income depends on the volume of milk that they sell every day. To sell milk to milk collectors, they must produce a certificate of vaccination against infectious diseases, including FMD, to prove that their animals are well-protected. This forces them to vaccinate their animals every six months. An FMD outbreak will cause them to lose part of their income, although they will be able to continue selling their product. However, if certification is lacking or has expired upon the collector's control, they will immediately be banned from selling their milk. In this case, farmers will have to sell off their valuable dairy cows at the price of basic beef cattle to survive; they, therefore, decide to vaccinate their animals. Income from beef cattle is raised when the animals are sold after several months or years of fattening. An affected animal with FMD can be symptomatically cured with folk remedies that are made by themselves based on their experience, i.e. cashew nut (*Anacardium occidentale),* false daisy *(Eclipta prostrata)* or found in traditional medicine store (personal communication) and then can be sold at the usual price after treatment.

Therefore the disease has little impact on farmers. This explains why vaccination is implemented by a lower percentage of beef farmers than dairy cow farmers. For the remaining farmers (discourse Challenge), the probability of disease outbreak is lower, with moderate consequences thanks to the possibility of emergency sales of infected/dead animal with lower price than usual price; they, therefore, choose not to vaccinate and sell their animals if needed. Farmers might underestimate the consequences of FMD in their herds because they never experienced it before. In fact, it is reported that consequences for pig farmers are substantial because of the high mortality caused by FMD, especially in piglets (almost 100%) (Radostits and Done, 2007).   With better information we could get farmers from this group to vaccinate more, they could get benefit regarding increased revenue and decreased level of stress when an outbreak occurs in their zone. Actually, in this hypothetical situation, a vaccinated animal (assuming that animal is fully protected thanks to vaccine) could be sold with a normal price while non-vaccinated animal of neighbour farms could be sold only at half price or lower. Farmers with vaccinated animal could maintain their revenue and avoid stresses on finding out a way to sell their animal as quickly as possible, what others who own non-vaccinated animals have to face.

4.2. Discussion on PE and Q methodology

For the PE approach, participants of the focus group interviews were usually invited by the commune's local veterinarian or by the village chief, meaning that the objective of the study must be well understood by these the main actors. An undesired consequence, which may form a bias in our study, is the lack of representativeness of our sample. In fact, the majority of participants have a close relationship with these key persons (clients, family members, neighbours and members of a particular group) and this may have modified the opinions expressed on certain sites. The problem of over-representativeness can be observed in discourse Confidence. Organising more than one focus group per village would help to solve this issue, although this is not possible in a time-limited survey. Another potential bias related to our studied population is the selection of only two volunteers per village to undertake the Q–sorting; also, these two volunteers were not always the ones identified by the randomised selection. This constraint might be an obstacle to the discovery and understanding of certain perceptions of the farmers who had been randomly selected in advance but who declined to participate in the game.

Sociological methods such as Q methodology were widely applied in policy, public health, rural sociology but have been remained very limited in the field of veterinary sciences. Therefore, this method could be considered as an innovative approach in this field. During the implementation of our survey, the veterinary authorities questioned the feasibility and effectiveness of those tools. However, to assess the validity of our findings, data were triangulated and confirmed with information collected during each interview with the help of open-end questions. The collection of information from a heterogeneous group of farmers in 30 randomized villages, located in different sites, ensured the representative of our results. Q methodology facilitated the active participation of respondents as they were freely classified statements within a grid and to explain the reasons for their choices during open follow-up interviews. These advantages helped to maintain the study’s objectivity. The logic nature of a particular viewpoint could be easy checked (with open end question) after Q sorting process within the statement classification results clearly presented on the table. This method also forced people to rank their preferences with helps of predefined grid score (with negative and positive point). Thus, researcher could fully understand point of interest as well as source of their agreement and disagreement of the prioritized issues. During data analysis process, each Q statement was sorted relatively to all other statements, so this method conserved the universal nature of a viewpoint better than surveying methods. Regarding practicability and simplicity, the strong point of this methodology was that it only required simple materials and the participation of a small number of respondents (Danielson, 2009). However, this method could also be the source of biases. Firstly, this exercise lasted more than one hour for each participant, which was long and could make them feel uncomfortable. As a consequence, the responses to the open-end questions at the end of this exercise, explaining their choices, were very short. Secondly, due to field constraints, the statement sorting activity was organised after a focus group interview on the topic of prevention and control methods of critical diseases of their animals. As the participants were aware of the research objectives before doing the game, it gave the impression that they were encouraged to express a favourable opinion on vaccination, which did not always reflect their original opinion. A bias might also have been being introduced due to the type of interviewer, as the latter was related to vet services to avoid any possible conflicts in the future. Finally, some participants complained that certain statements were organised in a contradictory or complicated manner, making them difficult to understand. Indeed, some of the statements were too difficult for the farmers; this concerned virus circulation, virus strains, the concept of emergency vaccination, etc. These points should be reviewed for further research.

4.3. Recommendation

It is important to note that a part of the studied population does not consider vaccination to be the first choice of preventive methods. This finding raises the question of how to improve the active participation of farmers in the vaccination strategy against FMD to eradicate the disease from Vietnam (cf. farmers' challenges found in our study). Regular awareness raising is an important tool to encourage active participation and maintain the farmers' motivation to vaccinate (Alders et al., 2007). It would seem that highly experienced beef farmers and women who raise a small number of pigs are the main actors who could benefit from a change in behaviour and attitude. A few key messages that recommend to be conveyed are listed below: i) selling infected animals is forbidden by policy; ii) vaccination certification facilitates trade and compensation from the government if a vaccinated animal is declared infected; iii) district veterinary centres are safe places to buy vaccines; iv) compensation is available only once per year through the government support scheme and the effect of vaccination lasts only six months, so farmers need to buy vaccines themselves and vaccinate their animals twice a year; v) vaccinating only when there is an outbreak close to the village is often ineffective due to the fast transmission of the virus; vi) good husbandry and disinfection are not enough to protect animals from infection. A good way for the veterinary services to prove the advantages of vaccination versus other control methods, such as the treatment or sale of sick animals, would be to implement simple cost-benefit analyses at farm level and to communicate the results. Moreover, a clear message from the authorities on the risk of FMD in pigs would help people to make appropriate choices to achieve the eradication of the disease. Other recommendations for vaccine suppliers could be to develop smaller packages, such as only 5 or 10 doses per vial, to tailor their products to the needs of small-scale production.

5. Conclusions

These results highlighted the fact that farmers in our study zone are aware of the objective of vaccination, its role and its value in preventing disease. Prevention by vaccination was also understood to be cheaper than treatment costs and vaccines provided by governmental authorities were perceived as being of good quality. However, a minor part of the population expressed doubts regarding vaccination as a prevention method. These results illustrated critical elements that influence the acceptability of the FMD programme by farmers in Vietnam and allowed certain recommendations to be developed on how to improve farmer involvement in national FMD control and prevention programmes. Their participation is critical to maintaining high vaccine coverage of populations and to ensure the success of the national program. Further research is required to understand better farmers' perceptions and how they interact with other stakeholders involved in the vaccination campaign.

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Author contributions

BT, AB and FG designed the study, contributed to the analyses, and drafted the manuscript. BT, HN, MP designed the data collection instrument and drafted the manuscript. MP and SB reviewed the results and drafted the manuscript. The manuscript has been read and approved by all authors.

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Supplementary Information

Table S1: List of statements used in this study and the statement factor scores[1] and statement z-scores[2] (in parenthesis) according to each factor/ discourse after Q-sort analysis, including consensus statements

Statement	Factor/Discourse			Consensus statements
	1	2	3	
1.1. Stress management				
1. I feel more secure after my animals are vaccinated against FMD	3 (1.87)	3 (1.94)	3 (1.50)	X
2. I am stressed if I do not vaccinate my animals against FMD	3 (1.58)	2 (1.46)	0 (-0.03)	
3. When the FMD vaccination is well done, my animals are completely protected against the disease	3 (1.70)	3 (1.96)	3 (1.48)	
4. I can introduce a new animal without fear of FMD if my animals are vaccinated against the disease	0 (0.03)	1 (0.32)	-3 (-1.79)	
5. I vaccinate my animals to protect them from FMD	2 (1.47)	3 (1.65)	2 (1.23)	X
6. I vaccinate to protect other herds from FMD	1 (0.70)	1 (0.32)	2 (1.41)	
1.2. Product control/ supplier confidence				
7. I have already refused vaccination against FMD because I thought that the vaccine was bad	-2 (-0.93)	-1 (-0.78)	-1 (-0.61)	X
8. FMD vaccines produced in China are of good quality	-1 (-0.78)	-3 (-1.24)	-2 (-0.88)	
9. FMD vaccines that come from the vet shop are of good quality	1 (0.24)	1 (0.68)	0 (0.17)	
10. FMD vaccines used by veterinarians are of good quality	1 (0.90)	2 (1.59)	2 (1.23)	
11. I have more confidence in a vaccine that I bought myself than the vaccine provided by the veterinarian.	0 (-0.23)	-1 (-0.8)	-2 (-1.14)	
12. I understand whom to ask and how to organize the vaccination of my animals against FMD with good products	2 (0.93)	1 (0.81)	0 (0.04)	
13. It is easy to identify whether an FMD vaccine is produced locally, in China or another country	0 (-0.12)	0 (-0.19)	-1 (-0.49)	X
14. The effectiveness of the product depends on the identity of individuals (place of supply) who provide me with the FMD vaccine	2 (1.01)	2 (1.07)	2 (0.97)	X
15. I believe that the higher the quality of the vaccine, the more expensive it is.	0 (0.11)	2 (1.28)	1 (0.54)	
16. The FMD vaccine used by veterinarians is not specific to the virus circulating	0 (-0.09)	0 (-0.15)	0 (-0.3)	X

17. The FMD vaccines used by veterinarians are not well preserved	-1 (-0.36)	-2 (-1.1)	-2 (-1.16)	
18. The FMD vaccines used by veterinarians are counterfeit	-1 (-0.43)	-3 (-1.48)	-3 (-1.65)	
1.3. Perception/ disease management				
19. I always have my animals vaccinated against FMD	3 (1.77)	3 (1.63)	-1 (0.86)	
20. I never vaccinate my animals against FMD	-3 (-1.9)	-2 (-1.18)	1 (0.91)	
21. In certain past years, I did not vaccinate my animals against FMD	-2 (-1.31)	-2 (-0.88)	2 (1.44)	
22. I vaccinate part of my herd against FMD	1 (0.56)	-1 (-0.56)	1 (0.84)	
23. I vaccinate only when there is an FMD outbreak near my village	-2 (-1.43)	-3 (-1.27)	3 (1.79)	
24. I take the decision to vaccinate alone (individually)	2 (1.22)	2 (1.34)	3 (1.52)	X
25. I take the decision to vaccinate in consultation with my neighbors	-1 (-0.59)	0 (0.15)	-2 (-1.16)	
26. I take the decision to vaccinate in consultation with my family	0 (-0.34)	1 (0.89)	0 (-0.08)	
27. My decision to vaccinate is influenced by traders	-2 (-1.08)	-1 (-0.57)	-1 (-0.66)	
28. My decision to vaccinate is influenced by the veterinarian's messages	0 (0.11)	1 (0.47)	1 (0.34)	
29. I believe that the diseases for which veterinarians propose vaccines are diseases that my animals are at risk of being contaminated with	2 (1.26)	2 (1.18)	2 (1.31)	X
30. Veterinarians can contaminate my herd with FMD during vaccination	1 (0.77)	-1 (-0.75)	-1 (-0.53)	
31. If my animals are vaccinated against FMD, I would not need to protect my animals with other methods (disinfection, quarantine)	-2 (-1.23)	1 (0.45)	-2 (-0.94)	
32. If I keep my animals in good condition (good food, good housing), I do not need to vaccinate them against FMD	-3 (-1.47)	-3 (-1.35)	0 (-0.36)	
33. If I properly disinfect my buildings, I do not need to vaccinate my animals against FMD	-2 (-0.88)	-2 (-1.12)	1 (0.39)	
34. For a pregnant cow or a calf, we must inject half of the normal dose	-1 (-0.48)	0 (-0.5)	-1 (-0.78)	X
2. Logistics/ Organization of vaccination				
35. Vaccination of my animals against FMD causes more work (constraints)	-1 (-0.82)	0 (-0.07)	-1 (-0.61)	
36. The timing proposed by the veterinary services for vaccination against FMD do not suit my calendar	0 (-0.20)	0 (-0.43)	0 (0.12)	
37. I prefer to buy vaccines in single doses	1 (0.92)	0 (-0.02)	1 (0.46)	
38. I prefer to buy the vaccines in a multi-dose vial	1 (0.27)	0 (-0.12)	-2 (-0.94)	
39. Asking a veterinarian to give the injections costs me a lot more	-1 (-0.36)	-1 (-0.62)	0 (-0.08)	

40. I prefer to vaccinate my animals myself rather than to let the veterinarian do it	0 (-0.07)	-2 (-1.16)	0 (-0.42)	
3. Vaccination cost				
41. I think the cost of treatment is cheaper than vaccination	-3 (-1.49)	-2 (-1.09)	-3 (-1.43)	
42. I think the loss of money paid by the trader when buying a sick animal infected with FMD is lower than the cost of vaccination	-3 (-1.44)	0 (-0.41)	-3 (-1.84)	
43. I think the cost of vaccination against FMD in my budget is too high	-1 (-0.85)	-1 (-0.66)	0 (0.08)	
4. Vaccination impact				
44. Vaccination against FMD decreases animal productivity (weight, milk)	2 (1.07)	0 (-0.17)	1 (0.73)	
45. Vaccination of pregnant animals against FMD causes abortions	1 (0.26)	1 (0.21)	1 (0.84)	
46. Vaccination of animals that are already infected with FMD causes sudden death	0 (0.14)	-1 (-0.72)	-1 (-0.62)	

[1] Statement factor score (other name: rang value, round value): the scores rounded to match the array of discrete values in the distribution of predefined grid score (-3 to +3).
[2] Statement z-score: (other name: non-round value): the weighted average value of each statement for each factor.

Table S2: Summary of demographic and characterised variables of the respondents who contributed to three discourses A, B, and C

Variable	Discourse A	Discourse B	Discourse C
Gender			
+ Male	18	10	1
+ Female	6	2	5
Age			
+ Under 30	3	1	0
+ 30 – 40	10	3	1
+ 40 – 50	6	2	3
+ More than 50	5	3	2
+ Unknown	0	3	0
Experience with livestock			
+ Under 10 years	12	5	2
+ 10 – 20 years	12	2	3
+ More than 20 years	0	4	1
+ Unknown	0	1	0
Academic level			
+ No school	1	1	0
+ Primary school	2	0	4
+ Middle school	12	4	1
+ Secondary & post-secondary school	8	4	1
+ Unknown	1	3	0
Production type			
+ Beef cattle	7	7	2
+ Dairy cattle	11	3	0
+ Small pig farm	6	2	4
Location at district level			
+ Trang Bang	19	4	1
+ Go Dau	2	3	2
+ Chau Thanh	3	5	3

CHAPTER 6

BENEFIT-COST ANALYSIS OF FOOT-AND-MOUTH DISEASE VACCINATION AT LOCAL LEVEL IN SOUTH VIETNAM

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Benefit-cost analysis of Foot-and-mouth disease vaccination at local level in south Vietnam

***Dinh Bao Truong*[1, 2*], *Flavie Luce Goutard*[1, 3], *Stéphane Bertagnoli*[4], *Vladimir. Grobois*[1], *Alexis Delabouglise*[5], *Marisa Peyre*[1]**

[1] CIRAD, UMR ASTRE, F-34398 Montpellier, France

[2] Faculty of Animal Science and Veterinary Medicine, Nong Lam University, Ho Chi Minh, Vietnam

[3] Faculty Veterinary Medicine, Kasetsart University, 10900 Bangkok, Thailand

[4] IHAP, Université de Toulouse, INRA, ENVT, Toulouse, France

[5] Center for Infectious Disease Dynamics, Department of Biology, The Pennsylvania State University, University Park, Pennsylvania 16802, USA

***** dinhbao.truong@hcmuaf.edu.vn/ dinh-bao.truong @cirad.fr

Abstract

This study aimed to analyse the financial impact of foot-and-mouth disease (FMD) outbreaks at household level and to perform a benefit-cost analysis of FMD vaccination in South Vietnam. Production data was collected from 53 small-scale dairy farms, 15 large-scale dairy farms and 116 beef farms of Long An and Tay Ninh province using questionaire survey. Financial data of FMD impacts was collected using participatory tools in 37 villages of Long An provinces. The net present value of FMD vaccination for large-scale dairy farms was 3 times higher than for small-scale dairy farms and 30 times higher than for beef farms. The benefit-cost ratio (BCR) of FMD vaccination over one year, for large-scale dairy farms, small-scale dairy farms and beef farms were 5.85, 5.04 and 1.83, respectively. The sensitivity analysis showed that the vaccination cost mostly affected the BCR of beef farms and market price mostly affected the BCR of dairy farms. This benefit-cost analysis of biannual vaccination strategy showed that investment in FMD prevention can be financially profitable for farmers and, therefore, sustainable. Additional benefit-cost analysis study of vaccination strategy at national level would be required to evaluate and adapt the national strategy if needed to achieve eradication of FMD in Vietnam.

Keywords: Animal health economics, benefit-cost analysis, evaluation, financial analysis, foot-and-mouth disease (FMD), vaccination.

1. Introduction

Foot-and-mouth disease (FMD) is recognised to heavily impact livestock production (OIE and FAO, 2012). The direct impact of this disease can be classified into two types based on their degree of damage visibility (OIE and FAO, 2012). The damages which are apparent include draft power loss (Young et al., F2013), milk production loss (Barasa et al., 2008; OIE and FAO, 2012), abortion (Senturk and Yalcin, 2005), death and decrease in livestock product value (Young et al., 2013). The invisible losses include reduction in fertility, delay in sale of animals and livestock products, change in farm structure (resulting from deaths, decreased parturition rate delayed sales) and reduction of market access (OIE and FAO, 2012). In addition, FMD cause additional expenditures in disease control such as vaccination, post vaccination monitoring, movement control, diagnostic, and surveillance (OIE and FAO, 2012). The impact of FMD is especially meaningful to small producers as it threatens their livelihood and food security (Madin, 2011). In Laos, annual losses due to FMD infection were reported to reach between 16% to 60% of the annual household income (Nampanya et al., 2015). In Vietnam, Forman et al. (2009) recorded net losses due to FMD ranging between 10% and 32% of the total annual household income. The financial impact of FMD in Cambodia reduces the household income by more than 11% every year (Young et al., 2013). Vaccination has been recognised as a helpful tool to control FMD and is an essential part of the progressive FMD control pathway from the World Health Organisation (OIE Sub-Regional Representation for South East Asia, 2011; OIE and FAO, 2012). In Vietnam, this tool has been applied since 2006 to improve FMD control at national level with the objective to reach eradication by 2020. Currently, the two major FMD serotypes O and A are circulating in Vietnam (MARD, 2015). Vaccines currently in use are either monovalent (targeting serotype O) or bivalent (targeting serotype O and A). Vaccination is usually implemented twice a year on March-April and September-October. The program targets the hotspot areas where the risk of outbreak emergence is considered as high (MARD, 2011, 2015). However, this strategy is facing many logistical and economic constraints, i.e. lack of stick implementation and sustainability at the household level and lack of attention to the disease after several year without outbreak, and its effectiveness, in terms of vaccine coverage and disease control, has not been demonstrated (MARD, 2011, 2015).

In Vietnam, an important budget of FMD prevention and control strategy is dedicated to vaccination, including delivery cost and subsidies for vaccine purchase (ranging from 50% to 100% of the vaccine price for farms in high-risk areas). However, outbreaks are still continuously recorded (MARD, 2015). Benefit-cost analysis (BCA) is a commonly used analytical framework that supports decision making process in animal disease control (Rushton, 2009). When the farmers need to remedy to a particular livestock constraint they will compare the cost incurred and the benefit derived from the different available control methods in terms of financial return (Rushton, 2009), livelihood or overall wellbeing (Yoe, 2012). The outputs of a BCA would not only foster the vaccination policy review and modification at national level but also provide evidence which can encourage farmers' participation in the campaign. In Ethiopia, it was reported that the national targeted vaccination program was the most economically beneficial strategy, with a median benefit-cost ratio (BCR) of 4.29 (Jemberu, 2016). In Cambodia, Young et al. (2014) estimated that the implementation of a biannual FMD vaccination campaign in large ruminants during five years had a BCR of 1.4 (95% confidence interval 0.96-2.20). In South Sudan, FMD vaccination BCR was estimated at 11.5 (Barasa et al., 2008). Despite its relevance, the use of BCA for FMD vaccination at household level never applied in Vietnam. The aim of this study was to analyse the FMD financial impact at household level in Vietnam and the BCR of the vaccination program to address this knowledge gap and better inform policy decision.

2. Material and methods

2.1. Study area

The study was performed in 5 districts of Long An (i.e. Tan Hung, Vinh Hung, Kien Tuong, Duc Hoa, Duc Hue) and 3 districts of Tay Ninh province (i.e. Trang Bang, Chau Thanh, Go Dau). These districts were selected, in agreement with the sub-Department of Animal Health of province under study, based on the importance of livestock production, the proximity to the Cambodian border, the importance of animal movements between provinces and countries, and the high-risk zones for FMD control.

2.2. Data collection process

A questionnaire-based survey was performed to collect general information on farm production and farm management practices such as the average number of cattle per farm (Njk), the average number of young calves (adult cattle) per farm ($N.calf.jk$ and $N.a.jk$), the unite price of one dose of a bivalent vaccine ($p.vac$), the live weight price per kg ($p.liveW$), the average price of an insemination service ($P.ser$), the milk price per litter ($P.Milk$). This survey was performed from June to October 2014 at the 8 districts of the study area, with the help of a trained group of 15 veterinary students from Nong Lam University, Ho Chi Minh city. The total number of interviewed farms par district was based on the cattle population density in each district. A stratified sampling of farms was performed based on the type of cattle production (dairy or beef) with a limit of 10 questionnaires per production type per village.

Data about the financial impact of FMD was collected using participatory epidemiology from farms with previous FMD suspicion declaration. Focus group interview of 10-15 farmers per village were implemented to collect general information about cattle diseases and farms with suspected case of FMD were subject to individual semi-structured interviews to collect data on FMD financial impact. The research team conducted this survey from November 2015 to April 2016, involving 129 farms from Duc Hoa and Duc Hue district of Long An province. Both districts were classified as high risk zone according to national plan to control FMD (MARD, 2015). Duc Hue district locates near border of Cambodia. Duc Hoa district was identified as presence of FMD cases in the past and presence of a high number of slaughter houses (Sub DAH of Long An province, 2014). General data on disease management, control methods, disease impact and all related costs were first collected. This included general questions on the number of cattle at risk, number of disease cases, number of deaths due to the disease, number of premature slaughters, number of cattle destroyed, number of cattle vaccinated, vaccine type used and actual vaccination practices applied in farm. The second part of the survey contained questions on the financial costs associated with FMD infections. Farmers were asked to describe the cost associated with each control measures applied in their farm such as treatment with modern and/or local medicine, disinfection, emergency sell or slaughter of infected (dead) animal, emergency vaccination of unvaccinated cattle in case of outbreak as well as the financial cost of disease-related increase in abortion and decrease in milk production. The value of infected (dead) animal was based on the price paid to farmers by traders. The value of new-born calves was estimated by farmers based on feed intake and the sale price of a healthy calves sold at 3 months of age.

2.3. Calculation of incidence rates and incidence risks of FMD in cattle farms in the study area

It was assumed that cattle infected once by FMD do not get infected latter in their productive life. A FMD sero-prevalence of 60% was measured in another study (unpublished data of this PhD thesis). It was assumed that antibodies against FMD are detected in cattle during 3 years post-infection (Alexandersen et al., 2003).

The incidence rate of FMD was calculated using the following formula:

$\lambda = -\frac{\log(1-p_x)}{x}$ *(Equation (Eq.) 1)*

With: λ being the incidence rate of FMD, p_x the measured sero-prevalence in the cattle population, x the duration of FMD immunity in cattle (the period during which FMD antibody are detected after infection).

The proportion of slaughtered cattle that have been infected during their whole lifetime is:

$p_T = 1 - e^{-\lambda T}$ *(Eq. 2)*

With: T being the average duration of a cattle productive life (or age at slaughter) (6 years in dairy cattle, 12 years in beef cattle).

The proportion of a given cattle farm being infected by FMD over one year is:

$p_y = \frac{1-e^{-\lambda T}}{T}$ *(Eq. 3)*

The proportion of calves being infected by FMD over one year is:

$p_{yc} = \frac{1-e^{-\lambda T_c}}{T_c}$ *(Eq. 4)*

With T_c The age cattle become adults (the age of first calving for females).

The proportion of adult cattle being infected by FMD over one year is:

$p_{ya} = \frac{e^{-\lambda T_c}-e^{-\lambda T}}{T-T_c}$ *(Eq. 5)*

2.4. Partial budget analysis at farm level

The analysis was based on the methodological frameworks proposed by Dijkhuizen et al. (1995) and Rushton et al. (1999), modified and adapted to the study context. The components used in the partial budget analysis are described below. The analysis includes additional revenue, foregone revenue, additional costs and saved costs, compares "status quo" scenario with no FMD vaccination to an alternative scenario where FMD vaccination is applied twice a year. The formula for calculation of additional costs, saved costs, additional revenue and foregone revenue as well as their sub-components and used variables are detailed in Table 1.

Additional costs represent costs incurred in the alternative scenario that are not present in the "status quo" scenario. It includes vaccine price (vac) and labour cost of vaccination practice ($labour$) that farmer needs to pay. Extra feed and labour cost of farming more cattle in farm because of the reduced mortality and drop in abortion was not included in our analysis as all animals were assumed to be replaced in "status quo" scenario.

Saved (Avoided) costs represent costs incurred in the "status quo" scenario that are avoided in the alternative scenario. It includes cost of disease treatment ($Treat.cost.k$) with modern and local medicine per cattle, cost of replacing adult cattle ($rep.a.d$) and calves ($rep.c.d$) in case of death over the considered period, cost of emergency vaccination ($e.vac.c$) and cost of additional insemination services ($Ser.loss$). Cost of movement restriction was excluded because feed intake during delay time could not be collected. Cost of disinfection was also excluded because the relative data could not be quantified.

Additional revenue represents the revenue generated in the alternative scenario which is not present in the "status quo" scenario. It includes revenue gain from additional milk production from healthy cattle ($M.prod$); from selling healthy cattle at higher price due to higher weight compared to lower weight of infected (weight lost during sick period) ($W.h.a$), additional cattle raised and sold when there is less mortality ($W.extra$) and less abortion ($Abor.red$) due to FMD infection. We did not include the additional revenue from additional milk production resulting from the reduction of cows' mortality. Indeed, we did not have the necessary data on the additional quantity of feed consumed to sustain this increased milk production.

Subsidies of government, which generally covered between 50 to 100% of vaccination costs, were not taken into account in the calculation since the analysis was done at household level, without considering any contribution from the government, which returned a more conservative result.

Foregone revenue represents the revenue generated in the "status quo" scenario which is not present in the alternative scenario. It includes revenue lost due to adverse impacts of vaccination on productivity such as decreased milk production, decreased daily weight gain and impact on reproduction such as abortion due to stress caused by bad practice. It also includes the revenue from selling dead or sick cattle and calves ($inc.a.d + inc.c.d$) at lower price. As data were missing foregone revenue due to adverse vaccination effects vaccination was considered to be null. It was also assumed the vaccination was perfectly implemented, and did not cause any adverse effect due to stress.

Table 1. Formula and variables used in the partial budget analysis of foot-and-mouth disease (FMD) vaccination in South Vietnam

Formula and variables
$\boldsymbol{Additional\ costs} = labour + vac = (labour.ani + p.vac) \times N.j.k \times n.p$
$labour$: Labour cost of vaccination, vac: Expenditure in vaccine purchase; $labour.ani$: Labour cost per injection per cattle; $p.vac$: Unit price of 1 dose of a bivalent vaccine; $N.j.k$: Number of cattle per farm depending on scale j and farm type k; $n.p$: Number of injections per year
$\boldsymbol{Saved\ costs} = Treat.cost.k + rep.a.d + rep.c.d + e.vac.c + Ser.loss$ $+Treat.cost.k = p_y \times (Treat.mod.k + Treat.loc.k) \times N.j.k \times Morb.k$ $+rep.a.d = p_{ya} \times (p.cow.h - p.cow.d) \times N.a.jk \times Mort.k$ $+rep.c.d = p_{yc} \times (p.calf.h - p.calf.d) \times N.ca.jk \times Mort.k$ $+e.vac.c = p_{ya} \times (labour.ani + p.vac) \times (N.jk - N.ca.jk) \times 2 \times Morb.k$ $+Ser.loss = p_{ya} \times N.a.jk \times per.cow.ges \times Abor.FMD \times no.ser.ges.i \times$ $P.Ser \times Morb.k$
2: vaccine injections are performed at 28 days interval $e.vac.c$: Cost of emergency vaccination over the considered period; $Morb.k$: Morbidity rate in case of FMD outbreak. $N.a.jk$: Number of adult cattle per batch. $N.ca.jk$: Number of calf per batch. $N.j.k$: the number of animal per batch (all cattle in the same production cycle); $(N.jk - N.ca.jk)$: Number of adult animal in scale j and farm type k. In emergency vaccination; $no.ser.ges.i$: the average number of artificial or natural insemination service performed by veterinarians for each cow to become pregnant; $p.cow.h$: Average value of a healthy adult cattle; $p.cow.d$: Average value of a dead or treated cattle p_{yc}: Proportion of calves being infected by FMD over one year (calculated using Eq.4), $p.calf.h$: Average value of a healthy calf, $p.calf.d$: Average value of a dead/treated calf; p_y: Proportion of a given cattle farm being infected by FMD over one year (calculated using Eq.3), p_{ya}: Proportion of adult cattle being infected by FMD over one year (calculated using Eq. 5); $P.Ser$: Average price of an insemination service. $rep.a.d(rep.c.d)$ the cost of replacing adult cattle (calf) in case of death over the considered period; $Ser.loss$ the cost of additional insemination services used due to FMD over the considered period; $Treat.cost.k$: Cost of FMD treatment with modern and indigenous medicine over the considered period; $Treat.mod.k$ ($Treat.loc.k$): Average cost of treatment with modern (indigenous) medicine per affected cattle during the outbreak period,
$\boldsymbol{Additional\ revenue} = M.prod + W.h.a + W.extra + Abor.red$ $+M.prod = p_{ya} \times t.ill \times M \times P.milk \times N.a.jk \times per.cow.lac \times Morb.k$ $+W.h.a = p_y \times t.ill \times dwg \times p.liveW \times N.jk \times Morb.k$ $+W.loss = p_T \times cull.rate \times per.W.loss \times W.cow.h \times p.liveW \times N.jk \times$ $(Morb.k - Mort.k)$ $+Abor.loss = p_{ya} \times N.a.jk \times per.cow.ges \times no.calves.prod \times Abor.FMD \times$

$p.n.calf \times Morb.k$
$Abor.FMD$ the increase in abortion rate due to FMD infection, $Abor.red$: $additional\ cattle\ raised\ value\ due\ to\ less\ abortion$ $cull.rate$ being the proportion of the cattle farm being culled each year (it is the inverse of the age at maturity - $cull.rate = \frac{1}{T}$); dwg: Average daily weight gain; M: Average quantity of milk produced per lactating cow per day; $M.prod$: Additional milk production value; $no.calves.prod = \frac{duration\ of\ a\ year\ in\ day}{overal\ mean\ of\ calving\ interval\ in\ day\ (ci)}$ *:* Number of calves produced per cow in one year; $N.a.jk$: Number of adult cows in farm; $P.milk$: Price of one litter of milk; $per.cow.lac$: Percentage of lactating cows in the farm (including cow with pregnant and lactating at the same time); $p.liveW$: Price of a live weight in kg; p_T: Proportion of slaughtered cattle having been infected during their whole lifetime (calculated in Eq.1); $per.W.loss$*:* Average percentage of weight loss of cattle due to FMD*;* $p.liveW$*:* Live weight price (per kg); $per.cow.ges$*:* Percentage of adult cattle which are gestating cow in the farm; $p.n.calf$*:* Price of a new-born calf estimated by farmer; $t.ill$: Duration of illness due to FMD; $W.h.a$: Additional weight gain value; $W.extra$:Additional cattle raised value due to lower mortality; $W.cow.h$: Average weight of a healthy cow at sale time in kg.
$\boldsymbol{Foregone\ revenue} = inc.a.d + inc.c.d$ $+inc.a.d = p_{ya} \times p.cow.d \times N.a.jk \times Mort.k$ $+inc.c.d = p_{yc} \times p.calf.d \times N.ca.jk \times Mort.k$
$inc.a.d$: Income of selling dead/sick adult cattle; $inc.c.d$: Income of selling dead/sick calves.

2.5. Benefit-cost analysis

Partial budget analysis was used to estimate the benefits (additional revenue and saved costs) and costs (additional costs and revenue foregone) of one given farm against FMD over a one year period. The total benefit of the vaccination program is the sum of the additional revenue and saved costs while the total cost is the sum of the foregone revenue and additional costs.

The net present value of the proposed change in disease control strategy observed in alternative scenario compared to "status quo" scenario was calculated on an individual farm for the period of one year as follow:

$$\boldsymbol{Net\ present\ value} = (saved\ cost + additional\ revenue) - (additional\ cost + foregone\ revenue \qquad \textit{(Eq.6)}$$

The BCR between alternative scenario and "status quo" scenario was also computed on an individual farm using following formula:

$$\boldsymbol{Benefit - cost\ ratio} = (saved\ cost + additional\ revenue)/(additional\ cost + foregone\ revenue) \qquad \textit{(Eq.7)}$$

2.6. Sensitivity analysis

The sensitivity analysis for benefit-cost of FMD vaccination was performed by changing vaccination cost and market prices of sold cattle and milk. This analysis was performed to understand the variation in benefit-cost and the influence of the variance of these parameters on the BCR associated with FMD vaccination. Eight scenarios (C1-C8) were tested by changing vaccination cost and/or market value of milk and slaughtered cattle (Table 2). In C1 and C2, vaccination cost was increased by 25% and 50%, respectively. In C3 and C4, the market price of cattle and milk were decreased by 10% and 20%, respectively. From C5 to C8, changes in both parameters were performed. The increase in vaccination cost of 25% and 50% was based on hypothesis that farmer would rather use trivalent vaccine in the future if the presence of the third serotype would be confirmed (vaccination cost increase of 25%) or farmer would practice vaccination more than 2 times per year (vaccination cost increase of 50%). The decrease in market value of 10 and 20% was based on market tendency of milk and meat product. The milk price tends to be decreased because of excess supply source and meat price also decreased because of the competition of imported meat from India, Australia.

Table 2. Proposed scenarios for sensitivity analysis of benefit-cost ratio

Scenario	Vaccination Cost	Milk and cattle market value
C1	Increased by 25%	NA
C2	Increased by 50%	NA
C3	NA	Decreased by 10%
C4	NA	Decreased by 20%
C5	Increased by 25%	Decreased by 10%
C6	Increased by 25%	Decreased by 20%
C7	Increased by 50%	Decreased by 10%
C8	Increased by 50%	Decreased by 20%

NA: not applicable

2.7. Assumptions used in the cost-benefit analysis

Some parameters used in the BCA were taken from the literature (Table 3) because those parameters could not be collected from the field studies. It was assumed that all dairy and beef farms used Holstein-Friesian crossbreeds and Red Sindhi crossbreeds, respectively, based on Vo (2011) and Hoang (2011). The duration of the productive life of dairy and beef cattle were considered to be 6 and 12 years, respectively. Subsequently, the BCA was calculated on one year but took into consideration the duration of the productive life of dairy and beef cattle in the calculation of FMD incidence risks to be able to compare the result for the 2 types of production. Milk price was based on its quality and was considered as being the same for every lactating cows. Vaccination was considered to be applied in conformation with the best practices and to be match with OIE standard for FMD vaccination. Vaccine should contain at least 3 PD50 (50% of protective Dose) which corresponded to 78% protection using protection against generalization test (Parida, 2009). The effectiveness of vaccination was then considered to be 100% and therefore vaccinated animals were considered to be fully protected. Vaccination was considered not causing stress in cattle and, therefore, not impacting abortion rate. Only acute FMD was taken into consideration in this analysis while chronic FMD was excluded.

Table 3. Input data and references used to estimate foot-and-mouth disease (FMD) vaccination benefits and costs for farmers

Input data (unit)	Production type		Description and/or data sources	Abbreviation
	Dairy cattle farms	Meat cattle farms		
Abortion rate due to FMD (%)	10	10	Senturk (2005)	Abor.FMD
Average number of milk produced per cow per day (litter)	16	NA	Assumption all of race used was 100% HF crossbreed, based on Vo et al. (2010)	M
Average weight of a healthy animal (kg)	255-470	167-276	Based on (Dinh, 2007) for beef, weight from 12-24 months; (Dinh, 2009) for dairy: weight from 10 months age to adult	W.cow.h
Average weight loss when infected (%)	23	23	Young (2013)	per.W.loss
Duration of illness (days)	11.1 (3-25) [a]	11.1 (3-25)[a]	Young (2013)	t.ill
Estimated mean daily weigh gain (kg/day)	0.5	0.36	Dinh (2009) for dairy, Dinh (2007) for beef	Dwg
Median calving interval (days)	441	390	Dinh (2009) for dairy, Dinh (2007) for beef	Ci
Age of first calving (years)	2.19	2.13	Dinh (2009) for dairy, Dinh (2007) for beef	T_c
Number of average service for a cow being gestation (time)	1.68-2.07	1.5	Dinh (2009) for dairy, author estimation for beef	no.ser.ges.i
Percentage of lactation cow in farm (%)	50	NA	Vo et al. (2010)	per.cow.lac
Percentage of pregnant cow in farm (%)	58	56,31	Calculation based on data of Vo et al. (2010) for dairy, Dinh (2007) for beef	per.cow.ges

NA: not applicable, [a] triangular data: average (min-max)

2.8. Data analysis

All analysis were performed using R software version 3.3.1. A framework of calculation that included functions and formula described above and in Table 1 was developed in R environment for three production types. Data were calculated using "reshape2", "DT" packages and reported using "knitr" package.

2.9. Ethical considerations

Ethical considerations were properly taken into account, as for each individual interview, each participant signed a written consent to be part of this study.

3. Results

3.1. Description of livestock production in the study area

Production data were collected by questionnaire from 53 small-scale dairy farms, 15 large-scale dairy farms and 116 beef farms located in 37 villages (Table 4). The distinction between small-scale farm and large-scale farm was based on the number of cattle kept in each type of farm at the time of the survey which was less than 20 cattle in small-scale farm and more than 20 in large-scale farm. Small-scale dairy farms had in average 3 times less cattle than large-scale dairy farms (10 heads and 30 heads per farm, respectively). Beef farms kept an average of 5 heads per farm. The average number of adult cattle per farm was highest in large-scale dairy farms (26.4 heads per farm), followed by small-scale dairy farms (8.9 heads per farm) and it was lowest in beef farms (3.5 heads per farm). For the young calves (less than 6 months old), it was highest in large-scale dairy farms (3.92 calves per farm), lower in small-scale dairy farms (2.54 calves per farm) and lowest in beef farms (1.89 calves per farm). Dairy farms were mainly practiced in Duc Hoa district of Long An province and Trang Bang district of Tay Ninh province that animal was generally confined in barn. Beef farms were observed in six other districts with two types of animal housing (i.e. on pasture and mingle on pasture). The average cattle morbidity rate at farm level was around 60% in studied districts (Table 5). The average FMD mortality in adult cattle observed in our study (12%) was lower than in calves (18%). Participants of dairy cattle farms ranked the six most important diseases as FMD, haemorrhagic septicaemia, mastitis, inflammation of hooves, blood parasites and digestive diseases in that order. For beef cattle farms, the four most important diseases are haemorrhagic septicaemia, FMD, ruminant tympani and diarrhea with or without blood. In case of being infected by FMD, 43.8% of the cattle in three production types received treatment with only modern medicine rather than local medicine (11.5%) or with both modern and local medicine (20.9%). Local medicine was especially used in beef production type (observed in 93% of cases).

Table 4. Description of the animal production parameters from the study area

Variables	Dairy cattle farm	Beef cattle farm	Abbreviation
	mean (min-max)	mean (min-max)	
Number of adult cattle per farm, small-scale	8.9 (1-19)	3.5 (1-14)	N.a.jk
Number of adult cattle per farm, large-scale	26.4 (13-41)	NA	
Number of calf per farm, small-scale	2.54 (1-8)	1.89 (1-10)	N.calf. jk
Number of calf per farm, large-scale	3.92 (1-9)	NA	
Number of animal per farm, small-scale (<20 heads)	10.5 (2-20)	4.6 (1-16)	N.j.k
Number of animal per farm, large-scale (>20 heads)	30.1 (20-50)	NA	

NA: not applicable

Table 5. Description of the estimated parameters from the collected data and used for the benefit-cost analysis of foot-and-mouth disease (FMD)

Parameters	Dairy cattle farms	Beef cattle farms	Abbreviation
Incidence rate of FMD	0.31	0.31	λ
Instantaneous sero-prevalence	0.6	0.6	p_x
Duration of FMD immunity in cattle	3	3	x
Average duration of a cattle productive life (or age at slaughter)	6	12	T
Proportion of slaughtered cattle having been infected during their whole lifetime	0.84	0.97	p_T
Proportion of a given cattle farm being infected by FMD over one year	0.14	0.08	p_y
Proportion of calves being infected by FMD over one year	0.22	0.22	p_{yc}
Proportion of adult cattle being infected by FMD over one year	0.09	0.05	p_{ya}

3.2. Description of the financial impact of FMD outbreak at household level

The FMD financial impact survey included 129 farmers from 14 villages (Table 6). The average cost of treating affected cattle with local medicine [166k Vietnam Dong (VND) per case] was lower than with modern medicine (330 kVND per case). The mean value of healthy calves (12,000 kVND per head) was approximately 4 times more than value of a dead or treated calve (3,600 kVND per head). The mean value of healthy adult cattle (34,300 kVND per head) was 1.7 times higher than value of a dead or treated adult cattle (19,800 kVND per head). The loss of daily milk production due to FMD varied from 15 to 41% (28% on average). Based on prior estimation of FMD prevalence at cattle level of nearly 30% in the study zone (Phan, 2014), it was estimated that the incidence risk over a full lifetime (p_T) of a dairy cattle (84%) was lower than for a beef cattle (97%). Labour cost of each vaccine injection was fixed as 4 kVND (MARD, 2015). The morbidity was considered to be higher for dairy farms (79%) than for beef farms (54%), based on confirmed cases at animal level.

The reported mortality in adult cattle in farm affected by FMD outbreak, based on farmers' declarations during interviews was highest in large-scale dairy farms (18%) and lowest in small-scale dairy farms (2%). The average number of possible calf produced per cow in one year was estimated to be 0.83 calf for dairy farms, which was lower than beef farms (0.94 calf). The percentage of adult cows per dairy farm was 86%, which was higher than in beef farm (78%). However, the percentage of calves per dairy farm (14%) was lower than the one recorded in beef farm (22%). The price of one dose of bivalent vaccine (37 kVND) was approximately 1.5 times higher than one dose of monovalent vaccine according to the district veterinary services and farmer's reports. The mean market value of one kilogram cattle live weight at slaughter was estimated at 140 kVND per kg (in December 2015). The price of one insemination dose (artificial or natural) was estimated to be 173 kVND per service. The price of one litter of milk sold to collectors was 13 kVND per litter.

Table 6. Description of the parameters used for the benefit-cost calculation of foot-and-mouth disease collected from the field study

Input data	n	Dairy cattle farm	Beef cattle farm	Abbreviation
Cost of treatment with indigenous medicine per animal (kVND/head)	46	166 (5-875) [a]		Treat.loc.k
Cost of treatment with modern medicine per animal	90	330 (30-2,300) [a]		Treat.mod.k
Value of a dead calf or after treatment (kVND/head)<=6 months	11	3,600 (0-14,800) [a]		p.calf.d
Value of a dead or sold cow after treatment (kVND/head)	15	19,800 (700-45,000) [a]		p.cow.d
Value of a healthy calf (kVND/head) <=6 months	11	12,000 (10,000-19,000) [a]		p.calf.h
Value of a healthy cow (kVND/head)	15	34,300 (18,000-55,000) [a]		p.cow.h
Labour cost per injection (kVND/head)	NA	4 [b]	4 [b]	labour.vac
Morbidity in a farm (%) (n=129	129	79 [b]	54 [b]	Morb.k
Mortality rate in a farm (%) for calf	8	18 (0-50)		Mort.c
Mortality rate in a farm (%) adult cattle	11	12 (0-50)		Mort.a
Number of possible calves produced per cow in one year	NA	0.83	0.94	no.calves.prod
Price of 1 dose of bi-valence vaccine (kVND/dose)	NA	37 [b]		p.vac
Price of 1 kg live weight (kVND), value in Dec 2015	NA	140 [b]		p.liveW
Price of one service (kVND/time)	184	173 [b]		P.Ser
Price of 1 litter of milk (kVND/litter), value in Dec 2015	NA	13.5 [b]	NA	P.Milk

[a]: data in format mean (min-max); [b]: data available in mean value
NA: not applicable

3.3. FMD vaccination was found profitable for all cattle production type

The net present value of FMD vaccination versus “status quo” scenario was always positive whichever production type considered (Table 7). The net present value was highest for the large-scale dairy farms (around 31891kVND per year), followed by small-scale dairy farms (around 10059kVND per year) and beef farms (around 1190kVND per year) (Table 7). The value of additional revenue in large-scale dairy farms was around

33510 kVND per farm per year which was 3 times higher than in small-scale dairy farms and around 30 times higher than in beef farms.

Table 7. Partial budget analysis results according to the different production types (small- and large-scale dairy cattle farms and beef cattle farms)

	Small-scale dairy farms	Large-scale dairy cattle farms	Beef cattle farms
Additional cost (kVND)	861	2468	337
Foregone revenue (kVND)	2873	7905	860
Saved cost (kVND)	3448	8755	1255
Additional revenue (kVND)	10346	33510	1172
Net present value (kVND)	10060	31892	1190

VND: Vietnam Dong (Vietnamese currency)

3.4. Benefit-cost ratio and sensibility analysis

All the parameters estimated and used in the analysis are presented in Table 7. The BCR of dairy farms was higher (5.04 and 5.85 in small- and large-scale dairy farms, respectively) than beef farms (1.83) (Table 8). The sensitivity analysis showed that vaccination cost mostly affected BCR of beef farms than dairy farms. However, market prices affected more BCR of dairy farms than beef farm (Table 8). For three production types, changes in market value had more impact on the BCR than changes in vaccination cost. The BCR of all of three production types was always higher than 1 in the 8 proposed scenarios - increased vaccination costs and/or decreased milk and/or cattle price. This implies that even at high vaccine price and low market value, FMD vaccination was still profitable.

Table 8. Benefit-cost ratio and sensibility analysis results of foot-and-mouth disease

Scenario	Benefit-cost ratio		
	Small-scale dairy cattle farms	Large-scale dairy cattle farms	Beef cattle farms
Baseline model[a]	5.04	5.85	1.83
Vaccination cost ↑25% (C1)	4.72 (-6.4)	5.47 (-6.5)	1.69 (-7.7)
Vaccination cost ↑50% (C2)	4.44 (-11.9)	5.14 (-12.1)	1.56 (-14.8)
Market price of cattle and milk ↓ 10% (C3)	4.56 (-9.5)	5.29 (-9.6)	1.66 (-9.3)
Market price of cattle and milk ↓ 20% (C4)	4.07 (-19.3)	4.73 (-19.2)	1.49 (-18.6)
Vaccination cost ↑25% + Market price of cattle and milk ↓ 10% (C5)	4.27 (-15.3)	4.95 (-15.4)	1.53 (-16.4)
Vaccination cost ↑50% + Market price of cattle and milk ↓ 10% (C6)	4.02 (-20.2)	4.65 (-20.5)	1.41 (-22.9)
Vaccination cost ↑25% + Market price of cattle and milk ↓ 20% (C7)	3.82 (-24.2)	4.42 (-24.4)	1.37 (-25.1)
Vaccination cost ↑50% + Market price of cattle and milk ↓ 20% (C8)	3.6 (-28.6)	4.15 (-29.1)	1.27 (-30.6)

[a]: data from Table 7, () percentage of change value from baseline model

4. Discussion

As specified in our assumptions, our study did not consider the specific chronic impact of FMD. Chronic impact of FMD typically was reported to reduce milk production by 80% in affected cows (Barasa et al., 2008; Bayissa et al., 2011) and caused some clinical signs such as heat intolerance, infertility and general a poor productivity (Kitching, 2002). Moreover, the chronic impact of FMD usually starts around four weeks after the occurrence of the acute form (Kitching, 2002) which makes its impact difficult to quantify as Vietnamese smallholder farmers do not usually have a systematic record of performance for each cow. Quantifying losses due to chronic impacts would require long-term farm surveys. Further studies focusing on the economic impact of FMD at the local level should consider the chronic impacts of this disease which might not be negligible, as shown in the BCA study in Sudan where chronic impacts was responsible for 28.2% of the total losses (Barasa et al., 2008). Therefore, including chronic impacts of FMD would have probably increased the estimated saved costs and BCR of FMD vaccination.

It was assumed that cattle infected once by FMD did not get infected latter in their productive life. Actually cattle can be infected in several occasions by viruses of different serotypes (Doel, 1996). The predicted FMD incidences values are, therefore, probably underestimated. This bias would again increase FMD vaccination BCR.

The government incentives for vaccination (subsidies) were not taken into account in this analyse in order to simplify the formula and make it conservative. Excluding such subsidies in our analysis enabled us to show that even if vaccination costs are fully supported by farmers, it still generates a positive net return. This scenario is not unlikely as currently only small-scale farms vaccine costs are covered 100% by the subsidies whereas larger scale farms already support part of their vaccination costs (subsidies cover vaccine cost for up to 20 cattle). Dairy cattle farms get a higher BCR from FMD vaccination compared with beef farms as losses caused by FMD are higher in dairy farms than in beef farms (Otte and Chilonda, 2000) in the “status quo” scenario (without vaccination). Indeed, the replacement cost of dairy cows is higher than beef cows as they are more valuable in terms of performance and productivity. As only a part of the beef cattle population currently participates in the vaccination program, our result can be used to demonstrate the usefulness of vaccination and to encourage beef farmers to practice it.

The cost of the movement restriction including additional feed intake during restriction time of unsold animal were not included in the analysis (saved cost). In general, movement restriction is implemented by the local veterinary authorities upon detection of a first FMD case in one area and is maintained all along the outbreak period. The ban is ended 21 days after detection of the last FMD case (MARD, 2015). However, the application of this control measure at local level might vary from one location to another and accurate data on the implementation of movement restrictions (or delay in selling time for affected farm) are difficult to collect in practice. The inclusion of such parameter would have increased the BCR of FMD vaccination.

The average cattle morbidity rate at farm level was around 60%, which is similar to published value from Ethiopia (Ashenafi, 2012) but lower than other published results where this rate could reach up to 100% (Radostits et al., 2011). In our study, FMD cases were defined by the presence of clinical signs recorded by farmers. Cattle present in an infected farm who did not develop clinical signs were considered healthy. In reality, unapparent infections may occur in cattle whose susceptibility has been reduced by vaccination (Radostits et al., 2011). Moreover, immunized animals subsequently exposed to infection may become persistently infected even if they do not develop clinical signs of the disease (Thomson, 1994; Alexandersen et al., 2002, 2003). On the other hand, endemic strains (e.g. serotype O in Vietnam) might cause mild forms in indigenous Zebu cattle in Asian endemic countries (Radostits et al., 2011). Those aspects could lead to misdiagnosis by farmers and to an underestimation of the mean farm morbidity.

The mean FMD mortality in adult cattle observed in the our study and used in the analysis (12%) was higher than the one reported in the literature (2%) (Radostits et al., 2011). FMD infected animals may have secondary infections during recovery time (digestive troubles, haemorrhagic septicaemia, etc.) which could delays or impedes their recovery or even lead to their death in some instance. In case cattle do not recover well or die from a secondary infection, they are sent to slaughterhouse, as consequence of FMD infection even if FMDV can not be directly link to the death. Moreover, high mortality was mainly observed in dairy farms using highly performing breeds which are more sensitive to the disease, in comparison to local breeds or crossbreeds used for beef farms.

In Vietnam, an important budget of FMD prevention and control strategy is dedicated to vaccination, including delivery cost and subsidies for vaccine purchase, varied from 50% to 100% of the vaccine price for farms in high-risk areas. However, outbreaks are still continuously recorded (MARD, 2015). This observation raises concerns about the effectiveness of the vaccination program and its acceptability at household level. The BCA demonstrated the financial interest for cattle farmers of using vaccination to control FMD as whichever scenario used, FMD vaccination was always profitable for the farmer. The output of this study might be used to motivate farmers to frequently participate in vaccination campaigns. However, decision of vaccination application depend on other factors such as real and perceived effectiveness of vaccination (Rushton, 2009). Perception of farmer may vary from time to time and maintaining farmers' motivation is a big challenge in smallholder because they always balance the risk of adverse consequences of diseases and cost of prevention. During the 6-12 year cattle life, farmers can stop using vaccination at any moment if they perceive the probability of infection is low. FMD surveillance data showed that in Vietnam, peaks of FMD outbreaks were occurring every two to three years and were negatively correlated with FMD vaccination coverage during the same periods (Phan, 2014). During our study we observed that some farmers refused to use vaccines because it's potential adverse effect on cattle. Abortion, growth delay, change in behaviour (increased aggressiveness) were reported as vaccination drawbacks.

Despite good coverage vaccination effectiveness also remains an important challenge under Vietnamese context. A study in Tay Ninh province showed that despite a vaccination uptake of 85.4%, the sero-conversion in this province was only 60.6% (Nguyen et al., 2014). The imperfect application, storage and delivery can explain the relatively low effectiveness of vaccination (Alders et al., 2007). Farmers are concerned with this low effectiveness and can refuse to use it due to their past experience of vaccine failures.

Advantages of vaccination in control measure such as avoidance of animal slaughter, avoidance of carcass disposal, and a decreased level of viral excretion (Hutber et al., 2006) are highly relevant to developing countries such as Vietnam. However, implementation issues linked to the man-power requirements for post vaccination surveillance and the need for multiple (cumulative) vaccine injections to achieve prophylactic protection (Hutber et al., 2006) can also impairs its effectiveness in the field.

5. Conclusion

Our study demonstrated that FMD biannual vaccination strategy is economically efficient for cattle farmers in Vietnam even if all the vaccination costs are paid by the farmers. It also showed that such program was more profitable for dairy farmers than beef producers. The results of this study could be used to motivates farmers and improve FMD vaccination coverage at national level. A similar study could also be implemented at national level to evaluate the BCR of the FMD vaccination strategy and adapt it to achieve the FMD eradication objective in Vietnam. This study's research framework and results are expected to become a firm ground for further research and awareness program.

Competing interests

The authors have declared that no competing interests exist.

Author contributions

BT, FG, AD and MP designed the study, contributed to the analyses, and drafted the manuscript. BT, MP designed the data collection instrument and drafted the manuscript. VG and SB reviewed the results and drafted the manuscript. The manuscript has been read and approved by all authors.

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CHAPTER 7

PARTICIPATORY SURVEILLANCE OF FOOT-AND-MOUTH DISEASE: A PILOT SYSTEM IN SOUTHERN VIETNAM

In preparation for *Preventive Medecine Veterinary*

Participatory surveillance of Foot-and-mouth disease: a pilot system in southern Vietnam

D B Truong [1,2*], T T Nguyen[2], N H Nguyen[2], M Peyre[1], SBertagnoli[3], L B Kassimi[4], F L Goutard[1,5]

[1] UMR ASTRE, CIRAD, F-34398 Montpellier, France

[2] Faculty of Animal Science and Veterinary Medicine, Nong Lam University, Ho Chi Minh, Vietnam

[3] IHAP, Université de Toulouse, INRA, ENVT, Toulouse, France

[4] UMR Virologie 1161, Anses, Laboratoire de Santé Animale de Maisons-Alfort, Laboratoire OIE de référence Fièvre Aphteuse, Université Paris-Est, 14 rue Pierre et Marie Curie, 94700 Maisons-Alfort, France.

[5] Faculty Veterinary Medicine, Kasetsart University, 10900 Bangkok, Thailand

* dinhbao.truong@hcmuaf.edu.vn or dinh-bao.truong @cirad.fr

Abstract

This study was aimed to assess the feasibility of integrating participatory methods within the surveillance system of foot-and-mouth disease (FMD) in Vietnam and to test the effectiveness of participatory surveillance through the setting up of pilot surveillance in sentinel villages. A protocol of participatory surveillance for the detection of FMD in cattle was designed and applied in a pilot area located in Long An province in Southern Vietnam. Tools from participatory epidemiology such as semi-structure interviews, timeline and participatory mapping were integrated into surveillance protocol and used to investigate 69 sentinel villages. From the focus groups organized at these sentinel villages, 18 new villages were identified as potentially infected by FMD. During secondary investigation, 265 individual interviews were organized and 128 of 723 suspected animals were sampled. Out of the 128 samples, 77 were confirmed positive for FMD, with viral serotypes O and A. Sensitivity and specificity of participatory surveillance were recorded at 0.75 and 0.65, respectively. Our results demonstrate the effectiveness of participatory surveillance to detect FMD outbreak in Vietnam. Further field implementations at larger scale (province or region) are still needed to assess the feasibility of integrating participatory methods in the day to day activities of the Vietnamese veterinary services.

Keywords: effectiveness, foot-and-mouth disease, participatory epidemiology, pilot surveillance system, sensitivity, specificity

1. Introduction

Foot-and-mouth disease (FMD) is known to cause significant impact on the performance of small producers and therefore threatens the livelihood and food security of the poorest communities worldwide (Madin, 2011). In Vietnam, FMD remains a major threat while causing outbreaks almost every year (Nguyen et al., 2014). Between 2013 and July 2014, 74 outbreaks caused by serotype O (strains of Pan Asia and Mya_98) and serotype A (strain of Sea_97) were reported (OIE Sub-Regional Representation for South East Asia, 2016). It had been estimated that each affected farm suffered an economic loss between $84 and $930 (Forman et al., 2009).

Several risk factors of FMD introduction and expansion in Vietnam were identified by some authors. In an cross-sectional and case-control study of FMD in hotspot areas, it was reported that cattle procured from unknown source were a major risk factor, with the odds ratio of 5.27 (95% CI 2.22 - 12.52) compared to cattle produced by households themselves (Nguyen et al., 2014). In a study on FMD outbreak in pigs by Nguyen et al., (2011) in Tien Giang province, the important risk factors ranked were: no vaccination, farm located near other infected farm, farm located near main road, having visitors (traders, private veterinary) within 21 days before outbreak. Farms of 6-12 animals had a significantly higher odds ratio of being infected in comparison with farm of smaller and bigger capacity (Carvalho Ferreira et al., 2015).

FMD is a notifiable disease in Vietnam and the surveillance is mainly passive. When a farmer is suspecting a case, he needs to inform the communal veterinarian. The communal veterinarians will be then in charge of verifying the suspicion and delivering advices on control methods to the farmers according to the national regulation. They will inform the district veterinarian and the communal peoples' committee. The district veterinarians need to inform the provincial veterinary service and the district peoples' committee. In the event of disease spreading with confirmed cases reported in two different communes, the head of the district peoples' committee will declare an outbreak at district level. Therefore the provincial veterinary service upon verification will inform the Regional Animal Health Office, the Ministry of Agriculture and Rural Development, and the provincial peoples' committee. A declaration at provincial and national level is similar with happens at the district level (Vietnam National Assembly, 2015).

Passive surveillance is fully based on farmers' motivation and often many socioeconomic constraints will discourage them to report the disease. Many studies have shown that the information about FMD situation in South East Asia is inaccurate because of under-reporting (Madin, 2011). Participatory epidemiology (PE) is often used in animal health surveillance in developing countries for a better understanding of epidemiological drivers and socio-economical contexts linked to disease emergence (Mariner, 2000). Relying on local knowledge, these methods involve actively the farmers to gather sanitary information and seem like an interesting alternative to classical passive surveillance. This tool had been used in surveillance system in Indonesia in case of high pathogenic avian influenza (Azhar et al., 2010), in Turkey for FMD (Admassu and Ababa, 2005) and in Uganda for various diseases (Nantima, 2012). In those studies, PE had proved to be effective in detecting suspected cases and new outbreaks from prior information. In Vietnam context, validation of its effectiveness is still lacking. The objective of this study was to assess the feasibility of integrating participatory methods within the surveillance system of FMD in Vietnam and to test the effectiveness of participatory surveillance through the setting up of pilot surveillance in sentinel villages.

2. Material and methods

2.1. Case definition of FMD

According to results of a previous study using disease impact matrix scoring method, suspect case definition for each species is present as below. In pig, animal holdings were considered as FMD affected (suspected cases) if there were occurrence of clinical signs as presence of vesicles on mouth and foot, salivation, hoof separation together with any of the following symptoms such as lameness, difficulty of movement and reduction of feed intake. In cattle, animal holdings were considered as FMD affected (suspected cases) if there were occurrence of clinical signs like hoof separation or lost, hyper-salivation, erosion in mouth and tongue, present vesicles, lameness together with any of the following symptoms as fever, loss of appetite, stop rumination, reduction in milk yield. A suspected case that had a positive result in any screening laboratory test such as ELISA Priocheck 3ABC for non-structural protein (serum sample) or RT-PCR for FMDV genome (oesophageal liquid/swab) was considered as confirmed case.

2.2. Location and target of surveillance

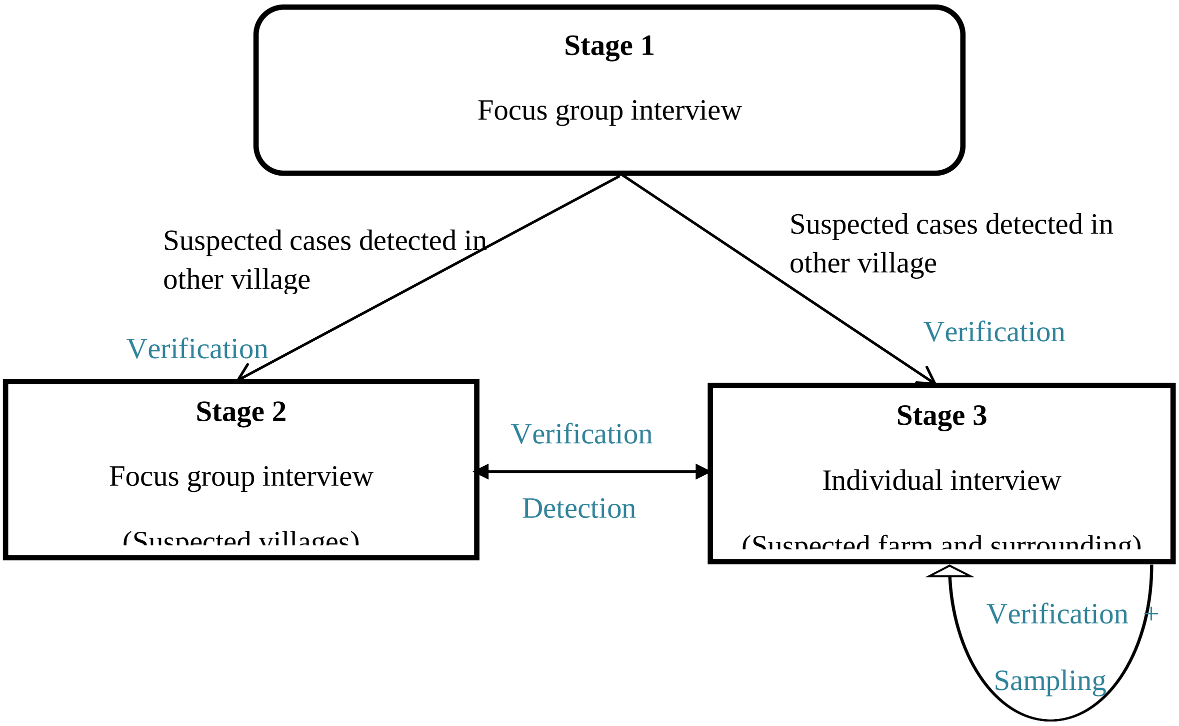
Two districts of Long An Province, Duc Hoa and Duc Hue, in South Vietnam were selected as our pilot study site. Both districts were classified as high risk zone according to national plan to control FMD (MARD, 2015). Duc Hue district locates near border of Cambodia. Duc Hoa district was identified as presence of FMD cases in the past and presence of a high number of slaughter houses (Sub-DAH of Long An province, 2014). In each district, several villages were randomly selected to be included in this study. The final selection of pilot village's was based on the outcomes of the discussion between research team and veterinary staff of district and province level. Besides that, study zone was also widened to Can Duoc district where information of suspected cases was available during the study.

For the purpose of this study, all domestic pigs and cattle in traditional livestock rearing system were monitored for FMD. Our survey focused on all of actors that have direct or indirect link in animal surveillance. Pig and cattle farmers in sentinel villages were informally interviewed using semi-structured interview with focus group and individuals. Other key actors (e.g. traders, private veterinary, etc…) in study zone were identified and included in participative interviews.

2.3. Surveillance protocol

The study lasted 5 months, between December 2015 and April 2016. Our surveillance protocol comprised of three stages with snow ball technique used for sampling. First stage was the organization of monthly focus group interviews in a random selection of 10 villages per district. During each focus group interview, 10 to 15 farmers were invited to discuss about FMD suspicion within or outside their village. When suspicions were evident, the surveillance team organized secondary focus group interview within the suspected village to identify potential infected farms. Then in the third stage, individual interviews with the farmers whose herd were suspected to be FMD were conducted to validate the disease situation in the farm, to identify potential source of disease introduction and potential spread. Individual interviews of neighboring farmers were also conducted to detect latent cases. When FMD infected farms could not be located after focus group interviewing in potential affected villages (Stage 2) some individual interviews with randomized farm in suspected villages were organized until infected farms were identified. Several participatory tools were used and samples (serum and esophageal liquid) from cattle were collected in and around the suspected farm (Figure 1).

Figure 1: Summary of stages of surveillance protocol for foot-and-mouth disease



2.4. Institutional organization of surveillance system and information sharing

The system includes existing organization of passive surveillance and participatory component. Passive surveillance network in Long An province is basically organized based on administrative division as well as the organization of the veterinary services. The province is divided into 1 city, 1 town and 13 districts, subdivided into 15 commune–level town, 14 wards and 136 communes. In terms of animal health, Long An provinces belongs the 6th region animal health office (RAHO 6). In each district of Long An, there are a district veterinary station (DVS) and a system of para-veterinarian at communal level. Number of para-veterinarian depends on the number of commune in one district. Passive surveillance system of important diseases monitors and manages the infectious diseases at farm level through local farmers. Participatory component integrated into surveillance system included four people of research unit, Hanviet laboratory and six students of mobile team. The research unit collected, centralized and reported information on suspected cases, samples and the results of laboratory analysis. Data was synthesized and interpreted by the research team leader (animator), then disseminated to veterinary services of district and province level in form of monthly and final reports. The research unit consisted of 1 animator (PhD student) who led this unit and three assistant animators (veterinary students) who played an important role to draw up the presentation of the network's results and interpretation. They also participated in the regulation related to the surveillance network. Laboratory is located in Nong Lam University (NLU), Thu Duc district, Ho Chi Minh City. The distance from NLU to closest district in study zone is approximately 60 km. Mobile response team may be requisitioned in order to collect samples at suspected farms as per the request of research team, particularly during the high risk period of disease. They were fully equipped and trained for sampling and sample transportation to laboratory.

Participatory tools: Our study was conducted with the use of PE tools that were described by Bagnol and Sprowles (2007), Catley (2005), Mariner (2000). PE included semi-structured interviews with open-ended questions, timeline and participatory mapping. Timeline was first used in focus group interviews to collect information about period of vaccination, cultivation, trade, rainfall and then completed with the time of suspected outbreaks. Then, in individual interview, timeline was used to recall the history of the disease with the indication of some keys events affecting the community or the livestock population for 2015. Participatory maps were used by the surveillance team to detect new suspicion of FMD and to identify possible spatial risk factors. A base map of the commune was prepared before the beginning of the interview. Then, participants were asked to draw the geographical limits of their villages and locate the farms, traders, slaughterhouses, direction of animal movement and any other related information. Each interview was performed in the most convenient place for the interviewee, in local language and lasted for an hour. Effort was made to ensure that all of attendants participated and exchanged ideas actively during the discussion.

Samples: In case of suspicion in a farm, one to six animals were sampled (collected both serum and oesophageal liquid samples from one animal) to confirm the presence of disease (targeting first animals with clinical signs). The surrounding farms were also sampled to detect latent cases. Strict biosecurity measures were taken by the surveillance team to avoid spreading contamination between farms. Samples were tested in Hanviet laboratory at NLU to detect non-structural protein using enzyme link immune sorbent analysis 3ABC PrioCheck (serum) and serotyping using real time reverse polymerase chains reactions (oesophageal liquid). Sensitivity and specificity of ELISA were 94% and 98%, respectively (Brocchi et al., 2006). For PCR serotyping, sensitivity and specificity were 96.1% and 63.1% (Shaw et al., 2004). Laboratory tests were done following the protocol of ANSES laboratory as previously detailed by ANSES (2012) and Gorna et al. (2014).

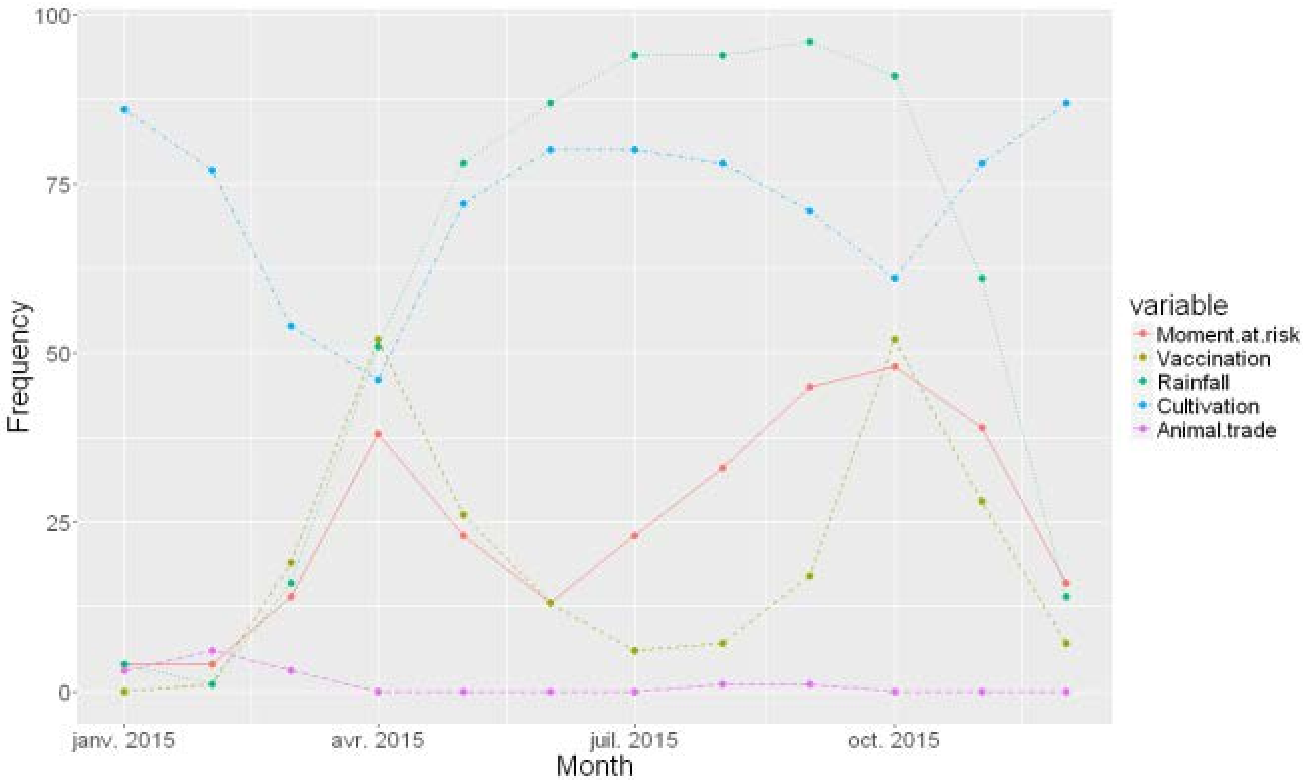
Data management and statistical analysis: Data analysis was done under the software R version 3.1.2. Figure was created with helps of ggplots 2 package (Wickham, 2009). Maps were created using the software Quantum GIS (available from http://www.qgis.org).

3. Results

3.1. Timeline of focus group interviews: Association between weather, cultivation, husbandry practice and risk of FMD infection

Rainfall duration in the study zone was recorded from April to November with peak from July to October (according to 98% of participants). At that moment, field was full of water for a long time as this was flood period in Delta Mekong. The beginning and the end of rainy season had a positive correlation with disease (Figure 2) which was reported as risk period for animal. Moreover, the time interval between July and November was highlighted as being more important than March to May in terms of risk of the disease. Vaccination to prevent FMD was also practiced in this period with two injections between six months. The risk period of disease in animal was also correlated with no cultivation activities. Animal trade was reported mainly in January and February before the New Year holidays in Vietnam. It was noted that animal trade was reported 1or 2 months before the risk period of FMD for animal (from March to May).

Figure 2: Timeline result of the association between husbandry practices, weather and risk of infection of foot-and-mouth disease in animal



3.2. Case detection through participatory surveillance

A total of 69 focus group interviews were organized with the participation of 697 farmers. During these meetings, 18 of 32 villages were identified as potentially suspected of FMD outbreak. During the secondary investigations, 265 farms were visited. Among them, 135 farms were detected as suspected farms with help of participatory surveillance and then 40 farms were confirmed having infected animals in farm with laboratory test. A total of 128 suspected cases out of 723 cattle under study were sampled and 77 were confirmed positive. 15 suspected animals that were sampled were classified as false positive. Sensitivity, specificity, positive predictive value and negative predictive value of participatory surveillance at animal level were computed as 0.75, 0.65, 0.79 and 0.65, respectively (Table 1) using formulas as mentioned by other authors (OIE - World Organization for Animal Health, 2014). Serotype O and A were detected in 8 and 9 tested samples, respectively.

Table 1: Positive and negative predictive values of participatory surveillance system of foot-and-mouth disease

	Real situation (results of laboratory test)		
Disease declaration by farmer (PE)	+	-	
+	58	15	Positive predictive value: 0.79
-	19	36	Negative predictive value: 0.65
	Sensitivity: 0.75	Specificity: 0.7	

Suspected cases were detected with high number in the middle of December, then brutally decreased and again increased with a peak in the middle of January. Another wave was found after 15th February which continued until the end of March (Figure 3). Suspected and confirmed cases were detected in both districts (Figure 4). In Duc Hue, cases were mostly detected in farm located near the border with Cambodia. In Duc Hoa, the infected farms were grouped at the center of the district. A third district was also investigated (Can Duoc) during study period after a suspicion (index case) was reported by the communal veterinarian. In that district, other suspicious cases were detected in second village near the index village. Those locations were also identified as potential hotspot area while computing heat map (Figure 5). The map was created based on information of confirmed cases in the study zone and location for improvement of surveillance activities was suggested.

Figure 3: Distribution of suspected and confirmed foot-and-mouth disease cases during surveillance period

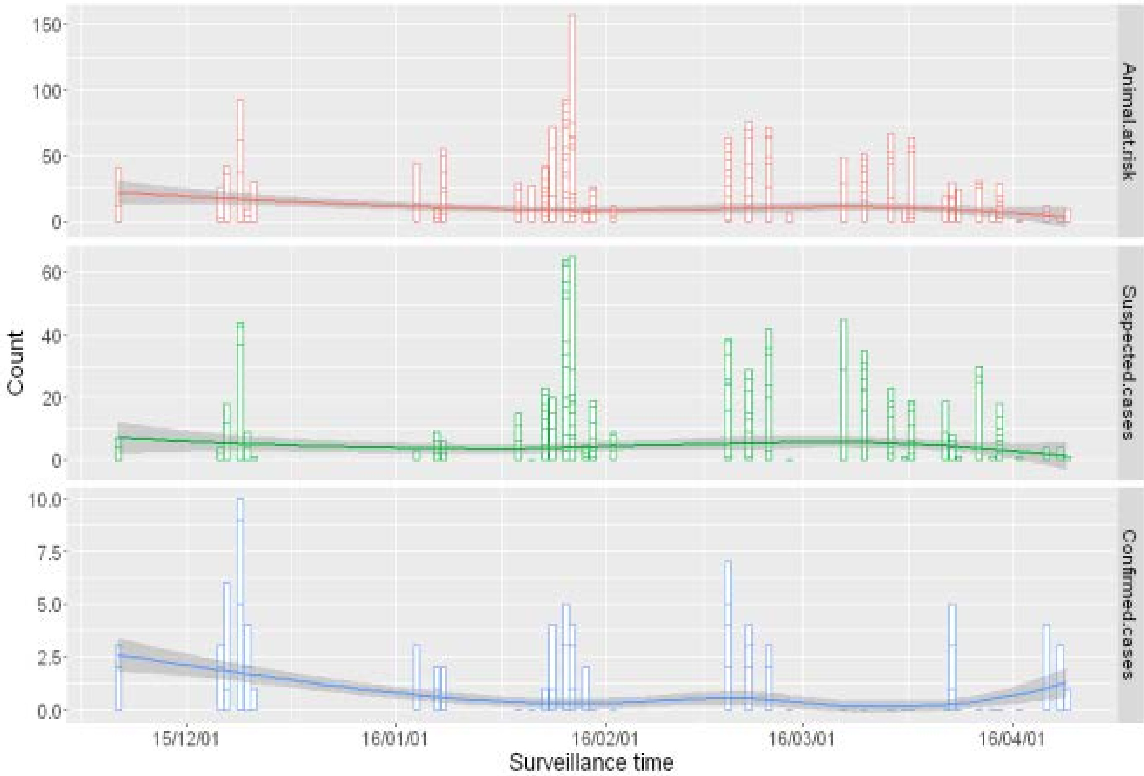


Figure 4: Distribution of suspected (top) and confirmed (bottom) foot-and-mouth disease cases in study zones

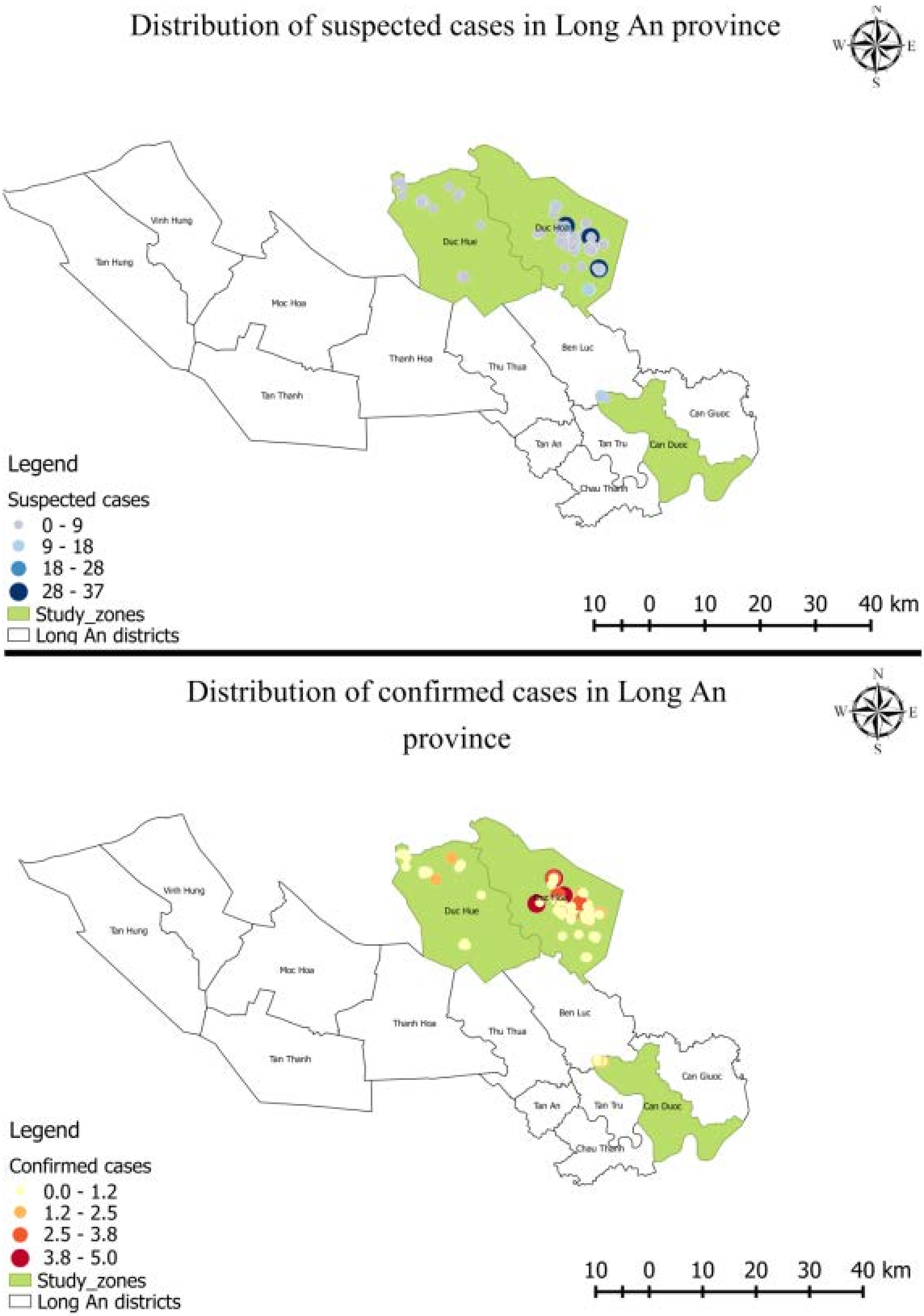
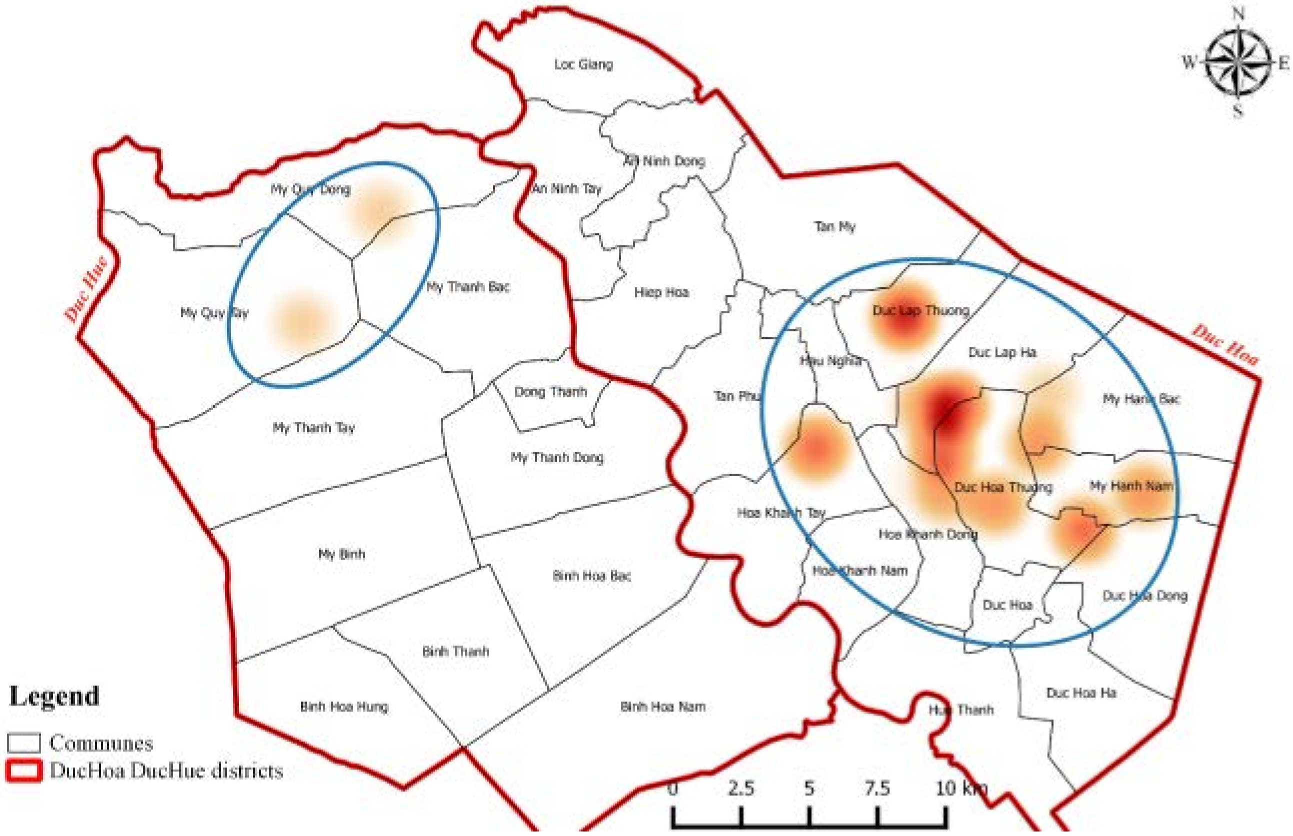


Figure 5: Heat map of hotspots detected of foot-and-mouth disease during surveillance period (based on number of confirmed cases at each location) at the communes of Duc Hoa and Duc Hue districts



4. Discussion

4.1. Farmers' perception of FMD risk factors

From the results of the association between weather, cultivation, husbandry practice and risk of infection, it is clear that farmers can identify risk period based on their experience. They experienced infection cases in their farm in the past or observed cases in neighboring farms. Their opinions were relevant to government policy regarding the timings of vaccinations. Moreover, pilot area under scope of our study included farms that were located in two different zones. Farms located far from border had more risk of being infected in our survey which could be due to difference in vaccination policy. Districts near border received subvention from government for two injections per year while others received one subvention per year. The second injection cost depends on farmers' opinion (MARD, 2011). In case a farmer did not regularly practice vaccination (normally in 2nd injection in September-October) their animal had higher risk of infection. Besides a lack of vaccination coverage, this raining period (as shown in Figure 2) along with high humidity favor survival of virus (Radostits and Done, 2007), which could lead to a high number of cases as a consequence.

4.2. Effectiveness of participatory surveillance

To date, there is very limited studies conducted using participatory methods in surveillance system and effectiveness of this method still remains a question for researchers and for decision making. Our findings highlight the fact that participatory surveillance could be highly effective in the detection of FMD infected cases in Vietnamese context. With basic participatory tools and limited human resources, participatory surveillance helped us to detect an important number of FMD infected cases from primary source of information. Moreover, participating in the discussion motivated farmers to spontaneously share information with us. On most occasions, information about suspected cases was mentioned first by farmers and they also did not feel uncomfortable to declare cases at their farm or in the neighboring farms.

Timelines and participatory maps allowed us to locate new infected farms, to track back possible source of infection and to predict the next village to visit by taking into consideration the disease mode of transmission (wind flow, animal movement road…). It was observed that these tools could also be useful to distinguish between an already existing virus and introduction of virus into an area. Further application was needed to confirm this observation. This information will be very useful for veterinary services to modify their control strategy on time (e.g. change of vaccine used, stamping out new source at small scale) in order to maintain its effectiveness.

Information from our study was shared in real time with the district veterinary services in order for the authorities to apply control measures at small scale. Those participatory tools could be used by communal veterinarians at local level in their routine surveillance activities. Distribution of suspected and confirmed cases also provided some information about potential hotspot areas where more attention and prevention methods (vaccination, disinfection) could be implemented during the following year to prevent new outbreaks from happening. Participatory surveillance results were appreciated and were also deemed as necessary for similar application in other disease by local authorities.

Most of the suspected cases of our pilot system were found before and after Vietnamese traditional holidays (e.g. Vietnamese New Year), suggesting that surveillance activities should be strengthened during this period. One reason for this might be that the second round of vaccination (between September and October) is not always strictly applied and consequently, most of the animals don’t have enough immunity to fight the disease. The expansion of such participatory surveillance system during a full year could give us more information about the high risk period of FMD infection. Moreover, according to the principle of modified stamping out policy in case of FMD outbreak in Vietnam, only the first animals with confirmed laboratory results have to be culled. Therefore, a significant number of infected animals in hotspot areas remain alive, maintaining the virus and becoming a potential source of infection in the following year. The surveillance should also be maintained at other communes where histories of this disease were recorded. In fact, several communes at northern parts of some districts did not declare any case in our study but there were several outbreaks presented in those area in 2013 (Carvalho Ferreira et al., 2015). Moreover, FMD outbreak peak tend to happen in 2-3 years (Nguyen et al., 2014) because of insufficient vaccination coverage (MARD, 2011). We recommend that participatory surveillance need to be maintained as a tool for early detection of cases in past and present hotspot area.

Some of the farmers observed serious clinical signs of the disease to diagnose their animals and declared the cases in their farms. Mild form of this disease might leads to misdiagnosis by farmer. Moreover, when expanding our investigation surrounding an infected farm, some farmers tried to hide suspected cases in their farms. Those false information then influenced on Se and Sp of surveillance system. Network building is very important to improve confidence in this case. So, an investigation with local staff is critical for success of surveillance.

However, some challenges of application need to be taken into consideration for participatory approach. Firstly, regarding the sensitivity and specificity of participatory surveillance, detection of suspected cases requires a lot of experience and time for in depth interview. Interviewer needs to be motivated in spending time with farmer to detect and verify new cases. Commune and district veterinarian who is in charge of collecting information needs to be supported by government. Indeed, salary of those agents is considered not satisfactory for their livelihood and they need to seek for more income from private work (Delabouglise et al., 2015). This situation might not encourage them to spend more time in surveillance system. Moreover, farmers feel more comfortable while talking about suspected cases in surrounding farms or what had happened to their farm in the past rather than talking about what is happening in the present. They prefer to hide or refuse to inform about suspected cases during surveillance because control policy is not well understood. They think that declaring suspected cases might lead to a total stamping out or a ban of commerce (selling animal and animal products). They need to be convinced about benefit of declaration including control policy such as modified stamping out, subvention of disinfectant products and technical support for FMD. Close relationship between veterinary agent and farmers also helps to figure out suspected case throughout regular conversation and visits. Milk collector and veterinary shop might also be a source of information through volume of milk recorded from each farmer and type of medicine sold. Even if it was not clearly highlighted in our result, field observation showed strong link between them and farmers. The importance of indirect system of information sharing was highlighted by Delabouglise et al. (2015). Further studies need to take into consideration for their role in surveillance system.

5. Conclusion

Our results demonstrate the effectiveness of participatory surveillance to detect FMD outbreak in Vietnam and propose a series of participatory tools applicable in the field for communal veterinarians. Further field implementations at larger scale (province or region) are still needed to assess the feasibility of integrating participatory methods in the day to day activities of the Vietnamese veterinary services.

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CHAPTER 8

GENERAL DISCUSSION AND CONCLUSIONS

8.1. Effectiveness of foot-and-mouth disease (FMD) surveillance and control strategies at local level using participatory epidemiology (PE) approach

8.1.1. Characterisation of farmers' behaviour

In Vietnamese rural context of cattle production, farmers are developing strategies that can be divided into two. One which is considered as conventional strategy that aims more to minimize the indirect effects of the diseases (i.e. strategies of alleviation). The other one which aims to avoid the disease itself (i.e. strategies of prevention and precaution). Those strategies appeared to have been relatively successful at the scale of the village (Desvaux and Figuié, 2011). Therefore, farmers can decide the strategy that meets their requirement in a particular case. According to Bellet et al. in 2012 and our report (chapter 2), contagious bovine diseases such as hemorrhagic septicemia have a much higher impact on small scale farms in Cambodia and Vietnam than FMD. FMD doesn't always play the primary role in bovine infection. FMD starts to become a concern for farmers when the disease spreads at a larger scale with several outbreaks and with temporary market ban policy. Nguyen (2014) was reporting that FMD outbreaks are present in Vietnam every 2 to 3 years (e.g. 2006, 2009 and 2011). This suggests that farmers tend to be worried about the disease the first year and so strongly require the vaccination for their herd, but then as the number of outbreaks decreases their concern rapidly disappears as well. If international community and national decision markers consider FMD as an epidemic threat for which emergency tools are required, on the contrary this disease is framed by the farmers in our study as an endemic problem manageable through routinized measures. These measures aim at firstly minimizing the economic impact of the disease rather than preventing cattle from the disease. These measures are also chosen based on their relative cost rather than their effectiveness. The effectiveness of control measures is challenged in dynamic situation and hard to persuade all of farmer in our study. Consequently, local management of the disease cannot fit with the precautionary approach promoted by the international community and national decision markers.

8.1.2. Farmers' prioritisation of animal production issues, disease impacts and their competence on disease differential diagnostic

The importance of each issue was different in dairy, beef and pig production type and mainly linked to the husbandry management such as insufficient biosecurity on farm, unsatisfactory of husbandry practice for high performance breed; weak linkage with other actors in value chain of production (Chapter 2). Even if FMD was never mentioned at the beginning of farmers group discussion, to avoid leading farmers' opinions, the disease was naturally mentioned by all focus groups in our study zone and was ranked as an extremely important constraint for all production types (Chapter 2).

Unlike veterinary authorities who are focusing only on the control of notifiable diseases such as FMD and porcine reproductive or respiratory syndrome (PRRS) because of the severity of their production impacts with high morbidity, mortality and rapid spread (Veterinary regulation, 2015). Farmers have a more holistic animal health point of view and are taking into consideration all the potential livelihood's impacts while prioritising diseases to control on their farms. Our findings highlighted that FMD was ranked differently depending on the type of farms. The difference in the priority diseases between our two main actors (i.e. farmers and veterinarians) implied that animal health surveillance and control programs can subsequently negatively influence farmer's adoption of diseases control strategies (Chatikobo et al., 2013).

Farmers under our study showed good knowledge about differential diagnostic of diseases through disease symptom matrix scoring exercise. They could recognize some basic and specific clinical signs of diseases. However, they could not recognize and clearly distinguished common signs that was presented in different diseases such as fever. Local description of disease name and signs were largely related to modern disease signs described by veterinary medicine textbook (Radostits et al., 1994). However in our study, farmers' knowledge of diseases diagnostic based on clinical signs, was not compared with veterinary competences to check for agreement or disagreement. This finding highlight the importance of local knowledge and demonstrated that indigenous knowledge of Vietnamese farmers is similar to what we can found in African farmers (Catley, 2006).

Our PE-based survey clearly identified 13 socio-economic impacts on livestock production. Some of them were similar to the ones identified by Pham et al. (2016) during their study of pig diseases in Northern part of Vietnam and by Bellet et al. (2012) who evaluated diseases impacts in pig, buffalo and cattle farms in Svay Rieng, Cambodia. Other impacts were specific to our population under study.

8.1.3. Farmers' preference on disease prevention and control methods used at local level

Vaccination was considered as the most important preventive method by farmers because its effectiveness can achieve 70-80% (results from farmer's interviews). Farmers' choices are relevant for Vietnam's policy (MARD, 2011, 2015) and strategic framework to prevent and eradicate FMD in Southeast Asia and China (OIE Sub-Regional Representation for South East Asia, 2016). Disinfection and cleanliness were classified as the second and third most important methods for prevention. From the PCA results, we noted that several dairy farmers were using vaccination, disinfection and quarantine together. They agree to invest more money in expensive methods to protect their valuable animals because of the high disease prevalence in dairy farms (nearly 30% of animals) (Carvalho Ferreira et al., 2015; Nguyen et al., 2015) and the severe consequences of the disease (OIE and FAO, 2012) on their livelihoods. Beef farmers favoured cleanliness and good husbandry management practices because of their simplicity and easiness to apply. Pig farmers weren't using any preferred preventive methods, they were applying whatever they find necessary to protect their animal but adapted to their financial capacities. None of the production type combined all the prevention methods that were identified through the study. This might influence the effectiveness of disease prevention at farm level. A comprehensive prevention management is not easily accessed by smallholder farmers with limited resources and the choice of prevention methods strictly depends on the capacity of each farm. Moreover, the use of prevention method was not exact as needed, e.g. quarantine new animal in separated cage beside to the old herd cage. Our direct observations were in line with what were already reported in other studies (Vo, 2011; Unger, 2015).

8.1.4. Farmers' perception of foot-and-mouth disease vaccination

The farmers' perception of vaccination were evaluated through flow chart tool (Chapter 4) and those prior information about advantages and inconveniences of vaccination allowed us to deeply investigate vaccination perception with the use of the Q methodology (Chapter 5). Farmers groups were identified based on their perceived value of vaccination. Some advantages of vaccination were recognised by the farmers, such as the contribution to stress management, savings made thanks to the vaccination rather than the more costly treatment option and the compensation received in the case of infection within a vaccinated herd. These benefits were also clearly identified by some participants who experienced outbreaks in their herd before using the vaccination. The farmers' strong confidence in governmental vaccination programmes was clearly shown. The issue of vaccines packaging was as well identified. In fact some farmers clearly favour the immediate use of individual doses because of their small herds' size (less than 10 animal per farm) and the difficulties they have regarding preservation. Others prefere using multi-dose vials because they have bigger herds and vaccine preservation are not an issue for them. This finding highlight the irrelevant between farmers' demand and available vaccine packaging that never demonstrated before in Vietnamese context. This critical poin need to be taken into consideration in future program in order to facilitate farmer participation in FMD control program. The fact that farmer's vaccination decision is not influenced by other stakeholders, illustrates one of the psychological traits of Vietnamese farmers who tend to rely on their accumulated experiences to guide significant decisions (Cao, 2015). This psychological trait could maybe as well explain why a minority of our participants indicated that they never vaccinated their herd because they never experienced FMD.

Issues related to the trust given by the different types of farmers to the vaccination done by veterinarians, were also identified in our study. Dairy farmers strongly believed that veterinarians can act as a vector to spread the disease to their herds during their visit for vaccination practice, while beef cattle farmers placed more trust in the veterinarians. Therefore, dairy farmers prefer to organise the vaccination by themselves. In contrast, beef farmers prefer to have their animals vaccinated by the veterinarian. This useful information was found through direct observation and in-depth discussions. The same result could not be achieved through our question-based survey that was performed during the same time.

8.1.5. Benefit-cost analysis of foot-and-mouth disease vaccination used at local level

In Vietnam, an important budget of FMD prevention and control strategy is dedicated to vaccination, including delivery cost and subsidies for vaccine purchase, which varied from 50% to 100% of the vaccine price for farms in high-risk areas. However, outbreaks are still continuously recorded (MARD, 2015). This observation raises concerns about the effectiveness of the vaccination program and its acceptability at household level. Our study demonstrated an insight into the benefit of vaccination in term of economic (Chapter 6). Data which were collected through questionnaire-based survey and semi-structure interviews during two years were used for this analysis. The cost-benefit analysis demonstrated the financial interest of cattle farmers to use vaccination to control FMD. Whichever scenario is used (i.e. increase of vaccination cost and decreases of market value of milk and slaughter cattle), the FMD vaccination was always profitable for the farmer. The output of this study might be used to motivate farmers to frequently participate in vaccination campaigns. Despite uncertainty of some input data, the outputs of this study highlight a strong difference between the benefit of vaccination for dairy cattle farms and beef cattle farms. The same calculation for pig production was not possible due to the lack of accurate data. This could be considered as one of the limit for this thesis.

8.1.6. Local socio-economic issues influencing the effectiveness of foot-and-mouth disease vaccination program

i. Weaknesses of farmers related to their perception of vaccination

Compared to semi-industrial production, small holders always need to invest more in production cost for feed, medicine, breed, or veterinary services. This consequently made their products less competitive than semi-industrial farms. This is also the main reason why smallholder farmers try their best to decrease the cost of input, including cutting vaccination cost. Before deciding to use vaccination in their herd, farmers weigh up the balance between costs and perceived benefits, if the cost is equal to or less than the benefits they will engage in the vaccination, but if the cost of the action outweighs its benefits, they will not engage in the action (Hedström and Stern, 2008). Although vaccination is considered to be inexpensive, farmers who are classified as having medium or low incomes (Bui and Le, 2010; Le et al., 2014) feel that avoiding this expense will benefit them, especially pig farmers who do not receive any government compensation for vaccination. Our results demonstrated that vaccination method was ranked according to production type and was directly linked to the severity of impact caused by a particular disease to farmer (Chapter 2). For dairy farmers, income comes from daily volume of milk sold and they know that FMD will directly affect their production. It is for this reason that prevention is done using vaccination and other methods. For beef cattle farmers, their animals are considered as household savings, and they are valuable only if they are alive. Management of disease is based mainly on treatment. Unlike farmers of surrounding countries where cattle or buffaloes are still used for draft power purposes(Young et al., 2013), Vietnamese farmers keep animal only for meat production (Hoang, 2011). Local and crossed breeds take an average of 24 to 27 months to bring capital back after selling their animal (300 kg live-weight) for meat purpose. Moreover, performance of breeds mostly used in Vietnam is moderate which requires minimized input cost, thus is easier to get benefit from them. Totally relying on animal resistance capacity and compensation of government for vaccination, only part of the beef farmers involved in the study (10-20%) are motivated to spend more money to do a second vaccine injection during the year (in-depth interview). For pig production system, implementation of the full list of vaccines against pig diseases from semi-industrial farms to smallholder farms is unrealistic. Smallholders do not have enough capital to practice similar preventive protocol. They choose to vaccinate only against the most important diseases that will have a direct and severe impact (e.g. capital loss). For other diseases, including FMD, preferred solutions are treatment and immediate selling of animals to the slaughter house. Government provides subvention to farmers in case of stamping out after occurrence of notifiable disease such as FMD but farmers have an aversion for this method (in-depth interview). Indeed, after reporting, farmers need to receive the compensation as soon as possible to be able to restart their production and pay the debts and bank loans. Delays in compensation are highlighted by farmers and then negatively influence their restock plans. In fact, the waiting time for compensation, varies from several months to more than a year and have been mentioned by the farmers. Therefore, farmers shift toward emergency selling methods to be able to get back quickly some of their capital. In many case, farmers who had experiences with compensation process are unwilling to wait for the government's help. That clearly means that no more information about suspected cases will be declared and selling of infected animals by farmers will continue. At this point, we can also suggest that an emergency aid for smallholder is lacking. This is a critical point that needs to be reviewed and taken into consideration while seeking a good way to achieve the objectives of prevention and control.

Our study highlight the fact that an animal affected with FMD can be cured of its clinical signs with folk remedies that are made by farmers themselves based on their experience, i.e. cashew nut (*Anacardium occidentale),* false daisy *(Eclipta prostrata)* or found in traditional medicine store (personal communication) and then can be sold at the usual price after treatment. In the context of our study, the evidence of indigenous medicine effectiveness has not been systematically addressed. However, these treatment methods were widely applied by local farmers as an alternative ways to control disease of their unvaccinated animals. Further study focusing on the relation between indigenous medicine and virus existence are needed to avoid the transmission of virus from carrier animal (Kitching, 2002).

Links between actors of the livestock production value chain are weak in Vietnam. There is a great number of intermediate actors that are involved in the livestock production value chain. In this context, the farmer is not the actor who receives most of the benefit from livestock activity. Currently, farmers receive only 15% of the net value-added (difference between output and input) for their final products while slaughterhouse and traders obtain more than 40% of the net value-added (Anonym, 2015). In such situation, it is worst to say that vaccination does not contribute to the value of an animal, according to farmer's opinion. In fact, it was found that the majority of dairy farmers appreciated the necessary of vaccination certificate, only 10% of beefs farmers and 25% of pig farmers mentioned about it (in-depth discussion). When purchasing an animal, traders often look at the form only and farmer can sell an unvaccinated animal to traders. Traders usually handle vaccination certificate for animal movement or slaughter. The lack of linkage between actors was observed during in-depth interviews with farmers in our study zone. To date, the customer demands for high quality meat products are very high. The need of traceability, hygiene and disease freedom are some of the requirements asked for meat products. In such situation, the consequence for beef production might be critical unless they change their husbandry management. Therefore, a vaccinated animal might benefit farmers in this trend.

ii. Difficulties of other stakeholders in the livestock production value chain related to vaccination

As they were not part of our study objectives, perception data on the constraints of other stakeholders in animal health are very few. However, through direct field observations about milk production value chain, we identified a link between farmers, collector's station and factory in the form of sanitary contract. It highlights the volume and sanitary conditions of hygiene in buildings and vaccination requirement for some infectious diseases, including FMD and hemorrhagic septicemia. For vaccination, a copy of valid vaccination certificate is always required to insure animal's health and the quality of the collected milk. The main constraint for other stakeholders involved in milk production is the regular verification of certificates. In order to do that, they need to implement regular awareness activities such as seminar, workshop, regular farm visit, discussion with farmers and internal evaluation.

For meat production in both beef and pig sectors, vaccinations do not contribute to the value of the animal when purchased by traders. It is only necessary in case of animal movement between provinces. For small traders, the certificates are not taken into consideration while buying animals. Then traders usually stock, treat and send animals that look healthy to local slaughterhouse. Big traders who always trade their animals between provinces ask for the help of veterinary authorities for the injection and certification of collected animals before transportation. Animals can be collected from various sources with or without certification, and stocked in one location where they receive injection and certification. It is believed that all of those activities are done in a short period of time before movement, in order to avoid loss in live weight of animals and also to avoid the manifestation of clinical signs of various diseases. Stocking a large number of animals in short time before transportation is seen as a good way for traders to gain profit. However, in term of sanitary protection based on vaccination, a minimum of 15 days post-vaccination is needed for the full protection of an animal. This conflict between trader benefit and animal protection makes the requirements of quarantine authorities for imported animals often not followed. In normal case, an imported animal needs to be quarantined at the border to have its health status checked and to receive vaccination against FMD. However, some traders do not accept this rule and trade animals illegally by crossing the border by foot to avoid veterinary verification. Those animals are then sold directly to farmers. After which, responsibility of animal health is passed to farmers as well as the loss due to disease that have been incubating during the transportation. This is believed to happen mostly in case of animal movement providing from surrounding countries into Vietnam such as Lao and Cambodia. Only countries such as Australia and New Zealand accept quarantine process because Vietnamese partners with whom they do business are big companies and huge number of animals are imported with direct involvement of Regional Animal Health Office for sanitary verification.

8.1.7. Relationship between stakeholders in passive surveillance system of FMD and its consequences on information sharing

Stakeholders in surveillance system are divided in two parts, government and non-government agencies. Government agencies include all agencies from the top of the system to district veterinary staff while non-government agencies consist of community of animal health workers (CAHW), other private veterinarians, farmers, slaughterhouse and traders. Head of CAHW is a particular case while they are not only a private veterinarian but also a government agency. In fact, he/she is recruited by the Commune People Committee and technically supervised by the District Veterinary Office. As a part of local government and local official, they are selected on the basis of their exemplary behavior as well as that of their family in relation to the socialist ideals and their participation in the activities of the party or mass organizations rather than on the basis of their education and their skills. Moreover, the financial resources allocated to each of them are very limited (Delabouglise, 2015). The passivity of local governments and their vulnerability to corruption or informal arrangements are a direct consequence (Pham, 2004). The insufficient financial resources for local actors might be considered as one of the main reason of FMD control failure.

The relationship between stakeholders are quite complex. Relationships between government agencies are co-ordination type, while those between the government and private sector (e.g. CAHW, farmer) tend to be of the cooperation. The result is that government veterinary authorities cannot force private sectors to submit diseases reports. District Veterinary Staff mentioned that while there are no punishment at all for CAHW in case they do not report disease situation, they are unwilling to do such things (Dung, 2006). Efficacy of passive surveillance is constraint by dividing of administrative responsibility and financial between central and local governments. The dependence of veterinary authorities toward local government limit the upward flow of information to central authorities (Delabouglise, 2015). Low salary, wide benefit from treatment, no allowance for disease investigation are also some explanation for the under reporting of CAHW. It is known that CAHW are not paid for reporting activities so they do not report disease situation while it's happen. District Veterinary Staff mentioned about the lack of data due to reduction of monthly meeting between them and CAHW team because of limited budget (Dung, 2006). With a monthly salary of less than 100 USD for veterinarians, they need to have a side job which is often private veterinary services that is mainly based on animal treatment. In case of notifiable diseases such as FMD, the income raised by 3 days of treatment for secondary infection is much more important for their livelihood than the extremely low allowance they get during disease investigation or surveillance. Being identified as a critical actor in public surveillance system for data collection and report (Jost et al., 2007; Delabouglise et al., 2015), regular support and verification from supervisors are suggested to ensure motivation of CAHW.

The information sharing bridge between private and public veterinary services was considered as weak in term of quality and quantity (Delabouglise et al., 2015). These local actors such as private veterinarians are the main route of transmission of disease suspicion information to distant areas as well as provide information on the sanitary situation of numerous farms of their area of activity to the public surveillance system (Delabouglise et al., 2015). However, they do not have the duty to report suspected cases for public site. The role of privates sectors and their valuable information need to be highlighted in order to change the behavior of the private sectors in information sharing.

Beside the benefit of treatment, satisfaction of their customer is the most important thing that maintains the relation between them. In case of sharing information about disease situation to public site the relation might be broken down. Traders get benefit from buying sick animals and require them to report suspected cases is a disadvantages for their business.

8.2. Implication of participatory epidemiology approaches in Vietnamese context

8.2.1. Application and validation of participatory epidemiology in foot-and-mouth disease surveillance

i. Application of PE in FMD surveillance

Focus group interview with open-end question also gave a chance to address some emerging questions during interview, i.e. the willingness of farmers to spent more money on the second injection of FMD vaccination without governmental subsidies. Those questions were used to cross-validate logistic nature of the prior information. With helps of PE tools such as pairwise ranking, open-end questions, a list of issues in animal production was generated and ranked by farmers (Chapter 2). Our findings is similar to the results of Suzuki et al. (2006), Ashbaugh (2010), Vo (2011), Lapar et al. (2012) and Nguyen and Nanseki (2015) by using conventional methods. As an orientation-method, PE helps research team to better understanding the issues' priorities at local level. PE helps not only to demonstrate the prioritised diseases but also to well understand hidden explanation for those results through open-end questions, which might be hard to archive through conventional survey. PE tools helped us to understand the similarity and the differences of interests of a particular population.

Applying matrix scoring exercise in the field allowed participants to contribute, share and revise their knowledge in an open environment. This approach is more effective than conventional seminar using top-down direction (one talk and one hundred listen) mainly seen in the field. Availability of working only with a small group is an inconvenience of this approach and that needs more time-spending while applying it in the field.

A huge data which was collected through questionnaire-based survey and semi-structure interview during two years were used in benefit cost analysis. To our knowledge, PE was considered as a good approach in collecting disease related issues. The information collected from this approach was better than questionnaire-based surveys that we performed in parallel. However, a standardised questionnaire show good effectiveness in collecting of demographic, farm structure and husbandry management. The combination of those such approach assure data quality and quantity for economical analysis.

From the primary results of our pilot study where PE tools was integrated in surveillance system, those such tools were really effective as it helps to detect more cases, track back the source of infection and locate zone of secondary infection.

ii. Validation of participatory epidemiology methods in FMD surveillance and control systems

The quantitative assessment of participatory disease detection (PDD)

The Bayesian approach allowed us to assess the performance of the PDD at animal level. While the specificity of PDD was relatively high at 0.81, the sensitivity was only estimated at 0.59. In our study, we asked farmers to recall individual clinical signs of FMD on their cattle and this information was used as a source for PDD. In an FMD endemic situation such as Vietnam, where vaccination has been systematically applied in cattle, clinical signs of infection could be mild (Davies, 2002; Kitching, 2002) and might be undetectable by farmers. Therefore, the sensitivity of PDD method at animal level was computed as a low value. Within the limited data issued from our study, the value of PDD of suspected cases at herd and village level could not be addressed in the scope of our study. However, comparing with other study at herd level (Morgan et al., 2014) and village level (Bellet et al. 2012) using similar methods, we could suggest that PDD is more adapted in the context of an unvaccinated population with clear clinical signs, and for outbreak detection at herd or village level. Our result would also suggest that information provided by farmers should be systematically validated with the use of other methods as already mentioned in previous studies (Dukpa et al., 2011; Catley et al., 2012). The Bayesian approach used in our study could also be applied in other endemic countries.

To verify the presence of new serotypes of FMDV in the study zone, information that was provided by farmers during focus groups, we had to collect oesophageal samples. The laboratory results provided the supported evidence of the circulation of two new lineages named O/SEA/Mya-98 and A/Asia/Sea-97 in cattle population within our study zone in 2014 (Long An province). Due to limited resources, the virus serotyping is not always being performed for each suspected case by veterinary authorities, then information of some minor lineages circulating might be missing. Our finding which is based on PE information and laboratory testing could be seen as a support for surveillance activities. Strengthens and weaknesses of PE were taken into consideration during the development of pilot surveillance component tested in our study areas (Chapter 7).

Cross validation

Cross validation of PE was done in our study with two types of methodological triangulation as “within-method” and “across-method” triangulation (Catley et al., 2012). Within-method triangulation in our study was performed during focus group interviews. For example, the importance of a particular prevention method mentioned an early stage of the interview was checked later on using a rephrase question or using a participatory exercise or comparing result of two different exercises about one topic at the end of discussion. This type of triangulation was performed regularly during study period and improved with accumulated experiences of research team. A cross-method triangulation applied two or more different approaches to study the same research question. A visualized example can be demonstrated in the study of FMD sero-prevalence (Chapter 3) where clinical examination conducted by farmers was cross-checked by ELISA NSP 3ABC Priocheck to obtain the final diagnosis of FMD infection. Triangulation was performed by comparing finding of matrix scoring of animal disease symptoms (Chapter 2) with description of diseases referenced in textbook such as (Radostits and Done, 2007).

8.2.2. Adaptation of participatory epidemiology in Vietnamese context

i. Sample size

In our study, the sampling strategy was based on the selection of key informants and a risk based approach to identify sampling sizes. Based on the principle of saturation used in social sciences, our sampling strategy enabled us to capture the heterogeneity of opinion and information but not to be representative for the whole country. Our data might represent the population in Mekong delta but not the other regions such as Central Highlands or Red River Delta. This characterization of the approach helped us to focus on specific problems related to local behavior which are different between regions. We managed to collect information related to different research questions from a total of 113 focus groups in the first (54) and the second (69) field study, 466 individual interviews, and approximately 600 questionnaires from the population under study.

ii. Timing

Conducting interviews through participatory approach requires more time than by conventional approach, e.g. mostly with the use of a questionnaire (Danielson et al., 2012). However, time consumption of participatory approach yields to richness and depthness of collected information. While conventional surveys with questionnaire provide the least depth of understanding of rationales behind opinions, focus groups provide the most opportunity for developing an in-depth understanding of people's viewpoints. Participants have the opportunity to speak about their views in their own words, and the moderator can probe for more information. Group dynamics can lead to deeper discussion because each person's comments are elaborated on or challenged by others (Danielson et al., 2012). By organizing focus group first and then continuing with individual interviews, data can be used for different objectives (e.g. specific opinion about vaccination or declaration suspected cases affected by FMD). Individual interviews after focus group interview create more chances for listening and understanding each participant. Moreover, spending more time allows relationship between research team and farmers to happen and also help during further investigation such as sampling or information sharing of others case in surrounding farms.

iii. Data collection process

Sensitive data such as disease situation in farm, cost of disease management were collected through in-depth conversation and were naturally mentioned by farmers during conversation. It means that few questions about production situation on farm at the beginning were critical to break through fence between participants and motivate farmers to tell the story about their farm. Veterinary researchers have noted the importance of interviewer communication skills and pre-testing of questionnaires as a means to reduce non-sampling errors. However, pre-testing is often difficult to implement in remote areas and advice on questionnaire use in the veterinary literature often fails to provide specific information on the communication skills that were needed by interviewer or how these skills could be acquired (Catley, 2004). In general, PE is conducted in local languages using trained researchers and facilitators who obtain good communication skills and wide prior knowledge about the specific study site. Those requirement reduce non-sampling errors (Catley et al., 2012). Examples include the use of disease-symptom matrix scoring, disease-impact matrix scoring to visualize differential diagnostics made by farmers based on clinical signs and importance of impact contributed by each disease (Chapter 1). In those exercises, local name of diseases, clinical signs and impacts that are mentioned by farmers at the beginning of each conversation were used and maintained unchanged until the end of discussion.

8.2.3. Experiences sharing for further application of participatory epidemiology in animal health surveillance system

i. Data management and analysis

Unlike the collecting data from conventional survey which are easy and simple to be recorded and manipulated with some database software, data from PE requires some manipulation skills and more time to get them in the good format for analysis. For each discussion, at least 4-5 writing papers report were normally recorded. In order to extract data for each specific topic, each report needs to be evaluated several times. Then, based on a list of answers provided by farmers, some categorizations are needed to represent different groups of farmers' idea and opinions. Though an advantage of the participatory approach was the flexibility in data collection, several different exercises to collect data on one topic were performed to adapt with local situation and farmers requirement, e.g. pairwise ranking to identify importance of prevention method was performed at the end of discussion instead of proportional piling (scoring tool) which took more time. Ranking and scoring data on one topic challenges the data analysis because of their different nature. A standardize process as mentioned in chapter 2 and 4 was useful to manipulate those type of data. A wide range of classical and advanced statistic tests was used to analyze data in our study such as Kendall coefficient of concordance for non-parametric data, fisher exact test, principal component analysis, logistic regression model, hierarchic clustering on principal component and Bayesian statistic which provided qualitative and quantitative results to be interpreted. Those results prove the effectiveness of participatory methods in data collection not only for qualitative research but quantitative too.

ii. Biases and biases control

There are six potential biases mentioned by (J. C. Mariner and Paskin, 2000) in participatory approach application such as spatial, project, person, dry season, diplomatic and professional biases. Spatial biases are overcome with randomized village selection for visit and some selected villages were located in remote areas bordering Cambodia that can only be accessed on foot. Direct observation is also conducted after receiving information from focus group to validate them. Cross border visit is made in some cases to interview some Vietnamese farmers who raise their herd in common pasture area in Cambodia. Project biases were not present in our study as this is an independent study conducted in this zone. Person biases were limited in our study with the help of some technique like selecting the most vocal persons in group interviews and proposing to have an individual interview. This helped participants in group to share their point of view. The place and time for interview are chosen to create comfortable environment for discussion.

iii. Other limits of our study

The investigated study zones did not represent whole of the socio-economic context of Vietnam. For example, all of the interviews were conducted with participants belonging to the ethnic group named *Kinh* (dominant group) and *Khmer* in Vietnam, none participants of other minority groups were included. Study zone located in Southern part of Vietnam, could not be representative for other economic regions in Center or Northern part. Expanding study in other socio-economic contexts might have different results while the study using participatory methods replying on local knowledge.

iv. Other experiences during the implementation of PE research in Vietnamese context

Usually participants were attending meetings to listen and ask questions related to their problems at the farm, rather than to share their knowledge. This attitude was originated from the attendance of other meetings organized by famers association, pharmaceutic Companies including experts' participation. Having a chance to communicate with experts motivate them to join a meeting. While invitation of participants in our study is done with the help of commune veterinarians, some of them use this reason (archiving some new information from expert) as the first place to invite people come to the meeting which is not meet research objective (understanding local knowledge). Therefore, some participants did not stay until the end of the meeting or were complaining about the objective of the meeting not being what they were expected. To overcome this phenomenon, a clear description of points to be discussed for commune veterinarians before the organization of the meeting as well as for participants during the meeting is critical to improve their participation. During an interview, some participants will try to ask several questions related to their own farm' problems. When answering those kind of questions you may block the group discussion flow and attention of the others participants. Researchers should provide the answers (if she/he can) at the end of the group discussion and honestly repeat the reason why they conduct this discussion. Farmer like to share information when they feel that their experiences are carefully listened and when they feel their position is considered as equal as the researcher team. Otherwise, any reaction from research team that make farmer feel being underestimated while sharing their experiences might block the conversation immediately. This point was clearly demonstrated by other authors as part of “understanding local cultures and context” in manual of practice PE in the field (Catley et al., 2012; J. Mariner and Paskin, 2000).

Among the five factors affecting the sensitivity of surveillance (OIE, 2014), two factors relate to the report of an event into the system and the transfer of information. When using participatory methods, a great number of suspected cases had been recorded. However, some farmers were avoiding to talk about information on disease suspicions, especially during the first contact between the research team and farmers who are neighbor of a suspected farm. Presence of local agents within the research team might be helpful or useless to overcome this problem depending on the relationship between local authorities and farmers. According to Delabouglise et al. (2015), public veterinarians were classified as one of the actors who received the least information from farmers, for various reasons such the fact that no useful actions are taken from public veterinarians to help the farmers. Solving this problem might improve the quantity and the quality of information shared between actors. A good relationship showing respect to farmers and their knowledge is needed for local agents who are involved in participatory surveillance. The used of participatory methods requires considerable problem solving skills and the ability to be adaptable which means learning of not only knowledge but also behaviors (Jost et al., 2007). For this reason, even an experienced veterinarian need to change his behavior to be able to apply participatory methods. Transfer of information along the surveillance system is a critical point for improvement. In our pilot study, sometimes researchers have been requested not to provide suspicious information to the province level during the time of the study (only sharing at district level who will then decide to report or not to the superior level) or to delay the reporting for at least a month after the observation day. The tendency in this case is to resolve the problem at commune or district level and report only index cases after that. This is an under – reporting problem in surveillance system (Madin, 2011) and in some case, a serious outbreak might occur due to imprecise, insufficient control methods.

When applying participatory surveillance in pilot area, information of some suspected cases were lately recorded sometimes more than 60 days after the observation day. This limit of our study was link to our limited human resource, having only two teams of four people daily investigating in two districts during four months. The increase of involved peoples in system may help to overcome this problem. More peoples need to be involved in the surveillance system during high risk periods or immediately after having prior information of index cases in one location to be able to capture disease situation. Late information has minor usefulness in disease investigation but give valuable tracks of disease transmission and its relative impacts on farmer's livelihood. Those information can also be useful for hotspot area mapping contribution in further surveillance.

8.3. Conclusions

This thesis adds several original contributions to the field of FMD surveillance and control. First, thanks to a series of in-depth investigation of cattle and pig production type, it assesses the wide range of prevention methods used at local level, the socio-economic opinions focused on vaccination used as well as the benefit-cost of this method for these production types. This research also proposes a new approach to take into account surveillance system of FMD in Vietnam. This thesis contains an in-depth exploration of the PE methodology such as tools and relative statistical analysis. The latter issue provides the material for implementing of PE in livestock production.

Several conclusions can be drawn from this thesis. First, the livestock production issues, disease impacts and farmer prioritisation on important diseases were different according to the production types. Especially, FMD was ranked as the first, the second and the forth in prioritized list of disease need to be control in dairy, beef and pig farm, respectively. Indigenous knowledge at local state has its value and helped farmers deal with complex situation in their herd.

Second, first experiment to apply PE to FMD surveillance in Vietnam showed that the sensitivity and specificity of PE at animal level was not as high as expected. However, the informative results obtained proved its value and cost-effectiveness as an epidemiological tool in developing countries. The framework of analysis developed from this thesis (chapter 3) is relevant to the study context.

Third, using various tools of PE approach and multivariable analysis, our study demonstrated a multivariate perception of risk factors of FMD introduction into farms, the variation in socio-economic impacts on livelihood of this disease for each production types and variation in prevention methods used by farms. It was found that FMD is not necessarily the worst risk for them and the ways farmers applied the prevention method was strongly depended on farmers' viewpoints.

Forth, using the Q methodology and prior information on advantages and inconveniences of FMD vaccination, the perception of farmers on vaccination used was demonstrated. The results highlighted the fact that farmers in our study zone are aware of the objective of vaccination, its role and its value in preventing disease. The prevention by vaccination was also understood to be cheaper than treatment costs and vaccines provided by governmental authorities were perceived as being of good quality. However, a minor part of the population expressed doubts regarding vaccination as a prevention method. These results illustrated critical elements that influence the acceptability of the

FMD programme by farmers in Vietnam and allowed certain recommendations to be developed on how to improve the involvement of farmers in national FMD control and prevention program.

Fifth, the application of benefit-cost analysis for FMD biannual vaccination strategy compared to non-used vaccination strategy demonstrated that this alternative strategy is economically efficient for cattle farmers in Vietnam. This also showed that such program was more profitable for dairy farmers than beef farmers. Sensitivity analysis of benefit-cost analysis always showed a benefit-cost ratio higher than 1 in case of increase of vaccination cost and decrease of market price of milk and slaughter cattle.

Finally, integration of PE tools in surveillance of FMD in our pilot study is considered as a strong support tool to detect more suspected cases for conventional surveillance system. The effectiveness of participatory surveillance to detect FMD outbreaks in Vietnam has been proved and a series of participatory tools applicable in the field was proposed to the veterinary authorities.

8.4. Perspectives

The thesis address the two mains objectives proposed at the beginning, but complementary studies may be performed as suggested in recommendation. In addition, the study result show some limits of the PE approach as it has been recently used in the study context, and some conceptual improvement are needed. Some clear recommendations can be drawn.

Farmers' competences are valuable at local level and could be helpful for surveillance activities in order to differential diagnostic between FMD and other diseases in the field. Veterinary authorities should take into consideration those benefits in the FMD surveillance activity.

A similar study using disease symptom matrix scoring and disease impact matrix scoring has not been performed with commune veterinarians in order to compare knowledge and competences between actors, farmers and veterinarians in disease recognition as well as impact estimation. Such study should be performed in order to evaluate the agreements and disagreements between two closest actors directly implied in animal health management.

The study result on the local socio-economic issues demonstrated some critical points influencing on the effectiveness of FMD vaccination program (Chapter 4 and 5). Those results should be communicated with other actors directly implied in animal health management such as decision markers, veterinarian authorities (communal, district and provincial level). Those results also should be taken into consideration in future policies to assure the effectiveness of FMD vaccination program. The results of our study can also be used as material for educational purpose such as farmers' perception about a predefined issue.

The work of determination of FMD sero-prevalence is one of the first experiments to apply PE to animal health in Southern Vietnam, may be applicable in other developing countries where FMD situation is comparable to our study area. This work used a latent class Bayesian model that combined PE and serological data at animal level. Based on the sensitivity and specificity of PE approach, we suggest that this method should be used at herd and village level in further study to provide more useful information in terms of animal disease surveillance and control. Other laboratory test such as virus neutralisation or RT-PCR could be replaced by ELISA as a gold standard test to cross-validate PE information in order to avoid the influence of some confounder factors such as age, vaccine type used in the ELISA result as discussed in chapter 3.

The benefit-cost analysis of biannual vaccination strategy showed that investment in FMD prevention can be financially profitable for farmers. Additional benefit-cost analysis study of vaccination strategy at national level would be required to evaluate and adapt the national strategy if needed to achieve the eradication of FMD in Vietnam. It could be used in awareness programme to motivate farmers in regular participation in vaccination campaign. Chronic FMD impacts should be taken in consideration in further study to test the hypothesis that binannual vaccination strategy probably increases the estimated saved costs and benefit-cost ratio of FMD vaccination for cattle production. Further benefit-cost analysis focused on small-scale pig production should be addressed to answer the question on the economic benefit of pig farmers for applying FMD vaccination. In fact, a part of farmers' population did not perceive vaccination as a prevention method of choice. They might underestimate the consequences of FMD in their herds because they never experienced it before. Complementary study on benefit-cost of FMD vaccination can demonstrate to farmers the benefits of this strategy (e.g. increased revenue, decreased stress level) in cases of occurring outbreaks in their zones.

The framework of PE methodology developed in our study such as semi-structure interview, matrix scoring, pairwise ranking, Q methodology, flow chart, participatory map, timeline could be generated and applied in other study context and other production types to access the local need and the local knowledge of farmers. Application of PE in the field allowed participants to contribute, share and revise their knowledge in an open environment which is more effective than conventional seminar using top-down direction (one talk and one hundred listen) mainly seen in the field. The widely application of PE is considered as a chance to test its effectiveness in different socio-economic and demographic context.

Deployment of FMD surveillance system

For wider application, we strongly recommend participatory tools such as proportional piling, pairwise ranking and simple seasonal calendar to be used firstly in primary study in a new zone to collect prior information about local practice and agricultural activities. Participatory map and timeline could be used in disease outbreak investigation. Those tools are easy to manage through a short formation that can be organized for all of actors collecting information. Some factors need to be considered while deciding PE tools for different levels are budget for active surveillance (training, maintain system, allowance and transport), time investment, benefit and constraints of farmer and veterinarians. Based on our knowledge of Vietnam husbandry context and experiences during implementation of pilot study, we propose a scenario involving one year surveillance period, at national level and in hotspot area focused on the detection of new suspected cases. In this scenario, special program (through financial incentives or educational campaigns) could be implemented to encourage farmers - main source of information - to practice vaccination, quarantine, notify the cases in their farms and treat their animals rather than sell animals when information on disease suspicions is shared in their neighbourhood. When appropriate, both public and private veterinarians should be part of a system in which both informal and formal information is shared. Private veterinarians who work for dairy and pharmaceutical companies are also the key informants for collecting information. Previous sociological studies emphasized the need for public veterinary surveillance systems to establish bridges with the private sector (Desvaux and Figuié, 2011; Delabouglise et al., 2015). They should be the main targets of programs aimed at diversifying information sources of public surveillance systems such as participatory surveillance (Mariner et al., 2014). They need to be regularly and clearly informed about objective of surveillance, disease management legislation implemented in place. Validation of suspected cases conducted by public veterinarian needed to be done in indirect ways by visiting surrounding farms, then asking disease situation in the zone for second source of information or repeating management control realized in the zone first to encourage farmer to declare the cases in their farm. Those methods are believed that hidden secret for key informants. Veterinarians in commune and district of hotspot area who will be main actors in data collection will receive training on the use of PE tools such as informal interview, timeline, pairwise ranking and participatory mapping. Farmers can consult and receive help at the same time of declaration. Local veterinarians can earn benefit from consultation, treatment of index cases and animals in the surrounding farms as well as the respect of farmers in their zone. A key person from epidemiological department of provincial veterinary services who can play as facilitator should be included in disease verification and investigation team. This person will collaborate with the field team, supervise them, analyse collected data and propose further investigation to capture the most relevant information of an event. Garnering information in real time during investigation is also useful for discussion and implementation of applicable control methods at each level as well as creating new relationship with local farmers. Several workshops on PE approach for decision-makers are proposed to help these managers use PE tools and participatory surveillance output directly and appropriately (Jost et al., 2007). Generating data could be maintained as part of a single national database that is consistent with standard practices and allows transparent and timely reporting of disease (Jost et al., 2007).

Maintaining surveillance system mainly in hotspot areas and improving surveillance activities during risk period might brutally decrease investment inconvenience. While public veterinarians need to spend more time to investigate and detect more cases with helps of PE tools, regular formation at least once per year need to be planned.

Compensation for those local agencies activities need to take into account to maintain effectiveness of the system. A completed definition of suspected cases of FMD which combine local knowledge and expert opinion should be used in the field to enhance the sensitivity of participatory approach. The specificity of approach can also be improved with help of pen-side test (e.g. lateral flow devices for FMD antigen detection) perfomed in the field by veterinarians (district or province level) and laboratory tests such as ELISA 3ABC and/or RT-PCR. Those laboratory tests protocol can be implemented at province level as appropriate.

Prior study demonstrated that all of stakeholders in surveillance system need information which could be used in their own decision making. Therefore, investigation results need to be feedback to the entire of stakeholders. Moreover, motivation of stakeholders in continuation of information sharing can be improved when their information is appreciated by the surveillance system. Local stakeholders are good at collecting information in one particular zone such as a commune but they require valuable information from other zone. Sharing information about disease situation of other zone collected by surveillance system facilitate discussion of what they know in their farm or particular zone. For farmers, they can be informed using short discussion several days after first investigation in order to confirm disease in their farm as well as to follow up the effectiveness of their control actions implemented in farm. Traders can be benefit while they are informed about disease situation for safety trade (decrease the risk of being punished due to trade sick animals). Veterinary authorities can update disease situation in their zone to verify and modify control measures. This is a critical point for maintain surveillance system in Vietnam context.

FMD, as an infectious disease can transmit without border. Therefore, transmission of a FMD case to other zone not only depends on relative conditions in this zone (population, climate) but also disease situation in other zone having population connection. FMD control at region level with surrounding countries is extremely difficult. Different policy of each country without cooperation might subsequently block the success of regional policy. In fact, coordination of different policies is really difficult while each country differ in politics and economic. In this case, participatory game concept can be useful to contribute to obtain an optimal strategy despite the cooperation of different communities. The selection of control measures with helps of modelling and surveillance data can optimize disease control policy in real time.

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