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QWeCI

Quantifying Weather and Climate Impacts on Health in Developing Countries

Deliverable 4.1.c – Description of the pilot integrated multi–agent system

Start date of project: 1st February 2010 Duration: 42 months

Lead contractor: UCAD
Coordinator of deliverable: UCAD
Evolution of deliverable

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Dissemination Level		
PU	Public	
PP	Restricted to other programme participants (including the Commission Services)	PP
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Quantifying Weather & Climate Impacts
QWeCI
on health in developing countries

UCAD D4.1C

Description of the pilot integrated multi-agent system

Period from February 1, 2010 to July 31, 2012

[UCAD Report D4.1C – July 2012]

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The present report introduces the deliverable work D4.Ic committed to Dakar Cheikh Anta Diop University (UCAD) as part of the QWeCI project.

The project current position can be analyzed through the activities carried out with a view to achieving the objectives assigned to UCAD. The activities defined and organized by the project were multifarious and varied; only the research work related to the MAS part will be presented in this report.

1. Project context

As part of the project QWeCI, UCAD is in charge of contributing to the integration of climate model output data with teledetection data by means of the Multi-Agent System (MAS). The pilot selected concerns the Rift Valley Fever (RVF). That disease is very well known by Senegalese researchers, which can be explained because of the amount of the data collected and particularly by the number of papers on the topic.

The Rift Valley Fever epidemiologic diagram is at the origin of how difficult it is to achieve a model adapted to the African context in general (Ndione et al., 2003). Several hypotheses have then been put forward to explain outbreaks in various points of the continent (Linthicum et al., 1981), (Ndione et al., 2003). They alas are only valid at a local level are not necessarily applicable when one changes regions. This shows that it is a complex system and the modeling activity has to integrate a maximum of parameters. The models produced this far are limited for most of them to a description of the overall properties which actually emerge from interactions among entities making up the system.

Within this context, working out a multi-agent system model based on geographical information systems integrating remote sensing data and taking into account the main environmental epidemiologic, climate aspects seems to be a relevant approach.

2. Project description

2.1. Mission

The main objective assigned to UCAD for the study is to implement a multi-agent simulation pilot based on the behavior description of the input climate data RVF system entities.

However, in order facilitate the data collection of the project different partners, it has been agreed to suggest a data model taking charge of the interactions among the different specialties entities to develop a gross data management platform (laboratory data and field data).

Besides, bibliography reviews have made it possible to concurrently suggest the setting up of a decision system with the same data to integrate analyses tools and data mining with cartographic views.

2.2. Human resources

The project team working in this part consists of several members whose functions are distributed as follows:

- Alassane BAH, Project leader;
- Ahmed Tidiane CISSE, Ph.D. student in charge of modeling the agents based model and the simulation platform;
- Aboubacar CISS, Ph.D. in charge of the RVF multi-point of view modeling;
- Fanta BOUBA, Ph.D. in charge of the problematic linked to decision system;
- Cheikh Mohamed Fadel Kébé, Jacques André Ndione, Amadou Thierno Gaye and Abdoulaye Deme;
- All the project partners (MSI-Hanoï, UMI 209, Ummisco)

3. Progress

3.1. External activities

A series of working sessions were initiated in accordance with the chronogram "needs analysis" phase by the project coordinator an UCAD team, responsible for the MAS part.

This, those tables, with the trades experts, in various formats (individual or collective sessions), where achieved in order to identify the needs, the data available and especially to understand the functioning of the activities conducted around the project.

The actors are mostly confronted with the following issues:

- Gathering data (comparison with other partners data)
- Availability for treatment. The data are treated in function of the deliverable.
- Production of statistics
- Work scale – work temporal scale compatibility
- Data centralization – non existing data base

3.2. Internal activities

Outside external activities, the UCAD team internally initiated the detailed analysis of needs expressed by the trade's experts and the implementation of some modules.

That notably consisted of:

- The definition of framing documents
- The modeling of data from various angles (concept, agent and multi-dimensional);
- The development of a field and laboratory data (tabular and graphic) storage and read out platform;

- The communication of the first results through posters, papers presentations;

3.3. Actual timetable

In the table below (Table 1) for each aspect of the execution of the project, the actual achievement rate has been evaluated in relationship with the activities estimated rate on the date of July 31 2012.

The activities progress in commented on in the analysis tables of the project chronogram below.

ACTIVITY		Effective start		Actual rate	Observations
		Date	Duration		
				1. ANALYSE DES BESOINS	
1.1	Definition of topics	Feb 2010	1 m	100%	
1.2	State of the art on vector-borne diseases	March 2010	4 m	100 %	
1.3	Interviews with experts	Aug 2010	/	100 %	IPD, CSE, DSV, PNLP, PPZS
1.4	Validation meetings	Aug 2011	/	100 %	Internally
				2. MODELISATION	
2.1	Conceptual modeling	Feb 2011	2 m	100%	
2.2	Literature review on models	July 2011	6 m	100 %	
2.3	Agent modeling	May 2010			
2.4	Multidimensional modeling	Feb 2012	3 m	100 %	
2.5	Technical and functional architecture	July 2011	1 w	100 %	
2.6	Validations "formalism"	April 2012	2 w	100 %	
2.7	Feedback meeting: Evaluation and corrections	May 2012	/	20 %	Health and monitoring of herds data have not been integrated
				3. DEVELOPPEMENT	
3.1	Database Implementaion	May 2011	/	70 %	Health data and monitoring of herds have not been integrated
3.2	Implementation of the platform for recording data				
3.3	Agent System implementation: Phase 1	May 2010		100%	
3.4	Decisional System implementation: Phase 1	Dec 2011	/	10 %	A set of epidemiological data has been tested with Pentaho tool for statistical output (dynamic table and graphs)

Tableau 1 : Actual Timetable

4. Implementation

4.1. Tools used

4.1.1. UML formalization

UML is used to formalize the model components. UML is an object oriented modeling language. It proposes a standard notation based on syntax, semantics and a graphic notation designed to make easy the expression of a model.

In strength depends on its ability to "clearly an accurately model the structure and behavior of a system irrespective of any method or programming language" (Muller and Gardner, 2000).

4.1.2. MAS implementation

The approach used is based on the implementation of a multi-agent system. The MAS principle is to study at an aggregate level several sub-systems known at a local level (Daude, 2005).

The chosen approach aims at identifying the agents, specifying the environment through which these agents evolve and finally transcribing the different algorithm governing then behavior and interactions. An effort will be made, during the simulator and by means of several scenarios to better understand the possible correlation between the disease occurrences and the environment phenomena.

4.1.3. GAMA platform

GAMA (Tailandier et al., 2000) was used to make this model work in a simulation. GAMA is a simulation platform designed to offer researchers and modeler a multi-agent systems development tool with notably the use of geographical information systems. GAMA is easy to use and proposes:

- Spatialisation tools: a GIS (geographic information system) interface allowing the study zone representation
- Configuration tools (number of camps, initial population of vectors and hosts, of grub places, …)
- Models output tools (vectors and hosts population dynamics, risk maps)

4.2. Multi-agent model

The model objective is to measure the compact of the rainfall intra-seasonal variability on the viral flow. The problem then is to observe the impacts of the events in the system ecology in order to express hypotheses on the role each of these events in the viral flow.

The inputs of the model are for early versions, the rainfall data as well as a GIS describing the pool, the situation of camps captured by satellites. That model simulates spatial cattle movements well as the evolution of vectors populations and their infections following the rainy events and the vectors host's contacts.

4.2.1. Structure of the model and scale

The spread of the RVF pathogen is linked to the contact intensity between the two categories of actors: the Aedes vexans, Culex poicipiles vectors) and the hosts.

4.2.1.1. The vectors

The spread of the pathogen is marked out by transmissions between vectors and animal hosts. The vectors are essentially mosquitoes of two different species whose behaviors are more or less complementary in the virus transmission.

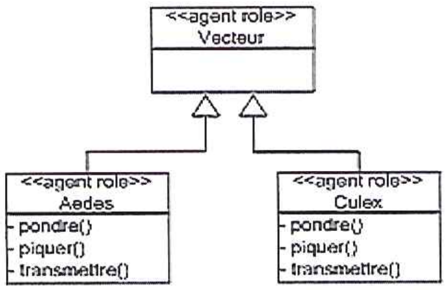

Figure 1: Vector agent model

The two species are different by the place where they lay their eggs (Figure 2) and their agressivity in relation with the lost described. The Aedes vexans has also two properties likely offering on it an important position in the disease virus the vertical transmission and the ability of the eggs to resist a whole dry season.

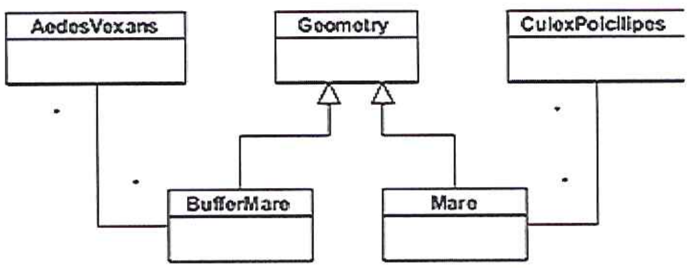

Figure 2: locating the places where they lay their eggs

4.2.1.2. The hosts

The hosts are made up of horned cattle, goats and sheep. It is considered that within a herd, the behavior is homogeneous. The entity "herd" will then be perceived as a situated agent, having a behavior very linked to the environmental conditions. A herd moves around temporary ponds in the rainy season and rejoins a surrounding camp at nightfall.

4.2.1.3. The environment

The study area is situated in Senegal, 1,600 km² around the village of Barkedji. It is a Sahelian pastoral zone (dry tropical climate, rainy season and dry season, a few permanent water points remain and in the rainy season temporary ponds appear. A "shapefile" type file was available on this environment data. Three "shapefile" were later extracted from that file: one being about all the data linked to the vegetation (steppe, savannah), another about the ponds and the last about the camps in the study area

4.2.2. The system dynamics

The system dynamics is the fruit of the agents' behaviors and their interaction. The main interactions describes are the hosts-vectors contacts sources of infection on both sides but also the reproduction of vectors which depends on the state of ponds. The diagram below (figure 3) sums up this dynamics within our MAS.

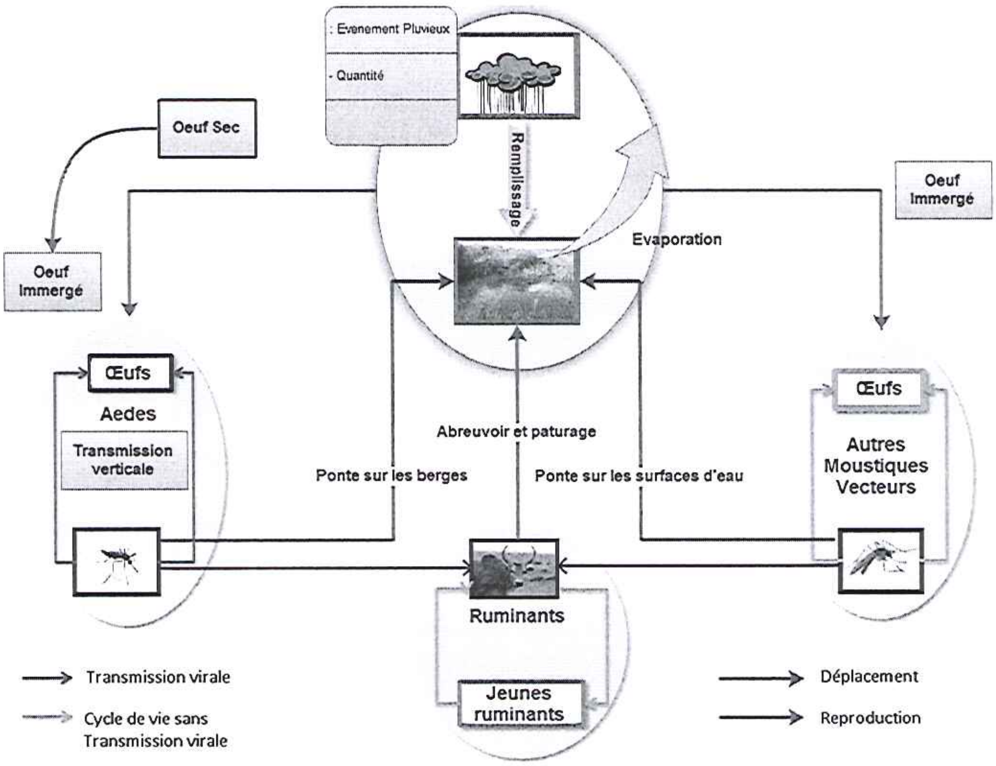

Figure 3: Overview of the model dynamics

As a whole, the viral flow is the result of an evolution of the hosts and vectors combined with an external contamination which favors these state changes. The epidemiologic diagram which have been described (Figure 4) follows the compartment model (McKendrick, 1926), total at the beginning on a population which a applied to individuals

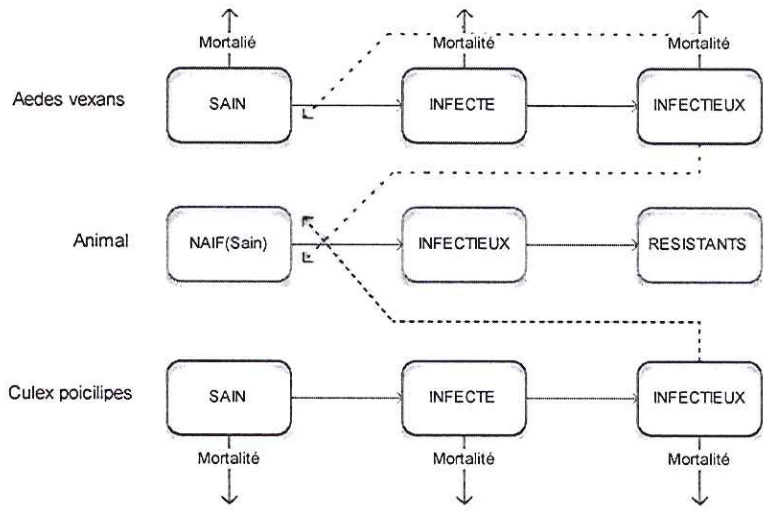

Figure 4: The disease infection model

4.3. Results

A first simulation has been developed under GAMA (Figure 9) which has made it possible to experiment different rainfall scenarios.

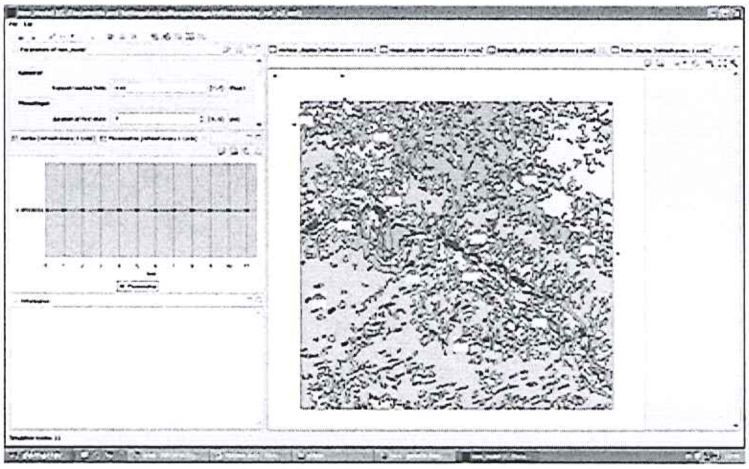

Figure 5: Screen simulation (initialization phase)

The first simulation results corroborate and succeed in well representing the RVF appearance mechanism identified in Ferlo (Ba et al, 2005; Ndione et al, 2008). The simulation data essentially come from different scientific areas that are climatology, hydrology, entomology, pastoralism, etc). The simulation platform suggest a certain number of tools (Figure 9)

- Specialization tools: a GIS (geographic information system) interface allowing the representation of study zone;
- Configuration tools (number of camps, initial population of vectors and hosts (vector and host population dynamics, risk map).

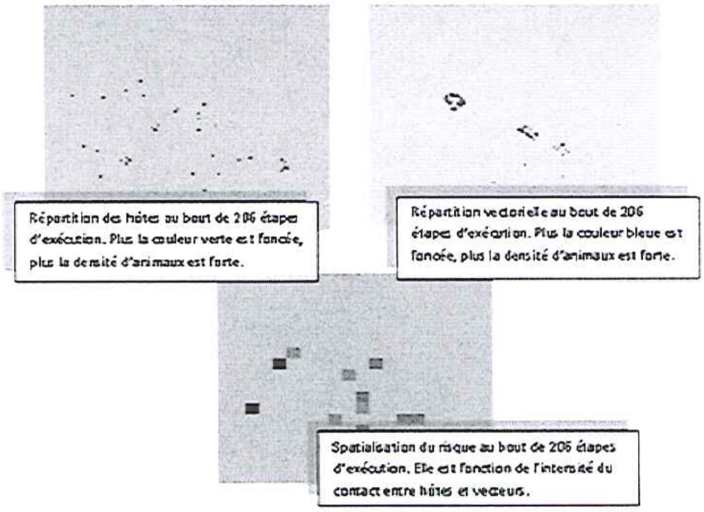

Figure 6: Output Screens of the simulation

4.3.1. Scenario 1 : Reference scenario

The rainy season 2012 rainfall remains the reference scenario. It recorded a strong intra-seasonal variability. A long rainfall superior to 21 days is observed between the weeks 28 and 32 (figure 8). This rainfall distribution has a consequence and impact on the vectorial dynamics materialized by figure 11.

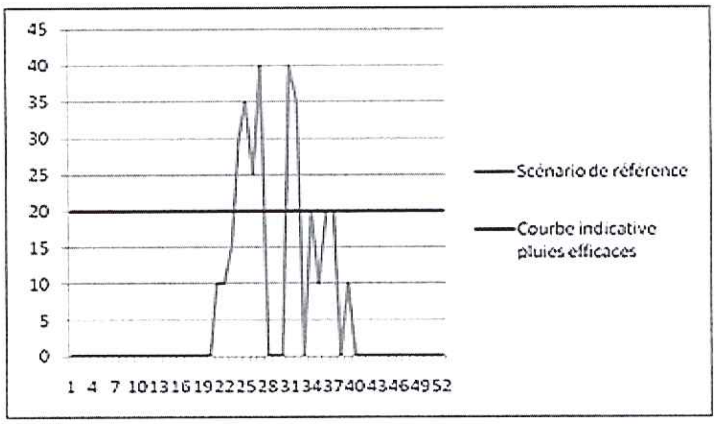

Figure 7 : Reference scenario rainfall curve

4.3.1.1. Number of Culex Poicipiles and Aedes Vexans Evolution

A quasi extinction of Aedes vexans at the end of a few rain weeks can be observed. At the same time, the appearance of Culex poicipiles is noted full in the season, at a moment corresponding to the Aedes vexans extinction phase. In an average situation, the Aedes emergence is fleeting and concerns only the first half of the rainy season. On the other hand, following the rainfall pause of about 21 days, an efficient rain has favored placement into water of formerly sufficiently dry Aedes vexans eggs, to finally allow uncommon emergence in October (Weeks 32 and 33).

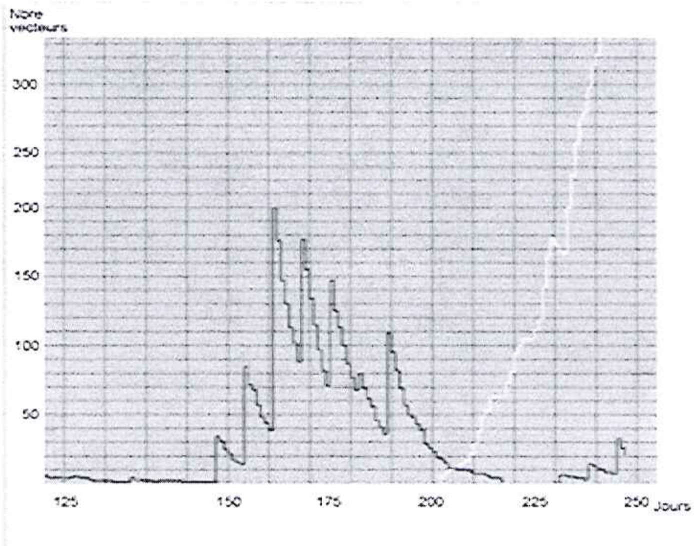

Figure 8: Evolution of the RVF vectors based on the reference scenario

As a matter of fact, those end of season strong rains allow the Aedes eggs to hatch which, in principle, should have occurred only at the beginning of the next rainy season on the one hand and on the other hand keeps the Culex population at a high level.

Thanks to the transovarian transmission, the virus is found again in a doubly favorable environment with possibilities of dispersion (or initialization of the epidemiological cycle, Aedes role) and of intensification (Culex role). In connection with the infected herd evolution, Figure 9 makes it possible to day that there is a strong viral flow in a period when the cumulated presence of the two vectors is noted.

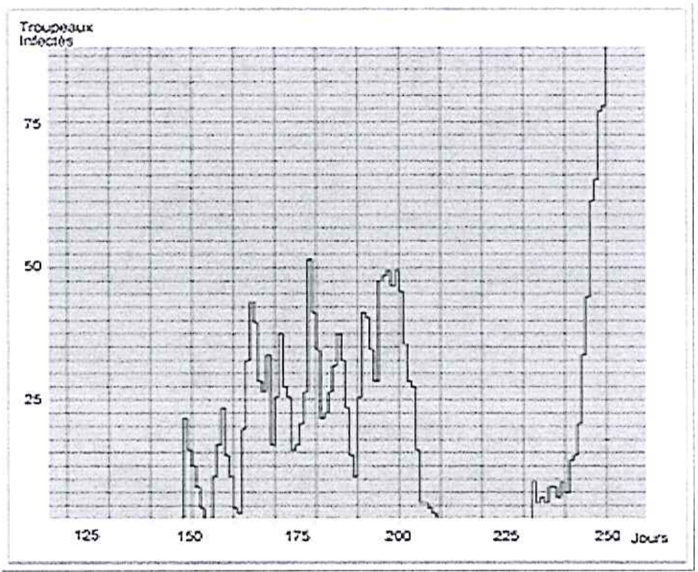

Figure 9: Reference scenario Infected herd evolution

4.3.2. Scenario 2: intense and regular rains

Scenario description: This is a season when the rains are intense (clearly higher than the reference value of efficient rains, 20mm) and regular.

4.3.2.1. Culex Poicipiles and Aedes Vexans number evolution

The first efficient rain has caused a quick upsurge of the Aedes vexans number; this number has steadily varied according to the rains recorded before gradually undergoing a fall until the end of the season.

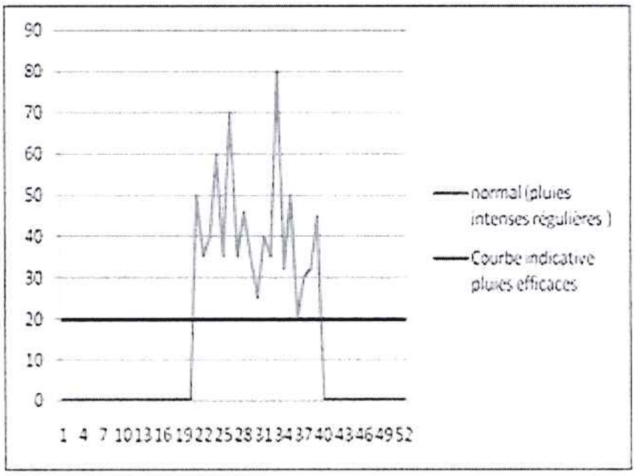

Figure 10 : Scenario 2 rainfall curve

The appearance of Culex poicipiles occurs early in the season, but their massive presence is observed only at a time when Aedes vexans are almost non-existant.

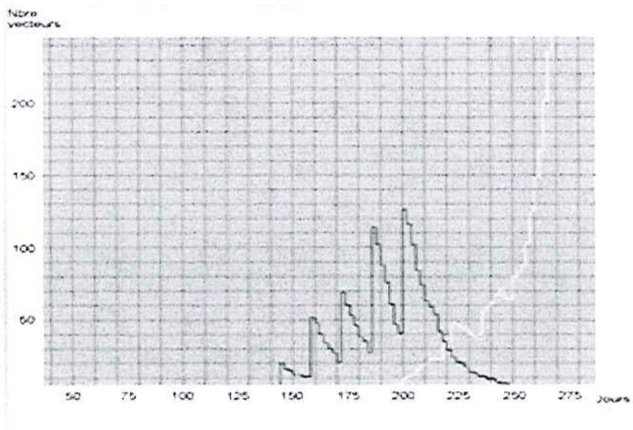

Figure 11: Scenario 2 Vectors Evolution

The low infected herd peaks (less than 2% of infected herds) :

- The first peak coincides with the massive presence period of Aedes vexans. With the lack of Culex poicipiles during this period , Aedes vexans make up the only vectors. Their number and aggressiveness, however, are nor sufficient to allow a significant viral flow;

- The second peak coincides with the densification period of Culex without the presence of Aedes. Despite their big number, the viral flow remains comparatively low

5. Next semester planning

ACTIVITY	PERIOD	ACTORS
Sharing results meetings: validating models	August 2012	UCAD Team Experts trades
Collecting data over 3 to 10 years	Aug - Sept 2012	UCAD Team Experts trades
PhD scientific stay	Oct/Nov 2012	UCAD PhD
Design the generic model on vectorial desease	Sept 2012 – Jan 2013	UCAD Team Experts trades
SMA Implementation : Phase 2	Oct 2012 – Fev 2013	UCAD Team
SID Implementation : Phase 2	Sept 2012- Dec 2012	UCAD Team
Software Validation meeting	Jan 2013	UCAD Team Experts Trades

Tableau 2: Next semester planning

6. Risks and hypotheses

The hypotheses underlying the project is highly linked to the technical assistance (graduate students) environment and that of the expertise (experts' trades):

- Technical team on site visit;
- Good collaboration and coordination between the different partners.

The risk factors and the main risks likely to affect the good performance of the project are summarized in the table below:

Factors	Risks
Non involvement of all the trades experts	Product not true to the expected functioning mode
Non involvement of structures	Inability to use and maintain the system
Bad coordination of activities	Delay in the activities progress

Tableau 3 : Factors and risks

7. Conclusion

The first semester activities were achieved in cooperation with the actors of the fields involved.

Meetings were arranged with the project coordinator in order to collect the required information;

On the field visits were planned with a view to understand the functioning and organization of the different structures

Nevertheless, the project carrying out process was peppered with delays, particularly because the trades experts, who cannot be ignored in the needs analysis phase, were not available.

Abiding by the proposed second semester calendar, however, could enable us to make up with the accumulated delays and thus to respect the delivery time.

The first research work on the SMA part made it possible to define a model centered around the environment hypothesis emphasizing the link between the disease occurrences and the rainfalls breaks followed by strong rains full in the season.

We are also working on a decision system with the same data to integrate analysis and data-mining tools with map views. The objective is to provide analysts and decision makers involved with:

- A functional view: processing and description of the characteristics of the manipulated objects;
- And operational view: scenarios description - the decisions are linked to a context according to the objectives?

Decision system is based on a essential element: the datawarehouse. To build the datawarehouse, the representation model (multidimensional model) has first to be designed.

The present approach aims at carrying out of a study in order to pool the different representation methods for the assumption of objects on all their aspects: structure, functioning and dynamics. This uniting approach could make it possible to integrate:

- The data coming from the conceptual models into the GIS;
- The epidemiological models results as analysis data.

Thus, the datawarehouse will be fed by source data but the data organization will be "analysis" orientated to make easier granular treatments and close treatments between data.

The second stage will consist in integrating analysis and datamining tools for dashboard, graphic, vectors diffusion maps, spreading maps …

The results (predictive analysis) from the Multi-Agent system can thus finally be confronted with those of the data-mining which is equally appropriate for simulation issues.

8. Publications produced

8.1. Journals

- A. Cisse, A. Bah , A. Drogoul , A.T. Cisse , J.A. Ndione, C.M.F. Kebe, 2012 : Un modèle à base d'agents sur la transmission et la diffusion de la fièvre de la Vallée du Rift à Barkédji (Ferlo, Sénégal), Studia informatica universalis, 2012,12, 77-97.
- A.T. Cisse, a, A. Cisse, A. Bah, J. A. Ndione, C.M.F. Kebe. *An agent based modeling method: Agent from "UP". An example on the Rift valley fever at Barkedji (Senegal);* Advance in Artificial Intelligence, Vol. 1, 685-690, 1-2 October 2011, Chengdu, PRC, ISBN 978-1-61275-994-4; Electronically (to be) available at http://www.ier-institute.org.

8.2. Refereed conference

- A. Cissé, A. Drogoul, P. Taillandier, A. T. Cissé, A. Bah, J.A. Ndione, C. M. F. Kébé, I. Dia, A. Th. Gaye, M.Sangharé, 2010 : Un modèle à base d'agents pour étudier l'émergence et la transmission de la RVF (La fièvre de la vallée du Rift), Commisco 2010, Paris, Bondy, France
- A. T. Cissé, A. Bah, Z. Guessoum, 2011 : conception d'un méta modèle agent sur les maladies à vecteurs, Doctoriales PDI 2011, Paris, Bondy, France.

9. References

Daude E., 2006 : A monte carlo approach to diffusion : une étude " historique " revisitée par la modélisation multi-agents. Modélisation et simulation multi-agents applications pour les Sciences de l' Homme et de la Société, pages 385–409.

Linthicum KJ., Davies FG., Bailey CL., and Kairo A., 1983: Mosquito species succession in a dambo in an east African forest. Mosquito News, 43 :464–470.

Muller P., Gaertner N., 2000 : Modélisation objet avec UML. 2eme edition. (Paris : Eyrolles).

Ndione J.-A., Besancenot J.-P., Lacaux J.-P. Et Sabatier P., 2003 : Environnement et épidémiologie de la fièvre de la vallée du Rift (FVR) dans le bassin inférieur du fleuve Sénégal. Environnement, Risques et Santé, 2(3), 176-182.

Ndione J.-A., Bicout D., Mondet B., Lancelot R., Sabatier P., Lacaux J.-P, Ndiaye M. , Diop C., 2005 : Conditions environnementales associées à l'émergence de la fièvre de la vallée du Rift dans le delta du fleuve Sénégal en 1987. Environnement, Risques et Santé, 4(2), S5-S10.

Taillandier, P., Drogoul, A., Vo, D.A. and Amouroux, E. 2012 : GAMA: a simulation platform that integrates geographical information data, agent-based modeling and multi-scale control. In 'The 13th International Conference on Principles and Practices in Multi-Agent Systems (PRIMA)', India, Volume 7057/2012, pp. 242-258.

10. Annex: the GAMA platform[1]

GAMA is a simulation platform, which aims at providing field experts, modelers, and computer scientists with a complete modeling and simulation development environment for building spatially explicit agent-based simulations. It is being developed by several French and Vietnamese research teams under the umbrella of the IRD/UPMC International Research Unit **UMMISCO** since 2007.

GAMA provides the modeler with:

- The ability to use arbitrarily complex GIS data as environments for the agents.
- The possibility to run simulations composed of vast numbers of agents (up to millions).
- A way to conduct automated controlled experiments on various scenarios, with a systematic, guided or "intelligent" exploration of the space of parameters of models.
- The possibility to let users interact with the agents in the course of the simulations.

GAMA relies on:

- A modeling language, GAML, for specifying agents and environments
- An extensible library of agents architectures, statistical and spatial analysis functions.
- A cross-platform reproducibility of simulations
- A user interface based on the Eclipse platform, with flexible plotting and graphical views

GAMA is an open-source project hosted on this site. Its latests stable version can be freely downloaded from here (and used without additional requirements on MacOS X, Windows and Ubuntu). It comes pre-loaded with several models, tutorials and a complete on-line documentation.

Spatially explicit agent-based simulations, like the ones that are being developed in **GAMA**, are at the heart of modern EDSS (Environmental Decision Support Systems) that support deciders and stakeholders in the management of environmental problems (flood control, mitigation of natural catastrophes, land-use and land-planning, plant pests invasions, and so on). Specifically, these simulations allow to couple social, institutional, economical, ecological or biophysical models in a seamless way, and to take into account their influences and interactions on multiple forecasting scenarios.

The different teams also offer training and courses on agent-based modeling and GAMA (please contact the project owners on this subject).

GAMA is developed on Eclipse, and profiled using YourKit Java Profiler. YourKit is kindly supporting open source projects with its full-featured Java Profiler. YourKit, LLC is the creator of innovative and intelligent tools for profiling Java and .NET applications. Take a

[1] http://code.google.com/p/gama-platform/

look at YourKit's leading software products: YourKit Java Profiler and YourKit .NET Profiler.

Research teams actively involved in the development of GAMA:

- UMI 209 UMMISCO IRD/UPMC, Bondy, France (2007 – 2012)
- MSI Research Team, Vietnam National University, Hanoi, Vietnam (2007 – 2012)
- UMR 6228 IDEES, CNRS/University of Rouen, France (2010 – 2012)
- UMR 5505 IRIT, CNRS/University of Toulouse 1, France (2010 – 2012)
- DREAM Research Team, University of Can Tho, Vietnam (2011 – 2012)

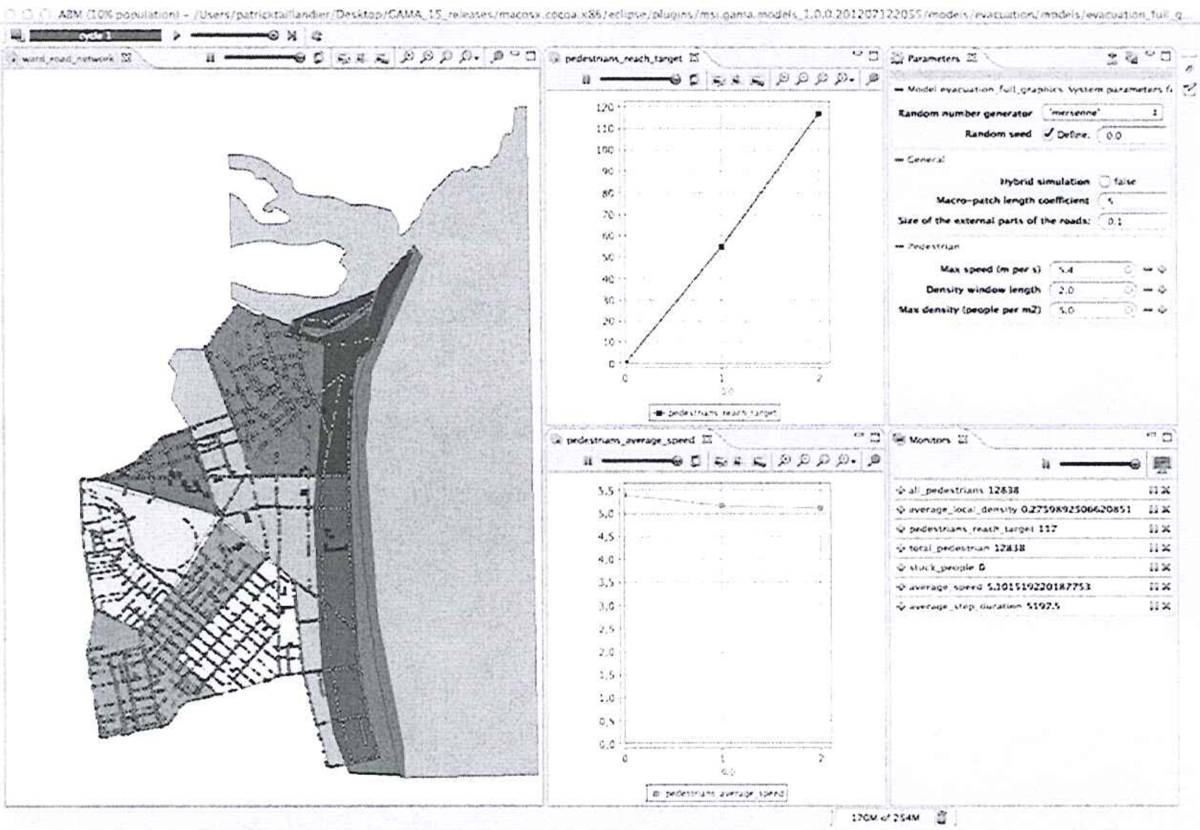

Figure 12 : A gama screenshot