AGROTERRORISM TARGETING LIVESTOCK: A REVIEW WITH A FOCUS ON EARLY DETECTION SYSTEMS

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Agroterrorism targeting livestock can be described as the intentional introduction of an animal disease agent against livestock with the purpose of causing economic damage, disrupting socioeconomic stability of a country, and creating panic and distress. This type of terrorism can be alluring to terrorists because animal disease agents are easily available. This review addresses the vulnerabilities of the livestock industry to agroterrorism. However, we also show that early detection systems have recently been developed for agroterrorism and deliberate spread of animal pathogens in livestock, including an agroterrorism intelligence cycle, syndromic surveillance programs, and computer-based clinical decision support systems that can be used for early detection of notifiable animal diseases. The development of DIVA-vaccines in the past 10 to 15 years has created, in principle, an excellent response instrument to counter intentional animal disease outbreaks. These developments have made our animal agriculture less vulnerable to agroterrorism. But we cannot relax; there are still many challenges, in particular with respect to integration of first line of defense, law enforcement, and early detection systems for animal diseases.

AGRROTERRORISM TARGETING LIVESTOCK can be described as the intentional introduction of an animal disease agent into livestock with the purpose of causing economic damage, disrupting the socioeconomic stability of a country, and creating panic and distress.^{1,2} Intentional introduction of animal diseases is not common, but livestock have been targets of biological warfare or bioterrorism incidents.^{3,4} Biological weapons for livestock have been developed; for instance, Germany had biological weapons research on foot-and-mouth disease (FMD) and rinderpest, and Russia developed biological weapons research on African swine fever (ASF), FMD, and rinderpest. The United States, Canada, and the United Kingdom have investigated diseases such as anthrax, brucellosis, and glanders, and the British developed 5 million “cattle cakes” with anthrax spores, which were supposed to have been dropped on German grazing

lands during World War II.⁵ The modus operandi and motives for terrorists attacking livestock cover a broad spectrum, ranging from individuals, to companies, to countries causing mass casualties in animals, humans, or both.⁶

Although agriculture may not be a terrorist’s first choice, because it lacks the shock value of more traditional terrorist targets, many analysts consider it a viable secondary target. Agriculture has several characteristics that pose unique vulnerabilities. Farms are geographically disbursed in unsecured environments. Livestock are frequently concentrated in confined locations and transported or commingled with other herds.^{7,8} The continuing trends of intensive production techniques, the vertical integration of the production continuum, increasing dependence on the export market, and the lack of resistance to pathogens that prevail in some countries are other factors contributing to the vulnerability of the livestock industry.⁷⁻¹¹

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Over the past century, there has been a shift away from livestock production as a highly localized enterprise, where animals were typically born, fattened, and slaughtered in the same region. This change presents an opportunity for pathogens to be introduced and to spread long distances in a single incubation period before a significant number of animals appear ill.¹² Mass animal movement may provide a built-in dispersal mechanism for bioterror agents.¹³ Simulation studies in the United States suggest that FMD would quickly spread beyond control once it is introduced.¹⁴

The biological, economic, and political impacts of agroterrorism have generated international concern,¹⁵ and since 2005, 4 International Symposia on Agroterrorism (ISA) have been organized. The fourth ISA took place in Kansas City in April 2011, and more than 1,000 individuals from 25 different countries have participated in past ISA meetings.¹⁶

Many agricultural diseases can be obtained, handled, and distributed easily. International trade in food products often is tied to disease-free status, which could be jeopardized by an attack.¹⁷ Many veterinarians lack experience with foreign animal diseases that have been eradicated domestically but remain endemic in other countries.

The use of animal disease agents against livestock in agroterrorism attacks between 1900 and 1998 has been carefully reviewed;^{18,19} the reviews indicated that such an event is very rare compared to attacks against other targets. However, an agroterrorism attack requires relatively little expertise or technology.²⁰ Many notifiable animal diseases are highly contagious and spread effectively from a source, as demonstrated by recent epidemics of FMD, classical swine fever (CSF), highly pathogenic avian influenza (HPAI), Newcastle disease (ND), and bluetongue.²¹⁻²⁶ Moreover, terrorists can safely handle most of the causative agents with no risk of becoming infected themselves. For several of these pathogens, trade sanctions are imposed in the wake of outbreaks, so even a small outbreak can have very large economic effects. An example of a small outbreak that generated many countermeasures was an outbreak of anthrax that occurred in 2008 in a beef cattle herd in the south of Sweden.²⁷ Only 1 farm with a single herd was infected, but it resulted in one of the most costly decontamination procedures ever undertaken in Sweden.

Animal agriculture is a vital part of the economy in many developed countries. According to Chalk,¹⁵ there are at least 3 levels of costs associated with an agroterrorism attack: (1) direct losses resulting from containment measures and the destruction of diseased livestock; (2) compensation costs paid to farmers for the destruction of agricultural commodities and losses suffered by both directly and indirectly related industries; and (3) international costs in the form of protective trade embargoes imposed by major external trading partners. Table 1 gives an overview of direct and indirect costs involved in recent epidemics of notifiable animal diseases and shows that outbreaks of these animal diseases can have a devastating economic impact. For the

United States and Australia, free of FMD for several decades, it is estimated that introduction of FMD and subsequent spread of the disease would cost approximately US\$14 billion and US\$5-12 billion, respectively.^{53,54} A recent report from the World Bank concluded that early control of animal and zoonotic diseases are cost-effective and prevent human disease.⁵⁵

DIFFERENTIATING BETWEEN NATURAL AND INTENTIONAL OUTBREAKS

Thanks to modern animal husbandry and management and advances in veterinary medicine, the frequency of major animal disease epidemics has been greatly reduced.² For instance, it was not unusual to have thousands of outbreaks of FMD and CSF for many years between the 1930s and the 1960s in the Netherlands.⁵⁶ The features of naturally occurring outbreaks have a certain predictability in terms of consistency with previous occurrences, or at least a biological plausibility. However, with the intentional introduction of an infection into an (animal) population, this predictability is reduced.⁵⁷ An epidemiologic investigation of a covert attack differs little from that conducted following a naturally occurring outbreak.^{9,58} Certain characteristics of an animal disease outbreak, although perhaps not indicative of a covert attack when considered singly, when combined with other observations may provide convincing evidence of intentional causation. The technical ease of introducing many pathogens makes it more likely that agroterrorists would release pathogens in several locations in an attempt to initiate multiple simultaneous outbreaks. This is the principal way in which an agroterrorism attack would differ from a natural disease outbreak.²⁰ This would ensure that trade sanctions would be imposed, because it would undermine any argument that the outbreaks are localized. It would probably overwhelm the response capacity and lead to the uncontrollable spread of the disease. Furthermore, an unusual presentation of clinical signs, perhaps from an atypical route of exposure, also may provide useful forensic evidence.⁵⁹

Other potential factors differentiating intentional from natural outbreaks include the disease's season and geographic presentation, variants or unusual strains of pathogens or antimicrobial resistance patterns that are different from those that are circulating, morbidity and mortality rates that are out of the normal expected range, concurrence with threats or hoaxes, and direct evidence of the release of a pathogen, with findings of equipment, munitions, or tampering.^{57,59,60}

The US Department of Agriculture (USDA) has developed a template for differentiation of naturally occurring from non-naturally occurring epizootics of anthrax in livestock populations.⁶¹ The methodology is intended to be used by veterinary practitioners or other early responders in the field to an anthrax incident. Approximately 20

Table 1. Economic Costs of Some Notifiable Animal Disease Outbreaks

<i>Animal Disease</i>	<i>Country</i>	<i>Year</i>	<i>No. Affected Herds</i>	<i>No. Culled Animals</i>	<i>Direct Costs in Millions (currency)</i>	<i>Indirect Costs in Millions (currency)</i>	<i>Reference</i>
Anthrax	Sweden	2008	1	78	60 (SEK)		28
HPAI	USA	1983-84	unknown	17 million	60 (US\$)		29
HPAI	Italy	1999	413	16 million	112 (€)	395 (€)	30
HPAI	Netherlands	2003	255	30 million	300 (€)	700 (€)	31, 32
HPAI	Canada	2004	42	17 million	380 (US\$)		33
LPAI	USA	1997-98	18	unknown	3.5 (US\$)		34
LPAI	Italy	2000-01	80	1.7 million	10 (€)		35
LPAI	Italy	2002-03	388	7.6 million	40 (€)		35
ND	USA	2002-03	912	3.2 million	221 (US\$)	121 (US\$)	36
ND	Northern Ireland	1997	26	546,000	3.5 (£)		37
CSF	Belgium	1990	113	1 million	212 (€)		38
CSF	Belgium	1993-94	52	743,871	75 (€)		39
CSF	Belgium	1997	8	74,140	10 (€)		40
CSF	Netherlands	1997-98	429	12 million	1,320 (€)	1,020 (€)	41
FMD	Italy	1993	unknown	8,000	11.5 (US\$)	120 (US\$)	42
FMD	UK	2001	2,030	6.1 million	3,125 (£)	4,000 (£)	43, 44
FMD	Netherlands	2001	26	260,000	273 (€)	1,027 (€)	45, 46
FMD	Taiwan	1997	6,147	4 million	379 (US\$)	1,300 (US\$)	47
FMD	South Korea	2010-11	157	9.7 million	2,700 (US\$) in 2010		48
Nipah	Malaysia	1998-99	946	1 million	233 (US\$)	267 (US\$)	49, 50
Bluetongue	Netherlands	2006-07	6,480	0	32 (€)		51
Q fever	Netherlands	2007-10	88	50,000	27 (€)	134-308 (€)	52

Note: HPAI: highly pathogenic avian influenza; LPAI: low pathogenic avian influenza; ND: Newcastle disease; CSF: classical swine fever; FMD: foot-and-mouth disease.

ecological and epidemiologic criteria are to be evaluated in order to differentiate a natural epizootic anthrax incident from a non-natural one.

POTENTIAL FOR AGROTERRORISM

Biological warfare programs, including biological weapons against livestock, are prohibited by the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction (commonly known as the Biological Weapons Convention, or BWC) under the regula-

tion of the United Nations.⁶² Of the hundreds of animal pathogens and pests available to an agroterrorist, perhaps fewer than a couple dozen represent significant economic threats.^{1,19} Determinants of this level of threat are the agents' pathogenicity, contagiousness, and potential for rapid spread across international borders; low levels of immunity to the agent in the target population;⁶³ and the potential to inflict catastrophic economic losses and social disruption, condensed in its international status as a reportable pest or disease under rules of the World Organization for Animal Health (OIE).⁶⁴ The US Agricultural Bioterrorism Protection Act of 2002⁶⁵ created a list of potential animal pathogens that draws heavily from the

former List A and B diseases of the OIE. The list is specified in the select agent rules implemented by the Animal and Plant Health Inspection Service (APHIS) of the USDA⁶⁶ (Table 2). The animal diseases on the select agent list of the Centers for Disease Control and Prevention (CDC)⁶⁷ are diseases that pose a risk to both human and animal health. The Australia Group, which is an informal forum of countries, has made a list of designated animal diseases with export controls to ensure that exports do not contribute to the development of chemical or biological weapons.^{68,69} The Australia Group activities serve to support the objectives of the BWC by harmonizing export controls; their list of animal diseases and agents is shown in Table 2. Others have added a few other diseases as potential bioterrorism agents,¹⁹ including pseudorabies virus, ornithosis/psittacosis, porcine reproductive and respiratory syndrome virus, lyssaviruses and rabies viruses, and screwworm myiasis.

The European Commission is currently working on the implementation (2010-2014) of the EU (European Union) CBRN Action Plan, and 1 Action (H1) focuses on the establishment of EU lists that includes high-risk biological agents and toxins, including animal pathogens.⁷⁰

EARLY DETECTION SYSTEMS

We must be prepared for the introduction of an exotic (animal) disease, and if an outbreak occurs, we must act without hesitation. “By preparing for the norm, one is prepared for the abnormal,” note Hugh-Jones and Brown.^{2(p24)} In principle, an effective response to an intentional agroterrorism attack is no different from that of an effective response to a natural introduction of exotic diseases.²⁰ Since the anthrax cases in 2001, development and use of syndromic surveillance has been promoted for early detection of infectious diseases and preparing anti-bioterrorism measures.⁷¹

Several surveillance systems for early detection of bioterrorism-related diseases exist and have been reviewed.^{72,73} Since September 11 and the anthrax letters, huge efforts have been made to develop early detection methods as part of bioterrorism preparedness, but unquestionably the experience and expertise of field and laboratory personnel are crucial to detecting an index case as quickly as possible.⁷⁴

First Line of Defense: Customs and Law Enforcement

Traditionally, the first line of defense against a foreign animal disease has been to try to keep it from entering the country.¹ In today’s interconnected global industries and economies, and with the intercontinental transport of foodstuffs, both legal and illegal, pathogens are moved globally in spite of restrictions.⁷⁵⁻⁷⁸ Meat and meat products may be contaminated with dangerous pathogens like

Table 2. Lists of Animal Diseases on Bioterrorism Lists and with Export Controls

Disease/Agent	APHIS ⁶⁶	CDC ⁶⁷	AG ^{68,69}
African horse sickness (AHS)	X		X
African swine fever (ASF)	X		X
Anthrax (<i>Bacillus anthracis</i>)	X	X	X
Avian influenza (AI)	X		X
Bluetongue			X
Botulism (<i>Clostridium botulinum</i>)	X	X	X
Brucellosis of cattle (<i>Brucella abortus</i>)	X	X	X
Brucellosis of sheep (<i>Brucella melitensis</i>)	X	X	X
Brucella of pigs (<i>Brucella suis</i>)	X	X	X
Chlamydia psittaci	X	X	
Classical swine fever (CSF)	X		X
Contagious bovine pleuropneumoniae	X		X
Contagious caprine pleuropneumoniae	X		X
Eastern equine encephalitis	X	X	X
Foot-and-mouth disease (FMD)	X		X
Glanders (<i>Burkholderia mallei</i>)	X	X	
Goat pox	X		X
Hendra virus (of horses)	X		X
Lumpy skin disease	X		X
Lyssa virus			X
Melioidosis (<i>Burkholderia pseudomallei</i>)	X	X	X
Newcastle disease (ND)	X		X
Nipah virus (of pigs)	X		X
Peste des petits ruminants	X		X
Pseudorabies			X
Q fever (<i>Coxiella burnetii</i>)	X	X	X
Rift Valley fever	X		X
Rinderpest	X		X
Sheep pox	X		X
Swine vesicular disease (SVD)	X		X
Teschen disease virus			X
Tularemia (<i>Francisella tularensis</i>)	X	X	X
Venezuelan equine encephalitis	X	X	X
Vesicular stomatitis	X		X
Western equine encephalitis		X	X

FMD virus, ASF, and CSF virus. National regulations are in force to prevent the importation of such pathogens, but the illegal importation of meat provides a route by which controls may be circumvented and pathogens introduced. A quantitative risk assessment study for the United Kingdom estimated, based on seizures of products of animal origin (smuggled products in freight, both air and sea; mail; and passenger baggage), the amount of illegal meat imported on an average to be about 12,000 tons per year.⁷⁹ The National Veterinary Research and Quarantine Services (NVRQS) of South Korea detected about 36 tons of smuggled meat in 2003.⁸⁰ It is assumed that between 50% and 90% of contraband food of animal origin in passenger baggage at airports in South Korea escapes interception. In 1999, Taiwanese authorities seized some 1,000 tons of meat products smuggled into Taiwan from the People's Republic of China, and this may represent only 10% of the total amount actually reaching its destination.⁸¹ Chaber et al⁸² estimated that about 5 tons of bushmeat per week is smuggled in personal baggage through Paris Roissy-Charles de Gaulle Airport in France.

It is clear that well-equipped and well-staffed customs agencies and border patrols are a necessary first line of defense against illegal introduction of such pathogens into countries that are free of these pathogens.⁸³ But professional surveillance at our borders will not be enough to protect us from intentional or unintentional introduction of animal pathogens.⁷ Simple means can be used to smuggle many of the most dangerous animal pathogens, further confounding efforts to prevent their intentional introduction. When pathogens are introduced and have infected livestock, surveillance systems should be in operation for early detection to prevent spread of the disease.

Recently, an agroterrorism intelligence cycle aimed at focusing on early detection of an agroterrorism incident has been proposed.⁸⁴ It outlines a framework for detecting intention using open source and overt electronic data. The role of first responders in agroterrorism is not always clear,⁸⁵ so a guidebook for first responders related to agroterrorism has been developed.⁸⁶ A criminal investigation handbook for agroterrorism⁸⁷ is available mainly for law enforcement officials but may also be useful for others involved in surveillance; it includes a list of indications of accidental or intentional threats to the food supply.

Surveillance Systems

The key prerequisite for any effective surveillance system is knowledge of the baseline disease prevalence and mortality. Without this information, it is impossible to tell whether disease occurrences are below or above the threshold for special action. Furthermore, timely knowledge of key production variables will allow early detection of adverse health events.¹⁰ For instance, a drop in egg production and a decrease in feed intake preceded the exponential increase in mortality during the H7N7 HPAI epidemic in 2003 in

the Netherlands.⁸⁸ Above baseline mortality in the index case was observed at the start of the CSF epidemic in 1997 in the Netherlands.²¹ Thus, farmers are key players in a surveillance system because they are the first to notice an aberration in the normal situation.⁵⁶

To facilitate reporting of incidents of herd health problems by farmers, a consultancy help desk (Veekijker) was developed at the Animal Health Service (GD) in the Netherlands.⁸⁹ The purpose of Veekijker is to detect exotic and new diseases by combining a second-line consultancy desk with the tasks of collecting and evaluating information. This information collection is passive; farmers and private veterinarians must initiate contact with Veekijker. In cases of incidents or herd health problems that are not fully understood, both farmers and, especially, veterinarians are encouraged to contact Veekijker through a nationally publicized telephone number. Calls are handled by a consistent group of 5 cattle health specialists. When necessary, the specialists visit the farms for free to pursue more detailed information. To further motivate farmers and veterinarians to contact Veekijker, regular feedback of information is provided on websites and in magazines, presentations, and newsletters. Similar systems, but predominantly focused on veterinary practitioners reporting extraordinary cases, have been developed in France (Émergences),⁹⁰ the United States (RSVP-A),⁹¹ and New Zealand (VetPAD).⁹² These all have the disadvantage that they can report only on possible suspect cases for which they have been called in by farmers, and, in addition, there might be a time lag between first clinical signs seen by farmers and their asking for the veterinarian's opinion. In New Mexico, a syndromic surveillance program has been developed for the early detection of animal disease outbreaks caused by either natural or intentional spread of pathogens.⁹³

Another prerequisite for responding to a bioattack against livestock is the ability to recognize the signs and symptoms of likely disease agents. Because notifiable animal diseases like FMD, AI, ND, and CSF are exotic in many countries and may not have been seen for decades, farmers and veterinary practitioners often do not think of these diseases in the differential diagnosis as a cause of the clinical problems they observe.⁹⁴ Continuing education in recognizing clinical signs associated with notifiable animal diseases is therefore very important.^{10,56} As an example, an instrument to help in recognizing pig diseases in the Netherlands was developed by research institutes, supported financially by the Dutch Product Board for Livestock and Meat and the Ministry of Agriculture. A website (www.varkensziekte.nl) was built with pictures and moving images of clinical signs of CSF and other notifiable animal diseases like FMD, swine vesicular disease (SVD), and pseudorabies, and pictures and information on 20 other endemic pig diseases. A simple decision tree helps visitors to the website to get a first impression of which diseases might have caused the clinical problems, and they are advised to contact a veterinary practitioner.

In theory, reporting of notifiable animal diseases by farmers to the veterinary authorities can be an effective early detection tool. Therefore, formal rules for reporting clinically suspect situations in livestock by farmers and veterinary practitioners are laid out in national and international legislation. In the Netherlands, the Dutch Cattle Act was officially put into force in 1870.⁹⁵ It consisted of a list of contagious diseases like rinderpest, anthrax, rabies, and FMD. It also contained regulations for isolation of affected and suspect livestock, notification of affected and suspect livestock to the mayor of the municipality, obligatory notification by veterinary practitioners, and prohibition of transport of sick and suspect livestock. In essence, not much has changed with respect to the reporting and eradication process of notifiable animal diseases since those early days. One of the first actions a veterinary practitioner or farmer should take when they suspect a natural or intentional animal disease outbreak is timely reporting to competent authorities.¹⁰

However, diagnosis of CSF, FMD, or AI based on clinical signs is often difficult, because these diseases are unfamiliar to farmers and sometimes veterinary practitioners, and also because signs may vary considerably, depending on the age and/or breed of the affected animals and the virulence of the virus strain.^{94,96} Thus, laboratory diagnostic confirmation is necessary. In many national regulations, however, laboratory confirmation is allowed only after reporting to the veterinary authorities. This sometimes leads to control measures being imposed—for example, isolation of the farm—until the results of diagnostic testing are available. Isolation of the farm, especially if it lasts for several days, may have negative economic consequences for the farmer. Furthermore, many endemic animal diseases cause clinical signs similar to those of notifiable animal diseases, especially in the early stages of the disease process. After a considerable period of freedom from notifiable animal diseases in a country, farmers and vets will have a tendency to think that clinical signs they observe are caused by the endemic disease and not by a notifiable animal disease. These phenomena sometimes cause farmers and veterinarians to be reluctant to report early clinical signs of notifiable animal diseases, meaning that the time needed for ultimate detection of a new infection provides time for the disease agent to spread. For instance, many case reports indicated that CSF was suspected only after prolonged use of medication had failed to produce desired results.²¹

Experience shows that epidemics of notifiable animal diseases in densely populated livestock areas are difficult to control, especially if the detection of the index case is delayed.^{21,88, 97-99} The length of the high-risk period is one of the most important parameters that determine the magnitude of an outbreak because it defines the period in which the disease agent can circulate freely and is able to spread to other livestock premises. The high-risk period begins when the first animal is infected and ends when all eradication measures are in full operation—that is, the region

concerned no longer presents any risk to other regions. The consequence of delayed reporting of a clinically suspect situation is a longer high-risk period. This will seriously hamper the eradication of the disease agent after it is introduced into a country that was previously free of the agent because disease may have spread to other farms. Problems with timely reporting (by the farmer or veterinarian) to the appropriate authorities of a clinically suspect situation on livestock farms is a worldwide problem.¹⁰⁰ Reporting could be facilitated by transparent communication of the processes involved in reporting; the farmer will be less frightened and stressed if he knows what to expect when he reports a suspect situation. Transparency of the reporting process will also help to rebuild trust between the farming community and the authorities.

Measures that facilitate the use of exclusion diagnostics in a clinical situation with nonspecific clinical signs would be helpful.¹⁰⁰ The poultry farmer's ability to submit swabs or tissue and blood samples at no cost would help to exclude AI in a clinical situation with nonspecific clinical signs, in particular if this has no consequences for the farm operations. Such a system has been operational in the Netherlands for 2 years.¹⁰¹ Obviously, one has to select appropriate samples based on post mortem examination in combination with certain preliminary diagnoses from veterinary poultry practices to be submitted to the National Reference Lab for PCR testing to exclude AI as a possible cause for the disease problems in poultry flocks. A similar approach was developed for the swine industry: When nonspecific clinical signs are seen on swine farms, and CSF cannot be excluded clinically, there is reason to submit samples from sick swine to a reference laboratory to check for CSF infection, without isolation of the farm.^{102,103} However, even when such a system does exist (eg, in the Netherlands and in Germany), farmers do not always use it as often as we would like them to. After the successful introduction of the system in the Netherlands in 2006, the number of submissions of samples for exclusion diagnostics has declined dramatically for several years.¹⁰⁴ Asked for their opinion, swine farmers and practitioners indicated that they were not satisfied with the current distribution of the costs involved in using exclusion diagnostics.¹⁰² The costs of the PCR test, the costs of the veterinary practitioner, and the costs for shipping the samples to the reference laboratory should, in their view, be paid for by the Animal Health Fund (a fund from which the direct costs of eradicating a notifiable animal disease are financed; it is filled 50% by government and 50% by industry) or by the government. It can be concluded that great improvements have been made in the past few years to facilitate the use of exclusion diagnostics, but there is still room for progress to be made.

Summarizing, early detection of the index case is crucial, and the collaboration between clinicians and farmers is essential to minimize the length of the high-risk period. Agroterrorism threats generate needs for multisectoral early

detection systems. Integration of the first line of defense and law enforcement with existing early detection systems for animal diseases is therefore a challenge. To improve future systems for early detection of deliberate spread of animal diseases, the animal health sector needs to collaborate with law enforcement. In the long run, this will require further research and development but also training and education to build a collaborative culture between the sectors.

RESPONSE

The response to covert and overt agroterrorism incidents is challenging. Covert and overt incidents will lead to various alarm chains. In a covert incident, which is characterized by an unannounced release, the early response and detection will be driven by public health organizations. But an overt incident is characterized by the perpetrators announcing responsibility, and the response will therefore be driven by law enforcement. As a result, response strategies must be able to face both types of incidents. This requires a multidisciplinary network of diagnostic capabilities both in law enforcement agencies and public health organizations that can respond to environmental, agricultural, veterinary, and food threats.¹⁰⁵ In addition to diagnostic capabilities, vaccination preparedness is crucial.^{20,106}

After a long period of being disease free, the Netherlands experienced epidemics of CSF, FMD, and HPAI in a period of 7 years.^{21,88,107} These epidemics had a devastating impact in terms of animal welfare, economics, and societal outcry and disturbance. This was at a time when preventive use of vaccines against FMD and CSF had been prohibited in the EU and mass culling of infected and at-risk animals was the common means of controlling the spread of disease. Probably the most important technological development for animal disease control has been the development of effective vaccines for all animal diseases that target livestock,²⁰ and vaccines are now designed so that a vaccinated animal can be reliably distinguished from a previously infected animal (DIVA-principle). Safe and effective FMD vaccine has been available for many decades, but its use in the developed world to respond to accidentally or deliberately introduced disease is not very common.^{106,108}

A recent study¹⁰⁹ indicated that emergency vaccination against FMD in densely populated livestock areas in the Netherlands with more than 4 farms/km² can halt the epidemic as rapidly as preemptive culling, while the total number of farms to be culled is reduced by a factor of 4. Furthermore, it was shown that vaccination and preemptive culling strategies yield comparable numbers of undetected infected animals after final screening.¹¹⁰ In a recent update of the Dutch contingency plan for controlling outbreaks of CSF, emergency vaccination is preferred to large-scale preemptive culling. A study by Backer et al¹¹¹ indicated

that emergency vaccination against CSF can be equally effective and as safe as preemptive culling.

Although the use of vaccines against avian influenza in birds has been discouraged over the years, the unprecedented occurrence of outbreaks caused by AI viruses recently has required review of this policy.¹¹² A variety of products are now on the market, ranging from inactivated conventional to live recombinant vaccines. The general consensus on the use of vaccination is that if vaccines comply with GMP standards and are properly administered, birds will be more resistant to field challenge.

Despite these technological advances, the actual use of emergency vaccination when needed is still under debate in the Netherlands.¹¹³ The Dutch Chief Veterinary Officer indicated in 2008 that the government would use an emergency vaccination against CSF when the circumstances demand it—for example, the start of CSF outbreaks in swine-dense areas or a large number of outbreaks in a short period of time after the first case is detected. But there is a great deal of uncertainty about the marketing of meat from emergency (DIVA-)vaccinated animals, and a formal agreement is still far off. It is virtually impossible for a European country affected by a disease outbreak to have all the meat from emergency-vaccinated animals consumed by its own population. Meat from emergency-vaccinated animals has to be exported to other European member states for consumption. Consumers' negative perception of meat from emergency-vaccinated animals might be an obstacle and may also result in a lower value for such meat. This seems ridiculous, because other preventive vaccinations are normally used during the production of food animals without the general public's making a fuss about it. There is a real need for a public information strategy and campaign to prepare the public for such a situation. In sum, before emergency vaccination can be used as a full-fledged, cost-effective response instrument after a natural or intentional outbreak, talks among representatives of the livestock industry, slaughterhouses, and retailers, supported by national and international animal health organizations, should come to a satisfactory agreement on how to deal with these hurdles.

CONCLUSION

There are many vulnerabilities in the livestock industry that can be exploited by agroterrorists. However, on the other side, we have also shown that various early detection systems have recently been developed for agroterrorism and deliberate spread of animal pathogens in livestock, such as an agroterrorism intelligence cycle, syndromic surveillance programs for intentional spread of animal diseases, and computer-based clinical decision support systems that can be used for early detection of notifiable animal diseases. Furthermore, the development of DIVA-vaccines in the past 10 to 15 years has, in principle, created an excellent

response instrument to counter intentional animal disease outbreaks. These developments have made our animal agriculture a harder target for agroterrorism. But we cannot relax; there are still many challenges, in particular with respect to integrating first line of defense, law enforcement, and early detection systems for animal diseases.

ACKNOWLEDGMENTS

This research was executed in the framework of the EU project AniBioThreat (Grant Agreement: Home/2009/ISEC/AG/191) with financial support from the Prevention of and Fight against Crime Program of the European Union, European Commission—Directorate General Home Affairs. In addition, financial support was provided by the Dutch Ministry of Economic Affairs (WOT project # 01-001-004: Veterinary Epidemiology and Risk Analysis of notifiable animal diseases). This article reflects the views only of the authors, and the European Commission cannot be held responsible for any use that may be made of the information contained therein.

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*Manuscript received December 13, 2012;
accepted for publication April 10, 2013.*

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