# Geographic management and monitoring of livestock disease events

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## Abstract

In case of an outbreak of a contagious livestock disease in the Netherlands, the Food and Consumer Product Safety Authority (VWA) puts procedures into action in an attempt to prevent the disease from spreading further. These procedures entail the demarcation of quarantine areas around the outbreak location and the selection of farm locations and parcels within this area. These farms will be subjected to certain measures, such as additional checks, protection measures, vaccinations or even culling of livestock. The current procedures involve some time consuming manual operations. Consequently, valuable time is lost in the first hours after a possible contamination. Therefore, the following research question was investigated: will the process to demarcate quarantine areas and to select farm locations and parcels involved benefit from the application of an online GIS? To answer this question, a geographical information system (GIS) containing functionality to demarcate quarantine areas and select farm locations and parcels involved was designed. Parts of the system were implemented in prototypes. This allowed us to assess whether the realization of a system as the one described is feasible and to answer the research question. Our research demonstrates that tools and technology are not a problem when implementing a system as the one described. However, our research also shows that the amount of spatial data which has to be administered, increases. A more important issue is the lack of up to date datasets. This compromises the reliability of the outcomes.

**Keywords:** GIS, veterinary medicine, processing web-service

## Background

In case of an outbreak of a contagious animal disease in the Netherlands, the Food and Consumer Product Safety Authority (VWA) of the Dutch Ministry of Agriculture, Nature and Food Quality (LNV) puts procedures into action in an attempt to prevent the disease from spreading further. These procedures are described in a number of scenarios, one for each disease. Examples are the scenario for foot and mouth disease (Voedsel en Waren Autoriteit, 2005) or the scenario for avian influenza (Voedsel en Waren Autoriteit, 2007).

The procedures entail certain measures for quarantine areas surrounding the outbreak or outbreaks. In an area of ten kilometers surrounding an outbreak, additional checks are put into place. In an area of five kilometers surrounding an outbreak, protection measures are taken. Livestock within a three kilometer radius of an outbreak is vaccinated and livestock within a one kilometer radius of an outbreak is culled. The boundaries of the five and ten kilometer areas consist of topographical features such as roads, railroads and watercourses and should follow a ten or five kilometer buffer

around the outbreak as close as possible. The three and one kilometer areas consist of buffers around the outbreak.

To be able to put these measures into action, a number of steps are to be completed. Purpose of these steps is to collect correct and complete information on farm locations and quarantine areas as fast as possible. The steps taken to obtain the information required are depicted in Figure 1.

The first step consists of the demarcation of the ten and five kilometer quarantine areas around the outbreak. A description of these boundaries is created and subsequently checked by the legal department. If the legal department approves of the description, it is published officially. Using the descriptions and the buffers, the Paying Agency (DR), another department of the Ministry of LNV, selects all the farm locations within the various quarantine areas. This entails digitizing the five and ten kilometer quarantine areas. For a number of diseases, the procedures also prescribe the selection of farms outside the areas using parcels inside the areas and the selection of parcels outside the areas in use by farms inside the areas.

The results of these steps consist of a number of tables which are imported into other systems. The workflow described here involves quite a lot of manual work and some of the steps are time consuming, causing valuable time to be lost in the first hours after a contamination, when chances of preventing the disease from spreading are highest.

Workflows/business processes like the one described here can be improved using internet GIS applications. Agriculture is a domain with many spatial components and the Ministry of LNV has already been implementing GIS applications for years. Many agricultural business processes are supported by IT systems and these systems will benefit from the inclusion of GI technology (Nölle,
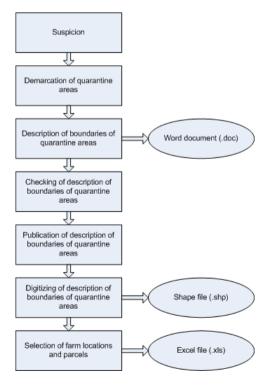


Figure 1. Current workflow.

2004). Norstrøm for example provides an overview of the possibilities and potential uses of GIS in the field of surveillance and monitoring of animal diseases (Norstrøm, 2001).

A similar application as the one discussed in this paper is presented by Ajdič *et al.* (2008). It concerns a an online GIS used at the Slovenian Veterinary Administration for efficient risk assessment of suspected disease occurrences and management of disease outbreaks (Ajdič *et al.,* 2008). Ehlers *et al.* describe the use of GIS during an outbreak of avian influenza in Italy in 1999 and 2000. The GIS was used to display the spatial distribution of farms affected and at risk, define the areas where restriction and surveillance measures were taken and identify farms in close proximity of infected farms (Ehlers *et al.,* 2003). The authors conclude that GIS can be used to minimize epidemiological risk and economic damages.

In case of animal disease control, both the location of contamination as well as the spread of the contamination are very much spatially explicit features. With an up-to-date database of all farms and their livestock a spatial analysis of the effects of a contamination can be very easily done. Integration of GI technology in main stream IT systems has been addressed by research and software vendors, among others in the field of business intelligence. When geo-spatial features are available in these systems, analysts can extract queries on these data, where location is the only relation between the features.

Therefore, it was decided to investigate the following research question: will the process to demarcate quarantine areas and to select farm locations and parcels involved benefit from the application of an online GIS? Can a workflow backed by an online system provide VWA with complete and correct information faster than the current, partially manual workflow? In the following section, the methods and materials used to answer the research question will be discussed.

**Methods and materials**

To answer the research question, a online geographical information system (GIS) based on geo-spatial web-services was designed. This GIS facilitates the demarcation of quarantine areas and the selection of farm locations and parcels affected by the measures. Some parts of the system were implemented in a prototype to see if the devised methodology is feasible. The prototypes focus mainly on the model to demarcate quarantine areas and to generate the description of the boundaries of the quarantine areas and on the datasets needed for the selection of farm locations and parcels since these components are specific for this particular application.

If this system would actually be used, the workflow would be as depicted in Figure 2.

The online, intranet accessible GIS described in this paper consists of a number of components (see Figure 3).

End-users log in to a user-friendly internet GIS client application with a number of functions:
- managing data with regard to suspicions of disease outbreaks;
- adapting the quarantine areas and the description of the quarantine areas;
- presenting data with regard to the farm locations and parcels affected;
- exporting data for use in other systems.

This internet GIS application depends on a processing web-service. This processing web-service provides the client with access to the model to demarcate quarantine areas and to generate a description of the boundary of these areas. This model was developed by a GIS specialist using ArcGIS ModelBuilder. ModelBuilder is an application to create, edit, and manage ArcGIS models. After a first version of the model to demarcate quarantine areas was created, the model was refined in several iterations, resulting in the model described in the 'Results and discussion' section.
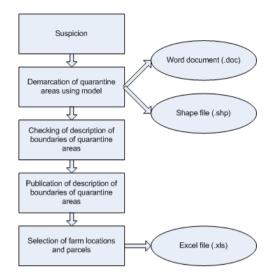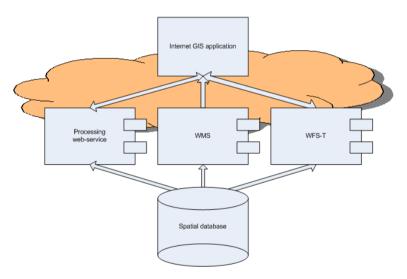
Figure 2. Proposed workflow.



Figure 3. Components of the internet GIS.

Subsequently, the model was made available as a processing web-service using ArcGIS Server (ESRI, 2009b).

The datasets needed for the system were collected from various sources. They were stored in a Relational Database Management System (RDBMS). This database is not only used by the model, but also by a Web Map Service (WMS) which produces images of maps for the internet GIS application and a transactional Web Feature Service (WFS-T) which provides read/write access to the data.

In the following section, results from the design of the system and the implementation of the prototypes will be discussed. At the end of the section, the research question will be answered.

**Results and discussion**

The design of the system proposed and the implementation of parts of the system in prototypes allowed us to assess whether the data and the tools necessary to implement the functionality required are available and what the advantages and disadvantages of the system proposed are. This allows us to answer the research question. First, results regarding the model will be discussed. Subsequently, results regarding the datasets will be discussed. Finally, the research question will be answered.

*Model to demarcate quarantine areas*
The model to demarcate the five and ten kilometer quarantine areas accepts the coordinates of the infected farm and the radius of the area to be buffered. It creates a circular buffer around the suspected farm location and generates a set of locations on the outside of the buffered area, starting in the north (five or ten kilometers north of the infected farm location), going clockwise with a new location every 30', finally returning at the starting location. These locations are used as 'stops' to create a path along the roads, railroads and watercourses around the area. The ArcGIS Network Analyst extension (ESRI, 2009a) is used to calculate the shortest path around the buffered area along roads, railroads and watercourses. Shortcuts through the buffered area are not allowed obviously and to prevent those, all crossings within the buffered area are marked barricaded (Figure 4).
The roads which are used to delineate an area can consist of several types of roads. All automobile roads, railroads and waterways should be used. All these roads must be preprocessed before they can be used in the network analysis, a network dataset has to be created. The construction of a network dataset may take some time initially, and if the roads change frequently the network dataset needs to be renewed.
At the moment, the model requires manual input in two cases. First of all, the distance between a stop point and an available road, railroad or waterway can exceed the maximum distance allowed.
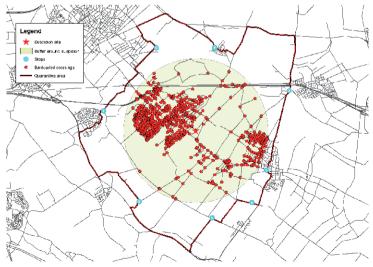


Figure 4. Quarantaine areas around an infected farm.

This requires a manual intervention to move the stop point closer to a road, railroad or watercourse outside the buffered area. Subsequently the route needs to be recalculated. Secondly, 'spikes' pointing towards the buffered area may occur. These 'spikes' are caused by the forced visit of a stop point. If the visit of this stop point is unnecessary (i.e. the list of farm locations affected is not altered if the stop point is removed), the 'spike' can be removed by erasing or moving the stop point causing it, resulting in a less complicated description of the boundary.

Application of the model caters for time savings in case of an outbreak. The model generates both the quarantine areas and the description of the boundaries of the quarantine areas whereas in the current workflow, two activities need to be carried out to obtain both. Furthermore, the boundaries of the quarantine areas are available in digital form right away, eliminating the need for a separate digitizing step.

A disadvantage of the use of the model is the increase in maintenance of geospatial data. The datasets used (roads, railroads and watercourses) have to be preprocessed before they can be used in the Network Analyst, a network dataset has to be created. The construction of this network dataset may take some time initially, and since the datasets used to create the network dataset are updated frequently, maintenance of the network dataset may require a considerable effort.

*Datasets for selection of farm locations and parcels*
Some of the attributes of the datasets used for the selection of farm locations and parcels affected by the measures are summarized in Table 1. The 'Refresh rate' column indicates how often a new version of the dataset becomes available. The 'Version' column indicates for what year the dataset used in this research applied. Meanwhile, the situation may have changed. The 'Age' column indicates how old the data in the dataset were when they became available for this research. And the 'Key' column indicates which identification is present in the dataset: BRS from the Ministry of LNV and UBN from the Animal Health Service (AHS). Datasets for this research were collected in autumn 2006.

- GIAB consists of the locations of farms (name and address with a location). GIAB is based on the annual census and on the Animal Health Service dataset. It is refreshed annually, and the dataset is completed half a year after the annual census becomes available for Alterra. Therefore, the data in the dataset were 1.5 years old when they became available for this case study.
- LPIS consists of crop parcels. Around 90% of the data is refreshed annually, together with the annual census, some 10% is being updated in a continuous process. Once the crop parcels have been collected, processing of the parcels takes one year, making the data one year old when they became available for this research.
- The annual census contains aggregated information on farms. The refresh rate of this dataset is annual, and the dataset is one year old when it is published. The annual census is used as input for GIAB.
- The Animal Health Service dataset contains data with regard to individual farm locations with livestock. This dataset is updated continuously, as AHS employees visit farm locations. Once a year, AHS provides an export of their dataset which is subsequently used to update GIAB.
- Table coupling UBN to BRS. This table is refreshed several times per year by DR.

The lack of up to date datasets is a problem. A lot of time elapses between collection and publication of the data, causing errors which is extremely undesirable given the sensitive matter. The problem may be reduced by providing VWA with online access to the latest versions of datasets using web-services. The architecture of the system proposed here facilitates such a link.

Table 1. Summary of attributes of datasets used.

| | Refresh rate | Age | Key | Version |
|---|---|---|---|---|
| GIAB | annually | 1.5 year | BRS | 2005 |
| LPIS | 90% annually, 10% continuous | 1 year | BRS | 2005 |
| Census | annual | 1 year | BRS | 2005 |
| AHS dataset | Several times per year | several months[1] | UBN | 2005 |
| UBN BRS coupling table | Several times per year | several days | UBN, BRS | September 4, 2006 |

[1] For cattle and pigs, for sheep and goats 1 to 7 years.

*Research question answer*

The research question introduced in the 'Background' section of this paper was the following: will the process to demarcate quarantine areas and to select farm locations and parcels involved benefit from the application of an online GIS? Our research shows that this process will indeed benefit from such a system. A workflow backed by an online system can provide VWA with complete and correct information faster than the current, partially manual workflow. This finding is consistent with other research on GIS and workflows/business processes discussed in the 'Background' section. The online availability of the datasets and the automated link between the datasets and quarantine areas is big step forward for the VWA workflow. First of all, results of the analysis will become available much quicker since a separate digitizing step is no longer required and access to the data does not require manual interference of a GIS operator. Secondly, the workflow will no longer depend on other departments of the Ministry. VWA will be able to complete the process in house. Furthermore, the system facilitates the development of 'what if' scenario's and it could be used for training purposes. In addition, an online system based on web-services facilitates the development of several other useful tools, such as a GPS enabled mobile application to support officials in maintaining the quarantine areas.

**Conclusion**

The results show that the VWA workflow will benefit to a large extent of a system as the one described. The online availability of datasets linked to each other allows for a much faster generation of quarantine areas and selection of farm locations affected. This allows authorities to come into action much faster, saving valuable time in the first hours after a possible contamination. The system could can also be used to develop 'what if' scenario's.

However, there are several issues which need to be addressed. First of all, to be able to demarcate contamination areas using a processing web-service, additional spatial data (datasets concerning roads, railroads and watercourses) need to be managed. Secondly, the lack of up to date datasets is a problem. This issue can be reduced by providing online access to the latest version of datasets. The system proposed facilitates this.

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