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PREDICT – PREVENTION AND RESPONSE TO EPIDEMICS WITH DEMONSTRATION OF INFORMATION AND COMMUNCIATION TECHNOLOGIES

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In many African countries, livestock farming is an important source of revenue that improves the quality of life for this particular community and ultimately strengthens the development of the economy. Therefore, the quality and health of livestock has important economic consequences. In addition to this domestic importance, countries must be able to demonstrate that their livestock is free of certain diseases for the export market. Given this, the country of Senegal through its Directorate of Veterinarian Services, DSV, has established a National System of Epidemiological Surveillance known as SNSE. SNSE monitors the health of the livestock and the outbreak of epizootics, and enables to control and restrain the spread of animal diseases.

Real time surveillance and prompt actions are paramount in diminishing the impact of epizootics on livestock. For this reason, shortening the time between detection, reporting and providing measures to contain an outbreak is crucial. Satellite communications enables a crisis team to communicate from a remote area to a central decision centre to take the right measures to predict and control the outbreaks. Earth observation data on vegetation, humidity, geography, wild fires and other sources derived from earth observation data, linked to forecast and modelling tools and to geographical information systems, enables to quickly assess the occurrence of epizootic outbreaks and to limit their impact.

PREDICT is a space-based support system aiming to enhance the current SNSE features, to improve communication and provide tools for decision making, based on computer based analysis, graphical maps and earth observation data to handle and analyse disease information. PREDICT will also establish performance indicators, monitor user activity, and establish systematic feedback which is an important factor in motivating users to see the value of their work.

Adding PREDICT to the actual Senegal's national system for epidemiological surveillance will allow a faster detection of outbreaks and a better coordination between the different agencies in charge of responses. The case of Senegal provides a firsthand example applicable to many countries of the impact that space can have in the daily lives of people, not only economically, but also socially, in particular the impact of zoonoses on public health.

PREDICT is currently undergoing a feasibility study within the Integrated Applications Promotion (IAP) programme of the European Space Agency (ESA) which should result in a demonstration of the system and services during 2012, also cofinanced by ESA.

I. CONTEXT

I.1. Zoonoses and the veterinary public health context

Any disease or infection that is naturally transmissible from vertebrate animals to humans and vice-versa is classified as a zoonosis according to the PAHO publication "Zoonoses and communicable diseases common to man and animals". Zoonoses are caused by all types of agents: bacteria, parasites, fungi, viruses and unconventional agents. According to WHO, about 75% of the new diseases that have affected humans over the past 10 years have been caused by pathogens originated from animals or from animal products [1, 2]. Many of these diseases, for instance avian influenza, have the potential to spread through various means over long distances and to become a global health problem. Moreover, many well known and preventable zoonoses continue to infect people in many countries especially in the developing world where they mostly affect the poorest segment of the human population. They infect millions of people and cause of a considerable amount of human deaths every year. They also prevent the efficient production of food of animal origin, particularly of much-needed protein, and create obstacles to international trade in animals and animal products.

Early warning and forecasting of zoonotic disease trends through functional surveillance systems is a key requirement for effective containment and control of any potential epidemic. Early intervention during a disease epidemic often leads to better results with reduced disease burden and associated economic impact. The World Health Organization (WHO), the Food and Agriculture Organization of the United Nations (FAO) and the World Organization for Animal Health (OIE) are collaborating in order to link networks from the international community and stakeholders, to assist in prediction, prevention and control of zoonotic diseases through sharing information, epidemiological analysis and risk analysis [3, 4]. These agencies currently promote the use of early warning systems and they decided back in 2006 to develop a joint system "GLEWS" Global Early Warning System for Major Animal Diseases, including Zoonoses.

I.2. Context in Senegal

Since many years, DSV « Direction des Services Vétérinaires » is actively promoting the use of advanced information and communication technologies, combined with the use of satellite based services for health early warning systems. In 2000, within the EMERCASE project, DSV contributed to study the role of the environment on the Rift Valley Fever on animals, an emerging fever in Senegal. This project resulted in an electronic surveillance network implemented at all county levels of Senegal. In parallel, DSV, in collaboration with the CSE "Centre de Suivi Ecologique" of Dakar, has participated in several projects studying the links between environment and animal environmental diseases. DSV is actually improving its surveillance network by implementing a Stock Farming Management System, SIGEL, "Système de Gestion de l'Elevage" developed by a local industrial provider. DSV has therefore a good expertise in understanding the added value of combining information and communication technologies with satellite based services to assess better resources on livestock, and to predict and manage outbreaks of animal diseases.

II. BACKGROUND AND PARTNERSHIP OF THE PROJECT

The idea of PREDICT results from needs expressed by the DSV, and from a long and fruitful collaboration with MEDES, initiated during the EMERCASE project. DSV and MEDES considered that the needs expressed by DSV could be fulfilled by a service in line with the scope of the ESA Integrated Applications Promotion programme. DSV's intention is indeed to implement sustainable services which require the use of several space assets. Therefore, DSV and MEDES decided to apply for a feasibility study within the IAP programme as a first step towards a future demonstration project.

To carry out such feasibility study and to support the subsequent demonstration phase, MEDES implemented a consortium of solution providers. Avia-GIS, a Belgium SME expert in the application of remote sensing in health, accepted to join the project. Avia-GIS provides support in all the earth observation and GIS (Geographic Information System) aspects of the project. MEDES also invited EHESP "Ecole des Hautes Etudes de Santé Publique", the French school for public health, in order to get support for all aspects related to service sustainability. This consortium is actually conducting the definition study. This study aims at starting a demonstration of the services for DSV in 2012.

III. PREDICT OBJECTIVES

III.1. Main needs of DSV

DSV intends to upgrade its existing capabilities to better the reporting process, to manage and to predict outbreaks of animal diseases. Three main needs have been identified.

The first need is related to improve the electronic surveillance, in particular by equipping the field agents at local level with terminals for electronic surveillance. Presently, only the regional and the county levels of the DSV are integrated in the network. Local levels and field agents send information by traditional post, a slow and non effective procedure. In addition, interested private veterinarians will have the capability to join the network and access to the PREDICT services. This function will be supported by the SIGEL data collection system. PREDICT will be interfaced with the SIGEL data base in order to provide enhanced capabilities for feedback reporting and calculation of performance indicators. It will also include a crisis field enquiry service using a mobile terminal communicating by satellite able to provide a distant access to the full range of PREDICT services in remote sites.

The second need, management of outbreaks, requires the management of resources and risk mapping. Resource management includes for instance the estimate of the current distribution of the livestock. Risk management can then help to provide zonation tools during outbreaks and to assess the effectiveness of preventive and/or curative measures.

The third need is related to reporting, for national needs and towards international bodies, like WHO, FAO or OIE. This implies the capability to handle advanced queries and to automatically produce reports at the standards defined by the users. It also implies the capability to send alerts according to predetermined rules, to end users and possibly global alert systems. However, in order to reduce the complexity of the project, no interface with external information system is planned in the first phases of the project.

III.2. Added value of space assets

Several satellite based services are relevant to fulfil the needs of DSV. Even though there is a good coverage by ground networks in living areas, satellite communications are relevant in areas where no such coverage is available, in particular in remote sites. Internet access using satellite for crisis field teams is one of the needs addressed by DSV. The required terminals and satellite mobile phones are commercially available.

Global positioning services are the base for georeferenciation. Georeferencing data for localisation of herds, of outbreaks, is important in order to define the zones at risk. PREDICT will use commercial terminals and the standard GPS service.

Earth observation data are relevant for many services. For PREDICT, earth observation data will for example be used to assess resources, like vegetation status, livestock census and detection of burnt areas. In addition to the satellite images, spatial vector data layers will be used.

IV. SYSTEM DEFINITION

IV.1 System of systems

The system of systems is described in figure 1.

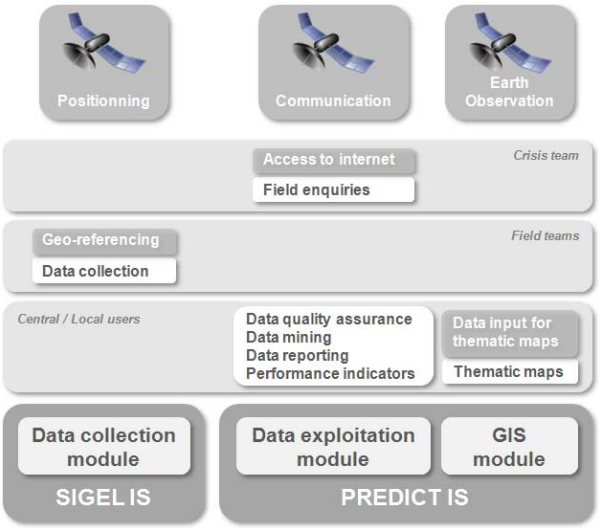

Fig. 1: System of systems

The system of systems includes the main following components:

The SIGEL “Stock Farming Management System”, a data collection information system for field agents, The SIGEL will mainly collect data, for instance for disease case declaration. SIGEL is currently under development by DSV.

Satellite positioning service enabling field agents using either SIGEL or PREDICT applications to georeference data. This function will use the standard GPS service.

Field enquiries service for a crisis team enabling distant access to the full range of PREDICT applications by satellite communication. The satellite service foreseen is Inmarsat. The DSV field team will be equipped with a BGAN terminal and a portable computer,

Data for thematic maps based on earth observation data and application layers. Current earth observation products which will be used are MODIS, NOAA, MSG and SPOT VGT. The products required are available, either free or as commercial products. In addition, spatial vector data layers such as road network, hydrological network, administrative units, land cover, land use, protected areas and altitude will be used. These layers are available at CSE "Centre de Suivi Ecologique" of Dakar, which has an established cooperation with DSV. CSE will provide both the satellite products and the application layers to DSV.

PREDICT information system. This system will implement the services answering the needs defined by DSV not fulfilled by SIGEL. The PREDICT information system will be directly interfaced with the SIGEL server.

IV.2 PREDICT information system

The PREDICT information system is described in figure 2.

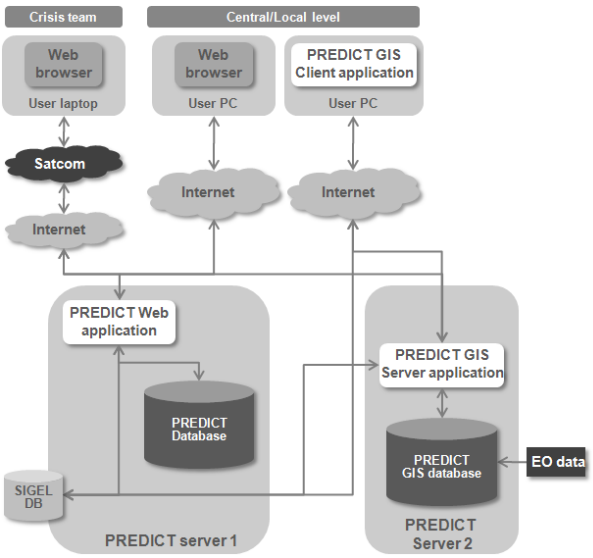

Fig 2: Information system

This system includes two main components:

- An exploitation module,
- A GIS module.

The SIGEL and the PREDICT servers will both be hosted at the Agency for the Information Development of the State (ADIE). This agency will provide the technical support to the Ministry of Agriculture during the follow-up of the project. A GIS module, including a data base and a rich client application, will enable to support the production of thematic maps.

IV.3 PREDICT exploitation module

The exploitation module includes a data base and a range of web applications. It will provide the following main functions:

- Data collection,
- Information quality control,
- Information analysis,
- Performance indicators,
- Users follow up.

Data collection

The collection of data should allow for near real time transmission and require little software installation on the user terminal. This function will be ensured by the SIGEL system, excepted for specific field enquiries. The data collected by the SIGEL will be accessible by the PREDICT information system through a direct link between the servers. When handling this data, the PREDICT information system will implement the security regarding user authentication, secured data transmission, definition of privileges and others.

Information quality control

Information quality is of paramount importance for epidemiological data. PREDICT shall ensure the reliability and exhaustiveness of the data with which it deals. The system will include functionalities such as data verification, highlighting data entry errors, search and detection of aberrations. These functionalities will be shared between SIGEL and PREDICT information systems.

Information analysis

Information analysis is very important for an optimal exploitation of the system. The end users of the analysis functions will be either the users of the network in Senegal (DSV, regional offices, field agents) or external users like international organisations. Four main types of services will be implemented:

- Advanced queries. The PREDICT information system will allow queries to the data base through user-friendly queries definition tools.

- Automatic reporting. This function is a key feature for epidemiological surveillance systems. The system shall provide tools to adapt easily the format of the report to be automatically generated for the different end users.

- Mapping. Information analysis is greatly facilitated by GIS functionalities, especially for data spatial analysis, data mapping. This function will be shared between the PREDICT mapping and data processing tools.
- Data export. This function will enable to export data from the PREDICT data base in file with standard formats, like Excel, CSV.

Performance indicators

This function will enable DSV to monitor the efficiency of the national system of epidemiological surveillance. PREDICT will measure indicators as for instance the ratio of biological samples able to be analysed versus the total number received by a dedicated laboratory.

User's follow up

The system will include functions enabling to follow the level of activity of the users and provide indicators of use of the system.

Technologies used for the exploitation module

Many of the functions to be developed for the PREDICT data processing tools are generic to epidemiological information systems. In particular, the information analysis functions will be integrated in an updated version of the open source applications editor "Imogene" [5]. This editor, based on a model driven architecture approach, enables to quickly model and deploy data collection applications. Thanks to a graphical modeling tool, an operator can model the forms and the fields to collect the data that he needs in an intuitive manner without the need for a demanding training.

Using this defined data model, the platform automatically generates a set of data collection applications:

- A web application,
- A desktop application,
- An application for mobile terminals that runs on the Android platform.

The data that are collected by this set of applications are stored in a common centralized database. The mobile application and the desktop application can be run in connected or disconnected mode. The data is stored locally and, as soon as a connection is made available, a synchronization process will synchronize the locally stored data with the data stored in the central database.

The Imogene editor will not be used to generate the data collection functions, because they are ensured by the SIGEL. However, the capacity to generate the generic applications required by the PREDICT information system could be added to the Imogene editor. A data model of SIGEL data will be elaborated to enable the automatic production of generic reports or queries, and more generally, support the applications provided by the exploitation module.

IV.4 GIS module

The geographic information system tool will enable the following:

- Delimitation of burnt areas,
- Localisation of herds,
- Livestock distribution mapping.

Delimitation of burnt areas

Bushfires have a direct impact on the availability of pasture. The objective of this application is to delimit the burnt areas and estimate the biomass with a minimum temporal resolution of 3 months and a minimum spatial resolution of 1km. The detection of burnt areas is a routine task for the CSE "Centre de Suivi Ecologique" of Dakar which will provide these layers at the required spatial and temporal resolution.

Localisation of herds

In order to identify the location of the herds, national herd censuses are carried out. However, these censuses are very expensive and they are usually carried out with a low temporal resolution. Moreover, the herd censuses usually yield livestock numbers at an aggregated administrative unit (such as counties) [6, 7].

PREDICT will set up a tool that will allow determining the optimal sampling strategy for herd census. The tool will take into account possible strata, for instance different zones with other vegetation patterns, and it will determine the optimal number of samples as well as the location of the samples. The unit of the sampling strategy is the household, which will be visited by field teams and for each household the heads of livestock are determined. The outcome of the sampling scheme will allow generating seasonal livestock distribution mapping.

Livestock distribution mapping

Whereas the livestock census will give the actual number of livestock, seasonal dynamics will influence the location of the herds. Based on the relationship

between the environment and the herds, it becomes possible to determine seasonal livestock distribution maps at a higher spatial resolution (1 km^2) than the aggregated livestock numbers [8]. The environmental characteristics are extracted from remote sensing data and are used as predictor data for the livestock distribution models.

Technologies for mapping tools

An ancillary data set comprising e.g. road and hydrological network, altitude, land use/cover, will be provided to the DSV. The data will be in a standardised format with specified projection system.

All data storage, retrieval and visualisation tools will be provided via the interface of the geographical information system.

V. DEPLOYMENT

After successful completion of the feasibility study, a PREDICT demonstration should be deployed at a national level in Senegal starting in 2012. The central, regional, county and local levels will all be integrated in the SIGEL network and participate to the demonstration.

The DSV central level in Dakar will be responsible for the administration of the system.

The 14 "Regional Stock Farming Services" acting at the regional level, managed by a veterinary surgeon will be equipped. The regional level reports to central level and gives commands at the county level.

A total of 45 Stock Farming Engineers responsible for the surveillance at the county level will be equipped. The stock farming engineers give commands to veterinary posts, the most decentralised and outreaching level of surveillance.

A total of 150 Stock Farming Agents responsible of the veterinarian posts will be equipped. In addition a minimum of 50 and possibly up to 150 private veterinarians will join the community of users.

VI. EVALUATION INDICATORS

The PREDICT system will be evaluated during the demonstration according to various criteria. Examples of evaluation indicators are given hereafter.

Performance indicators

- User satisfaction,
- Availability of the services time and coverage,
- Flexibility of the system, for instance to implement new queries.

Use indicators

- Acceptance of the system by the field agents,
- Number of connections to the system by the users,
- Number of electronic files recorded,
- Number of diseases cases notifications delivered electronically/Percentage filled without deficiencies/Percentage of the total reports,
- Number of reports produced,
- Number of queries for the different services,
- Easiness to deploy.

Economical indicators

- Capability of self funding of DSV for running costs,
- Capability of DSV for investing for system upgrade.

VII. SERVICE SUSTAINABILITY

Sustainability is the main guiding principle of PREDICT, and will be favoured by several factors.

The first is due to the fact that PREDICT fulfils needs clearly addressed by DSV. DSV will therefore take all possible actions to maintain the system beyond the demonstration phase. DSV and its local partners have already undertaken actions for that purpose. A cost/benefit analysis should be performed during the feasibility analysis to prove to DSV the economic viability of the various components of the PREDICT services.

A second factor is related to the approach of the project, which focuses on sustainable rather that technological options. The technologies used are mastered and well known by the consortium, and use industrial standards, which limit the development risks and the maintenance costs. The technologies used are available at low cost. PREDICT will be an add-on component of SIGEL which is sustained by DSV. The additional running cost of PREDICT will be kept at a minimum level. The hosting of the server will be ensured by the Agency for the Information Development of the State (ADIE). Satellite images and layers will be provided to DSV by CSE at preferential rates. During the demonstration, DSV, with the support

of local partners, will acquire the capacity to master and operate the system, which will also contribute to the sustainability.

VIII. CONCLUSIONS AND PERSPECTIVES

The combination of ICT and satellite services has already proven able to bring innovative solutions to support epidemiological surveillance and health early warning in various contexts, for example through the ESA SAFE project [9, 10]. The main objective of SAFE was indeed to provide flexible "On Demand" data collection services for health early warning, for instance in disaster scenarios. PREDICT should demonstrate this added value in the context of animal diseases and veterinarian medicine.

The PREDICT services that will be demonstrated in Senegal are representative of situations of many countries. The PREDICT Senegal case could become a showcase of the services offered by the combination of advanced ICT and satellite services for animal health.

Further developments of PREDICT could include a more integrated approach of disease surveillance, as promoted by the United Nations Agencies, for instance through the GLEWS initiative "Global Early Warning System" for major animal diseases including zoonoses. In order to keep the focus on the priority needs identified by DSV and to limit the complexity of the project, this global approach will not be part of the PREDICT demonstration project. However, it should be a natural evolution of PREDICT.

Demonstrations of sustainable services for animal health requiring space assets based Senegalese case could be facilitated by the availability of an "implementation facility" based on a generic PREDICT solution. Such facility would serve as a training centre enabling end-users to get familiar with the system and services. It would also serve as a test-bed for new services and features. Such a facility could be an extension of PREDICT as a joint endeavour between space agencies, public health agencies and services providers.

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[1] WHO website - page on Zoonoses - http://www.who.int/zoonoses/en/

[2] World Organization for animal health OIE website http://www.oie.int/en/

[3] Tripartite GLEWS website http://www.glews.net/

[4] A tripartite concept note FAO-WHO-OIE- April 2010 - Sharing responsibilities and coordinate global activities to address health risks at the human-animal-ecosystems interfaces. http://www.oie.int/fileadmin/Home/eng/Current_Scientific_Issues/docs/pdf/FINAL_CONCEPT_NOTE_Hanoi.pdf

[5] Web Address Imogene code http://code.google.com/p/imogene/

[6] Vaughan IP, Ormerod SJ, 2003. Improving the quality of distribution models for conservation by addressing shortcomings in the field collection of training data. Cons Biol 17, 1601-1611.

[7] Bryssinckx W, Ducheyne E, Muhwezi B, Godfrey S, Mintiens K, Leirs H, Hendrickx G, Estimating the spatial distribution and density of reservoir animals. Manuscript in preparation.

[8] Wint W, Robinson T, 2007. Gridded Livestock of the World, FAO, 131 pp.

[9] Chronaki CE, Berthier A, Bastier S, Kontoyiannis V, Matsakis Y, Lleo MdM, Gikas A, Kritsotakis E, Braak L. Satellite-enabled Applications for Health Early Warning in Public Health after a Disaster: Experience from a Readiness Exercise. eChallenges 2008.

[10] Official website of the National Centre for Tuberculosis and Lung Diseases in Georgia: http://www.tbgeo.ge WHO Georgia Tuberculosis – Country profile http://apps.who.int/globalatlas/predefinedReports/TB/PDF_Files/geo.pdf