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ECONOMIC EVALUATION OF FOOT-AND-MOUTH DISEASE CONTROL STRATEGIES USING SPATIAL AND STOCHASTIC SIMULATION

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Lors d'un foyer d'une maladie contagieuse animale comme la fièvre aphteuse par exemple, les acteurs de la police sanitaire confrontés à beaucoup d'incertitude quant au développement du foyer et à l'efficacité de la stratégie de contrôle, doivent prendre des décisions sur la manière d'agir. Le testage des différentes stratégies possibles est impossible et les simulations informatiques sont donc les seuls outils adaptés pour l'évaluation épidémiologique et économique des différentes stratégies de contrôle. Un modèle développé pour la lutte contre la fièvre aphteuse est présenté dans cet article en partant du point de vue que l'évaluation économique des stratégies de lutte correspond à la simulation de la diffusion de la maladie. Le modèle InterSpread, spatial et stochastique simule la diffusion de la fièvre aphteuse dans une zone. Le point de départ est l'information sur la localisation géographique et le nombre d'animaux de chaque ferme. La maladie est diffusée par différents mécanismes (mouvements d'animaux, de personnes et de véhicules, et diffusion aérienne). Dès la détection du premier cas, plusieurs mécanismes de lutte sont mis en place (par exemple abattages préventifs, contrôle et surveillance des mouvements, vaccinations) pour réduire la diffusion. Les incertitudes concernant la diffusion de la maladie et les mesures de lutte ont été simulées grâce à un modèle de Monte Carlo. Les pertes économiques ont été calculées pour quatre catégories : 1/ pertes dues à l'abattage des élevages infectés, 2/ coûts additionnels, a/ des fermes ayant la maladie, b/ de la restriction des mouvements dans la zone, 3/ les pertes commerciales, 4/ les coûts de l'organisation de la lutte ont été quantifiés pour différents niveaux de la filière. Les résultats des calculs pour une zone pilote sont montrés, incluant la sensibilité de l'analyse et la comparaison de différentes stratégies. Le modèle est très sensible au respect des différentes méthodes de contrôle à évaluer et aux différentes situations envisagées.

INTRODUCTION

Outbreaks of contagious animal diseases, such as foot-and-mouth disease (FMD) and classical swine fever (CSF) can be very costly, especially for exporting countries such as the Netherlands and New Zealand. In case of an outbreak rapid and adequate elimination of all virus sources has the highest priority. Policy makers are faced with many uncertainties regarding the development of the outbreak, expected efficiency of control strategies and possibility of export bans set by other countries. Despite these uncertainties they have to make decisions on how to control the outbreak. Experiments with different control strategies are not feasible, and therefore computer simulation is the adequate tool to evaluate the epidemiological and economic consequences of different options.

A set of models is being developed that simulates the technical and economic consequences of different control strategies for outbreaks of FMD taking into account these uncertainties. Policy makers can use this information to prepare and make their final decisions about what control strategies to apply. In terms of managing an FMD epidemic using stamping-out, strategies include adjusting the size of protection and surveillance zones around diagnosed infected herds, instigating pre-emptive slaughter of dangerous contact herds and implementing a ring vaccination buffer. The modelling approach is part of EpiMAN, a decision support system for the control of FMD. EpiMAN has been developed in New Zealand (Sanson, 1993) and its applicability for the European situation has been investigated within a European Union funded project (EpiMAN-EU; Jalvingh et al., 1995). Currently, the system is further modified to suit Dutch conditions and will be implemented for use by Dutch disease control authorities (EpiMAN-NL).

The modelling approach for the economic evaluation of FMD control strategies requires simulation of (a) disease spread between farms, (b) direct costs of eradication and (c) indirect costs due to export bans. In that, the simulation of disease spread serves as starting point for the economic calculations. Input parameters on disease spread are especially difficult to obtain, since (data about) epidemics of FMD are scarce. Therefore, quantification of the uncertainties in the model output that result from uncertainties in the input is absolutely essential.

OUTLINE SIMULATION OF DISEASE SPREAD

The spatial and stochastic simulation model InterSpread simulates within a region from day to day the spread of FMD between farms. Starting point of the simulation is infection seeded to an index farm. Via different spread mechanisms, i.e. (a) movements (animals, people, vehicles, material), (b) local/neighbourhood spread and (c) airborne spread, the infection can be spread to other farms, and if infected the further spread is simulated for these farms as well. Once diagnosis of the first infected farm is made, several control mechanisms can be put

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into place (e.g. slaughter, tracing, surveillance, movement control, pre-emptive slaughter, vaccination). Starting point is data on the location of individual farms and corresponding animal numbers. The geographic location is used in simulating disease spread and its control (e.g. which farms are in the surveillance zone and which in the protection zone around a certain farm).

All processes (disease spread and its control) are modelled stochastically using Monte Carlo simulation, i.e. random numbers are drawn from appropriate probability distributions and the outcome determines what happens (i.e. whether a movement results in infection depends on the probability of infection and the random number drawn). In this way, the model mimics what happens in real life; one can be very lucky in controlling the disease or one can be very unlucky. In order to get reliable results replicate calculations are necessary, each of them representing a possible pattern of the outbreak. The main output results of the model are the probability distributions of number of affected herds, the number of days the outbreak lasts and the number of farms that are faced with movement restrictions. These output results are used in calculating the economic losses.

The conceptual model was developed by Sanson (1993) as part of EpiMAN-NZ. Within EpiMAN-EU InterSpread has been further developed and modified to suit Dutch and EU conditions. The modifications implemented were related to differences between New Zealand and NL/EU in (a) contingency plan, (b) structure/organisation of animal production and (c) data availability. The model kernel has been programmed in Borland C++. The user interface is made in Microsoft Access.

RESULTS SIMULATION DISEASE SPREAD

A prototype version of the model was used to carry out preliminary calculations. Calculations, with 50 replications, were carried out for an area of 50*50 km, with the average Dutch farm density (2 per km2). So in total almost 5000 farms (dairy, pig and mixed farms) were situated in the area. The first infected farm was located in the centre of the area. The control strategy applied represented the basic EU strategy. Since the results are rather skewed, next to the mean number of infected herds, parameters reflecting the variation in number of infected herds are presented. In the basic situation the number of infected herds varies from 2 to 140. On average 39 herds were infected, but the standard deviation was large (31.9). In 50% of the cases the number of infected herds was 32 or less and in 6% of the cases the number of infected herds was above 100. The time period with controls in place lasts on average 50 days (ranging from 37 to 76 days).

Sensitivity analysis

Part of the parameters in InterSpread are unknown or difficult to estimate. Therefore, sensitivity analysis is important to find out which parameters have a large impact on the outcome. An extensive sensitivity analysis of the model is currently undertaken. For illustration purposes a few results are shown in Table I. An increase in the number of animal movements with 10% (from on average 2 per week to 2.2) results in a 17% increase in the average number of infected herds. When the daily probability of local spread (radius of 1 km) is increased with 10% (0.011 instead of 0.01), the number of infected herds is only slightly increased. When animal movements are reduced by 50%, the size of the epidemic is strongly reduced from on average 39 to 13 infected herds. In the basic situation the majority of movements takes place within 5 km of the infected herd. By shifting part of these movements to distances between 5 and 30 km, the average distance of movements is increased from 7.1 to 12.7 km. As a result the number of infected herds increases, since less herds that have been infected through movements will be in the zones with movement control (max. 10 km radius) around the herd that infected them.

Table I

Number of infected herds for basic situation and alternatives in which input parameters are chang

Situation	Average	SD	Minimum	Median	95% Perc.	Maximum
Basic	39.4	31.9	2	32	108	140
Animal movements +10%	46.0	37.6	1	35	131	147
Local spread +10%	40.6	32.5	2	34	111	139
Animal movements -50%	12.7	9.5	1	11	27	51
Distance movements +50%	54.1	39.0	6	47	118	206

Economic comparison of control strategies

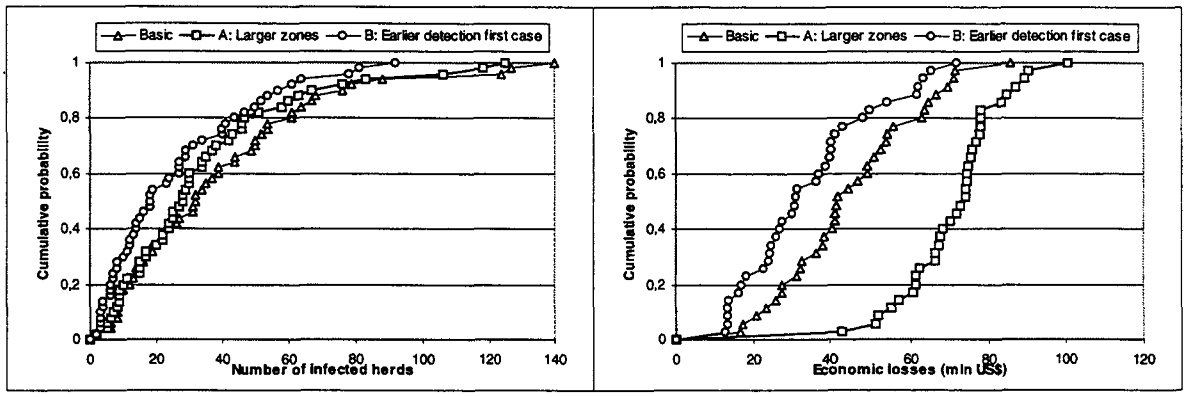
Losses due to an outbreak can be distinguished into four categories: 1) losses due to slaughtering of infected herds, 2) additional losses on a) diseased farms, and b) in the area with movement controls, 3) trade losses and 4) organisational costs of disease control. Meuwissen et al. (1997) developed a spreadsheet model to calculate these losses for various stages of the livestock production chain (e.g. farms, traders, slaughterhouses, dairy plants), except for trade losses resulting from reactions of other countries. However, the costs of buying and slaughtering animals from farms which are not infected but prohibited to deliver their animals were included.

Epidemiological and economic results of the basic situation will be compared with two alternative strategies. In strategy A the radius of the zones with movement control is doubled (protection zone from 3 to 6 km and surveillance zone from 10 to 20 km). In strategy B the detection of the first case is on average a few days earlier. Figure 1 gives for the basic strategy and for strategies A and B the cumulative probability distributions of the number of infected herds and the total economic losses.

Installing larger zones with movement control (strategy A) results in a small reduction of the number of infected herds (from 39 to 35) and the maximum changes from 140 to 125. Due to the presence of larger zones, more farms are faced with movement controls, which results in much higher costs (72 mln US$ versus 45 mln US$ in the basic situation). When interpreting these results one should take into account that the area is only 50 by 50 km. When the basic strategy and strategy A are compared for a situation in which the average distance for movements is increased (as in Table I), then the effect of strategy A is larger; the reduction in infected herds is 20% instead of 10% in the basic situation.

For strategy B the interval between the first introduction of the disease in the country and the first diagnosis is 15.7 days (SD 1.3), and was 18.0 days in the basic situation (SD 2.5). Due to the earlier detection of the first case the number of infected herds is reduced with 33%. In 50% of the cases there are less than 18 infected herds, instead of 32 in the basic situation. Figure 1 shows very clearly that the extreme values are no longer occurring, resulting in a reduction of the economic losses (35 mln US$ versus 45 mln US$ in the basic situation). Fewer farms need to be emptied and controls are in place during a shorter period of time. The difference between strategy B and the basic situation gives an indication of the costs that could be made to realise an earlier detection.

Figure 1
Cumulative probability distributions of number of infected herds and economic losses for basic and two alternative strategies.



FUTURE OUTLOOK

The simulation model for spread of FMD is currently validated using sensitivity analysis and expert opinion. Some input parameters already showed to have a large effect on the outcome. Often the values of these parameters are quite uncertain, and it will be difficult to get more precise estimates. Sensitivity and uncertainty analysis are therefore important tools when evaluating control strategies. It is especially important to study the ranking of the control strategies in relation to different sets of uncertain, but important, input parameters.

The trade losses due to reactions of other countries (export bans) will be included in the model. Starting point for that is the export model developed by Berentsen et al. (1990), which was used to compare the economics of different control strategies under a situation with and a situation without annual preventive vaccination. In analysing the results of control strategies, decision rules (such as stochastic efficiency criteria) will be applied to show the impact of various risk attitudes of decision makers in determining what control strategy to apply. The modelling approach can be used to test control strategies prior to implementation during an actual FMD outbreak, and can also be used as a research and training tool in periods without outbreaks. The influence of farm/animal density, control strategy and disease spread parameters on the extent and costs of outbreaks can also be examined. Furthermore, activities will be undertaken to develop a similar modelling approach for the economic evaluation of control strategies for outbreaks of CSF, as part of and EpiMAN system for the control of CSF that will be developed in the Netherlands (also in collaboration with New Zealand) in the coming years.

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REFERENCES

Berentsen, P.B.M., Dijkhuizen, A.A., and Oskam, A.J., 1990. Foot-and-mouth disease and export: An economic evaluation of preventive and control strategies for the Netherlands. Wageningen Economic Studies, No. 20, Wageningen Agricultural University.

Jalvingh, A.W., Nielen, M., Dijkhuizen, A.A., and Morris, R.S., 1995. A computerized decision support system for contagious animal disease control. Pig News and Information, 16 (1): 9N-12N.

Meuwissen, M.P.M., Horst, H.S., Huirne, R.B.M. and Dijkhuizen, A.A., 1997. Losses for certain! A feasibility study on risk calculation and insurance options with respect to notifiable animal diseases. Department of Farm Management, Wageningen Agricultural University. (In Dutch) 164 pp.

Sanson, R.L., 1993. The development of a decision support system for an animal disease emergency. PhD-thesis. Massey University, Palmerston North, New Zealand.