LIVE STOCK DISEASE SURVEILLANCE SYSTEM EVALUATION: A COST-EFFECTIVENESS STUDY FOR DUTCH CLASSICAL SWINE FEVER SURVEILLANCE

Xuezhen Guo[1,*], G.D.H. Claassen[2], W. Loeffe[3], A.G.J.M. Oude Lansink[1], H.W. Saatkamp[1]

[1] Business Economics Group, Wageningen University, The Netherlands

[2] Operational Research and Logistics Group, Wageningen University, The Netherlands

[3]Central Veterinary Institute of Wageningen UR (CVI), Virology Department, P.O. Box 65, 8200 AB Lelystad, The Netherlands

Corresponding author: Xuezhen Guo E-mail address: xuezhen.guo@wur.nl

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Abstract
This paper presents a comprehensive cost-effectiveness analysis of CSF surveillance in the Netherlands, taking into account the specialized Dutch pig production chain structure and a wide range of possible surveillance system components. The results indicate that the routine serology related SSCs is not cost-effective for early detection of CSF, while conducting PCR tests on the dead animals is cost-effective.

Keywords: classical swine fever; surveillance system; cost-effectiveness analysis; stochastic simulation modelling

Introduction
Classical Swine Fever (CSF) is a highly contagious pig disease that causes considerable impacts, e.g. economic losses and impaired animal welfare (Meuwissen et al., 1999; Saatkamp et al., 2000; Hop et al., 2014). Two key factors that determine the impacts of a CSF epidemic are 1) the quality of the surveillance system (i.e. early detection of CSF) and 2) the effectiveness of the control strategy (i.e. rapid eradication). Hence, the main aim of pre-epidemic surveillance is to minimize the High Risk Period (HRP) and the number of the infected farms at the end of this period (Klinkenberg et al., 2005; Guo et al., 2014). Consequently, analysis of CSF surveillance should be focused on these performance parameters. Moreover, given the budget constraints for CSF surveillance, such an analysis should include the economic aspect as well.

Previous studies (e.g., Elbers et al., 2002; Backer et al., 2011) increased the insights in CSF surveillance in the Netherlands substantially. However, they all lack one or more of the following aspects: comprehensiveness of surveillance (i.e. coverage of different surveillance system components), cost-effectiveness analysis, and/or trade-offs between surveillance performance and costs from a (national) decision making point of view.

The current paper attempts to overcome these shortcomings. The Dutch CSF surveillance system is analyzed using a modelling approach based on the general principles proposed by (Guo et al., 2014). The aim is to provide a comprehensive cost-effectiveness analysis of Dutch CSF surveillance from the decision-making viewpoint of the Dutch government.

Materials and methods
The used CSF surveillance simulation model is stochastic and dynamic, and captures the specialized structure of the Dutch pig production chain by distinguishing three different types of farms (i.e. farrowing, finishing and farrow-to-finish), which are derived from a dataset of Dutch pig farms in 2010, provided by the Animal Health Service (AHS). The main structure of the model is presented in Figure 1 and consists of four linked modules.

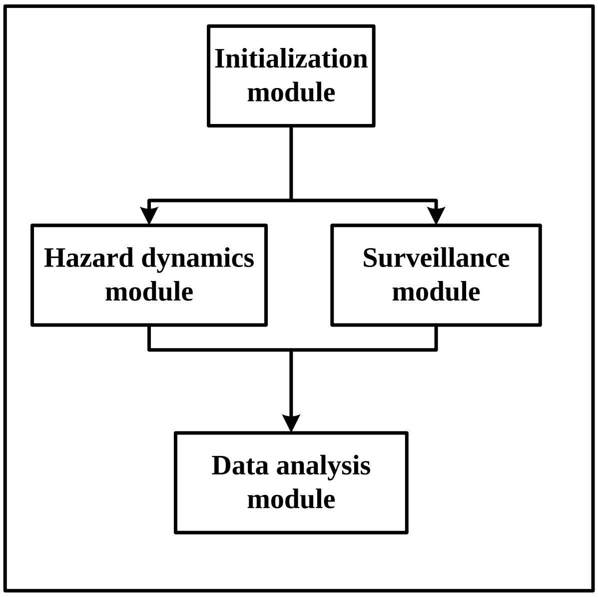

Figure 1: The main structure of the model

The Initialization module includes loading and initializing different sets of input parameters and matrices. The CSF dynamics module simulates the development of CSF in Dutch pig population at three interrelated levels: (1) CSF symptoms within individual animals, (2) disease spread between animals within farms and (3) disease spread between farms. Parallel to this, the surveillance module simulates the daily surveillance activities in the pig population. Finally, the simulated and stored data are analysed in the data analysis module. A surveillance setup (of the surveillance system) is defined as a combination of surveillance system components (SSCs) (a SSC is a specific surveillance activity) with their respective levels of intensity (e.g. sampling frequency and size). The default surveillance setup for Dutch CSF includes seven SSCs: (1) Daily clinical observation by the farmer, (2) Veterinarian inspection after a call, (3) Routine veterinarian inspection, (4) Pathology in AHS, (5) PCR on tonsil in AHS, (6) PCR on grouped animals in CVI, and (7) Confirmatory PCR by NVWA. There are also three alternative SSCs that have the potential to be applied in the furture, including (8) routine serology in slaughterhouses (9) routine serology on sow farms, and (10) PCR on rendered animals.

The starting point is the default Dutch CSF surveillance setup (denoted as D) which provides a baseline for further comparison. Then, one of three alternative SSCs is in turn added to the default surveillance setup to create new surveillance setups, D+SL_5, D+$R_{6,3}$ and D+S_{12}. SL_5 denotes the routine serology in slaughterhouses with the sample size "5 animals per batch per ten days"; $R_{6,3}$ denotes PCR on rendered animals with the submission thresholds: (1) 6 dead animals in a day for farrowing and farrow-to-finish farms, (2) and 3 dead animals for the finishing farms; S_{12} represents the routine serology on sow farms with the sample size 12 blood samples per farm per 4 weeks. Next, two of the three alternative SSCs each time are added to the default surveillance setup. Afterwards, all SSCs are included to create the most intensified surveillance setup, D+SL_5+$R_{6,3}$+S_{12}. More new surveillance setups are created through modifying the sample sizes or submission thresholds for the alternative SSCs. For example, surveillance setup, D+SL_{10}, is yielded by increasing the sample size to 10 animals per batch per ten days. In total, there are 14 surveillance setups to be analysed, including: D, D+SL_5, D+$R_{6,3}$, D+S_{12}, D+SL_5+$R_{6,3}$, D+SL_5+S_{12}, D+$R_{6,3}$+S_{12}, D+SL_5+$R_{6,3}$+S_{12}, D+SL_{10}, D+SL_{15}, D+$R_{6,1}$, D+$R_{1,1}$, D+S_{24}, D+S_{36}. For each surveillance setup, 1,000 iterations of simulation are conducted to obtain the technical performances and the annual surveillance costs, based on which the efficient set of surveillance setups is derived.

Results

The 10th, 50th and 90th percentiles of the duration of HRP for each surveillance setup as well as the corresponding annual surveillance costs are presented in Figure 2.

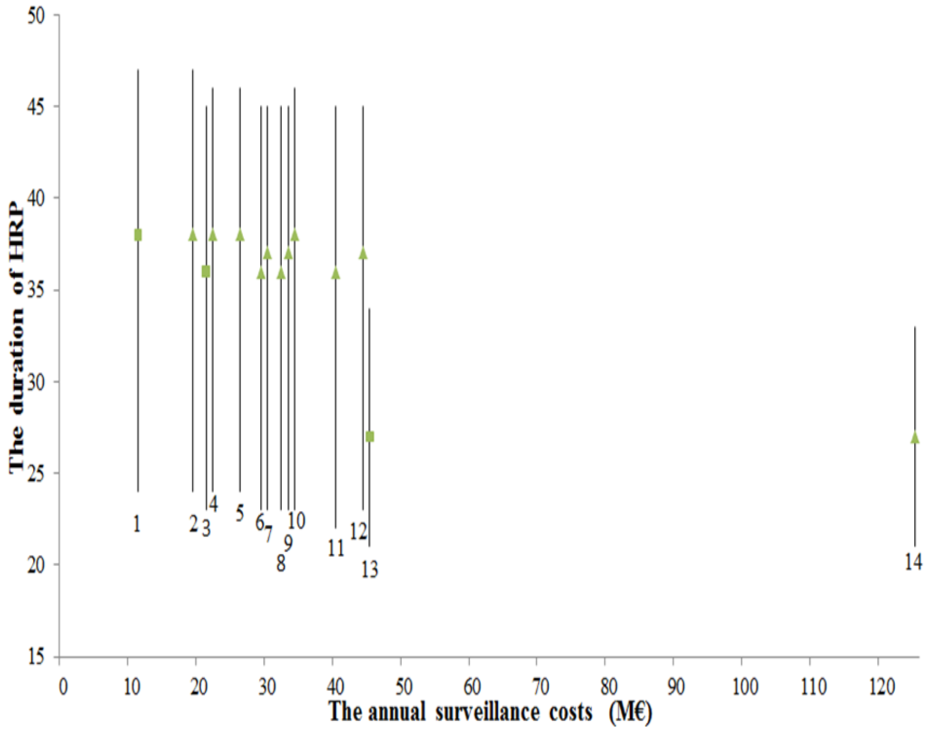

Figure 2: The 10th, 50th and 90th percentiles of duration of HRP in the default scenario: D: 1, $D+S_{12}$: 2, $D+R_{6,3}$: 3, $D+SL_5$: 4, [5]$D+S_{24}$: 5, $D+R_{6,3}+S_{12}$: 6, $D+SL_5+S_{12}$: 7, $D+SL_5+R_{6,3}$: 8, $D+SL_{10}$: 9, $D+S_{36}$: 10, $D+SL_5+R_{6,3}+S_{12}$: 11, $D+SL_{12}$: 12 , $D+R_{6,1}$: 13, $D+R_{1,1}$: 14.

The median of the duration of HRP under the default surveillance setup (D: 1, Figure 2) is 38 days, and the 10th and 90th percentiles values are 24 and 47 days respectively. Adding SSC "routine serology on sow farms" with the sample size 12 blood samples per farm per 4 weeks to the default surveillance setup ($D+S_{12}$: 2, Figure 2) does not have an impact on the duration of HRP but causes 7.5 million euro extra annual surveillance costs. Even though increasing sample size to 24 and 36 blood samples per farm per 4 weeks, the median of duration of HRP is not affected. Including the "PCR on rendered animals $R_{6,3}$" to the default surveillance setup ($D+R_{6,3}$: 3, Figure 2) reduces the median of duration of HRP by two days (36 days) and increases the annual surveillance costs by 10.5 million euro. In this way, for each surveillance setup, the HRP and the annual surveillance costs are plotted. Based on the median of the duration of HRP and the annual surveillance costs, subsequently, a set of efficient surveillance setups for the moderately virulent strain are obtained: (D: 1, Figure 2), ($D+R_{6,3}$: 3, Figure 2), and ($D+R_{6,1}$: 13, Figure 2). The medians of the efficient surveillance setups are square-shaped. The two efficient alternative surveillance setups contain SSC "PCR on rendered animals".

The numbers of the infected farms at the end of HRP are presented in Figure 3.

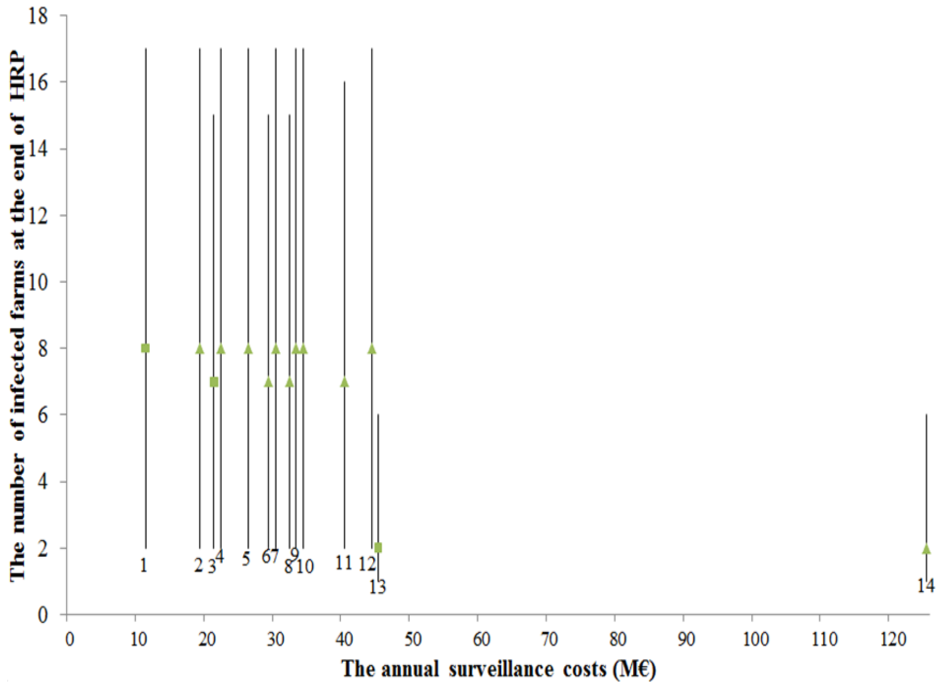

Figure 3: The 10th, 50th and 90th percentiles of the number of infected farms at the end of HRP in the default scenario: D: $_1$, D+S_{12}: 2, D+$R_{6,3}$: 3, D+SL_5: 4, D+S_{24}: 5, D+$R_{6,3}$+S_{12}: 6, D+SL_5+S_{12}: 7, D+SL_5+$R_{6,3}$: 8, D+SL_{10}: 9, D+S_{36}: 10, D+SL_5+$R_{6,3}$+S_{12}: 11, D+SL_{12}: 12 , D+$R_{6,1}$: 13, D+$R_{1,1}$: 14.

Since the variation of the number of infected farms between surveillance setups is smaller than that of the duration of HPR, the same efficient set is retained.

A sensitivity analyses was conducted for the factors that might have large impact on the results. Specifically, the values of the within- and between-farm transmission parameters were changed; the speed and severity of expression developments in the diseased animals were varied (through modifying the CSF expression matrices); the sensitivities of the ELISA and PCR tests were changed. Such parametric changes shortened or lengthened the absolute durations of HRP for all surveillance setups following the same pattern, but did not affect the efficient set of surveillance setups. To save space, those results are not presented here.

Discussion

This paper presents a comprehensive study on the cost-effectiveness analysis of Dutch CSF surveillance. The CSF surveillance simulation model is used, which have been extensively addressed by the previous study (Guo et al., 2014). The results show that the routine serology related SSCs is not effective for early detection of CSF because 1) the occurrences of the clinical symptoms are much faster than the occurrences of “antibody”, and 2) it takes a long time to obtain a positive result from the serological tests before a report to NVWA (Netherlands Food and Consumer Product Safety Authority) for confirmation tests. The SSC “PCR on rendered animals” has obvious impacts on the reduction of the duration of HRP and the number of infected farms at the end of HRP. Since the infection of CSF greatly increases the mortality of the infected animals, conducting PCR tests on the dead animals can profoundly enhance the detection probabilities of CSF. Hence, both of the efficient alternative surveillance setups contain the SSC “PCR on rendered animals”.

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