Grant agreement no. 243964

QWeCI

Quantifying Weather and Climate Impacts on Health in Developing Countries

Deliverable D5.3.d: Vulnerability and risk cartography of malaria and RVF at the Barkedji Observatory

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

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

Due date :	M29
Date of first draft :	M35
Start of review :	6 May 2013
Deliverable accepted :	28 June 2013

Project co-funded by the European Commission within the Seventh Framework Programme (2007-2013)		
Dissemination Level		
PU	Public	PU
PP	Restricted to other programme participants (including the Commission Services)	
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)	

Introduction

Among vector borne diseases in Senegal, RVF and malaria are both of strong concern for researchers and decision makers.

Rift Valley fever (RVF) is an acute fever causing viral disease that affects domestic animals (such as cattle, buffalo, sheep, goats, and camels, among others), and humans. RVF is most commonly associated with mosquito-borne epidemics during years of unusually heavy rainfall events. The RVF virus, a member of the genus Phlebovirus in the family Bunyaviridae, is responsible for the disease. RVF was first reported among livestock by veterinary officers in Kenya in the early 1900s. Numerous epidemic/epizootic outbreaks have been reported periodically in many African countries during the past 30 years (Meegan 1979; Hoogstraal et al, 1979; Arthur et al, 1993; Jouan et al, 1988; Digoutte and Peters 1989; Zeller et al, 1997; Fontenille et al, 1998; Linthicum et la, 1999; Nabeth et al., 2001; Woods et al, 2002; Sissoko et al, 2009; Caminade et al, 2011; El Mamy et al, 2011). The virus has been recently located for the first time outside of the African continent, in Saudi Arabia and Yemen during 2000-2001 (Miller et al, 2002; Jupp et al, 2002).

Several studies were carried out on malaria vectorial transmission in many bio- geographical areas in Senegal as part of program targeting its epidemiology or vectors bioecology. These studies to date have not feed into in country operation systems that are leading the fight against malaria. The big challenge for the scientific community but also the political decision makers is rather to find for each geographical area and each ecological context operational, methods of control in order to reduce as much as possible the burden of the disease.

Barkedji is located in the sahalian transmission profile characterized by a seasonal transmission during the short rainy season. The presence of temporary ponds which remain almost the only sources of water until January in the area and which their dynamic is completely under rainfall control constitutes the local ecological characteristics which influence locally the interrelationships between the vectors, parasite and hosts. The first investigation realized in 1994-1995 revealed that *An. gambiae* and *An. arabiensis* constitutes the principal malaria vectors in the village (Lemasson et al, 1997). Therefore, the malaria transmission is seasonal and is concentrated over four months of the year, from September to December with an entomological inoculation rate between 100 and 120 infecting bites per human per year. The only study well documented on the malaria morbidity and mortality undertaken in 1994-1995 in the village of Barkedji (Molez and al., 2006) showed that the malaria onset are most common from November to January (70%). This study indicate further that the high intensity of the transmission and the persistence of the temporary ponds remain the key factors influencing the level of malaria morbidity and consequently on the development of a natural malaria immunity by the indigenous population.

This study is focusing in the Barkedji Health and Environment Observatory (figure 1).

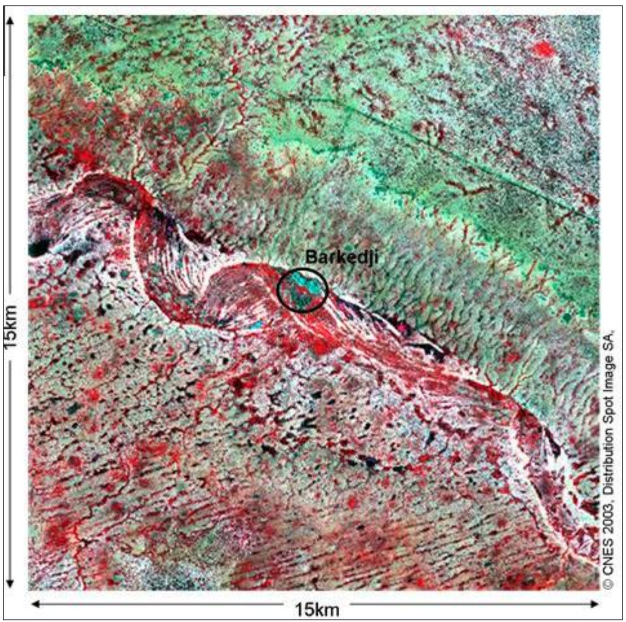

Figure 1: The Barkedji Health and Environment Observatory, study area of the QWeCI project in Senegal.

1. The issue of vulnerability and risk in health sector

Vector-borne infectious diseases, such as malaria, Rift Valley fever, dengue fever, yellow fever, and plague, cause a significant fraction of the global infectious disease burden; indeed, nearly half of the world's population is infected with at least one type of vector-borne pathogen (CIESIN, 2007; WHO, 2004a; Kelly-Hope and Thomson, 2008; Institute of Medicine, 2008).

Vulnerability is a very complex issue that involve in the same process sensibility, exposure and adaptive capacity. *Exposure* is related to the nature and degree to which a system is exposed to significant climatic variations. *Adaptive capacity* refers to the ability of a system to adjust itself to climate variability and, including extremes in order to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. In general with regards to health issues, adaptive capacity can refer to all responses and actions that can: (i) mainstream environment and health into economic development, (ii) promote sustainable and equitable patterns of production/consumption, (iii) build capacity to monitor and manage waster and resources, (iv) monitor health and improve personal protection from pollution and infections, (v) treatment and rehabilitation.

On the other hand, the hazard has to be determined, and finally if one combines hazard and vulnerability, we can obtain a risk map. Whatever the issue, assessing vulnerability should be based on an analytical framework. Literature gave a large overview of opportunities regards to this thematic (Chardon, 1996; Chambers, 1989; Caplan, 2000; Weichselgartner, 2001; Berdica, 2002; Kovats et al, 2003; Bates et al, 2004a; Bates et al, 2004b; D'Ercole and Metzger, 2005; Elbi et al, 2006; Obrist, 2006; D'Ercole and Metzger, 2009; Hongoh et al, 2011).

2. Vulnerability and risk cartography of malaria and RVF in Barkedji

RVF epidemics in Senegal (Ndione et al, 2003; Ndione et al, 2005; Ba et al, 2005; Ndione et al, 2008), do not seem to follow the same relationships as that over East Africa. During the rainy season the abundance of mosquitoes over the Ferlo is linked to dynamics of vegetation cover and turbidity of temporary and relatively small ponds. Research has led to the development of vulnerability maps based on the dynamics of the pond size, the distances over which the infected mosquitoes seek blood meals, i.e. the flying range of mosquitoes, their aggressiveness, and the localisation of villages and cattle pounds around ponds (Lacaux et al, 2007; Tourre et al, 2008a; Tourre et al, 2008b; Tourre et al, 2010; Ndione et al, 2009; Vignolles et al, 2009; Ndione et al, 2011).

2.1- Rift valley fever

2.1.1- Hazard map (dynamic map of mosquitoes' density)

The hazard should be tackled in two aspects: first, the presence or not of water (figures 2 and 3); second, the presence or not of vectors. Temporary ponds (water bodies or breeding sites) could be considered as a good epidemiologic indicator for different vectors of infectious diseases. The first level of hazard can be provided with different means based on rainfall events.

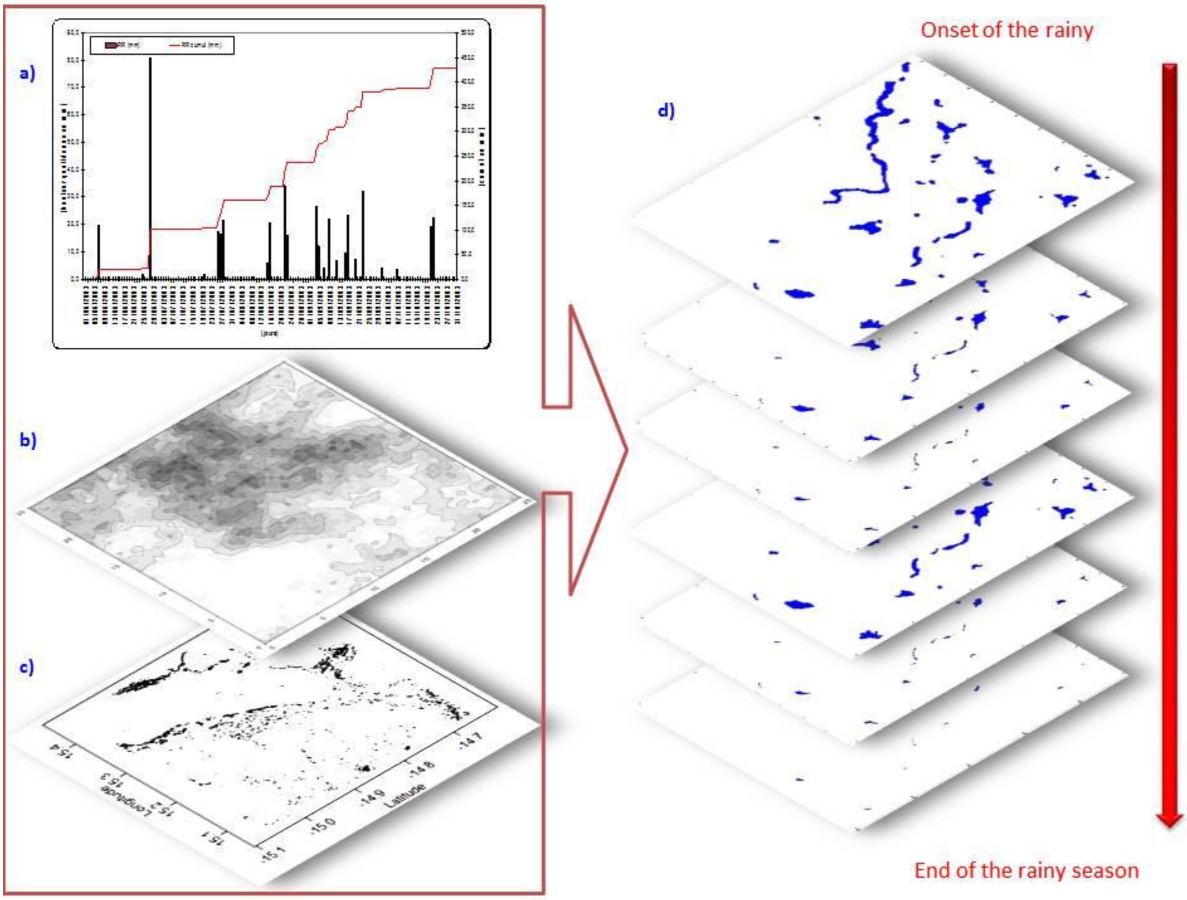

Figure 2: Estimated breeding sites filling from rainfall events in Barkedji (adapted from Sabatier, 2008) : *a) rainfall daily distribution; b) spatial rainfall distribution that can be obtained by kriging from several raingauges stations, or by satellite or radar data; c) extracted view from satellite image showing the breeding sites and d) estimation of filling breeding sites depending on rainfall).*

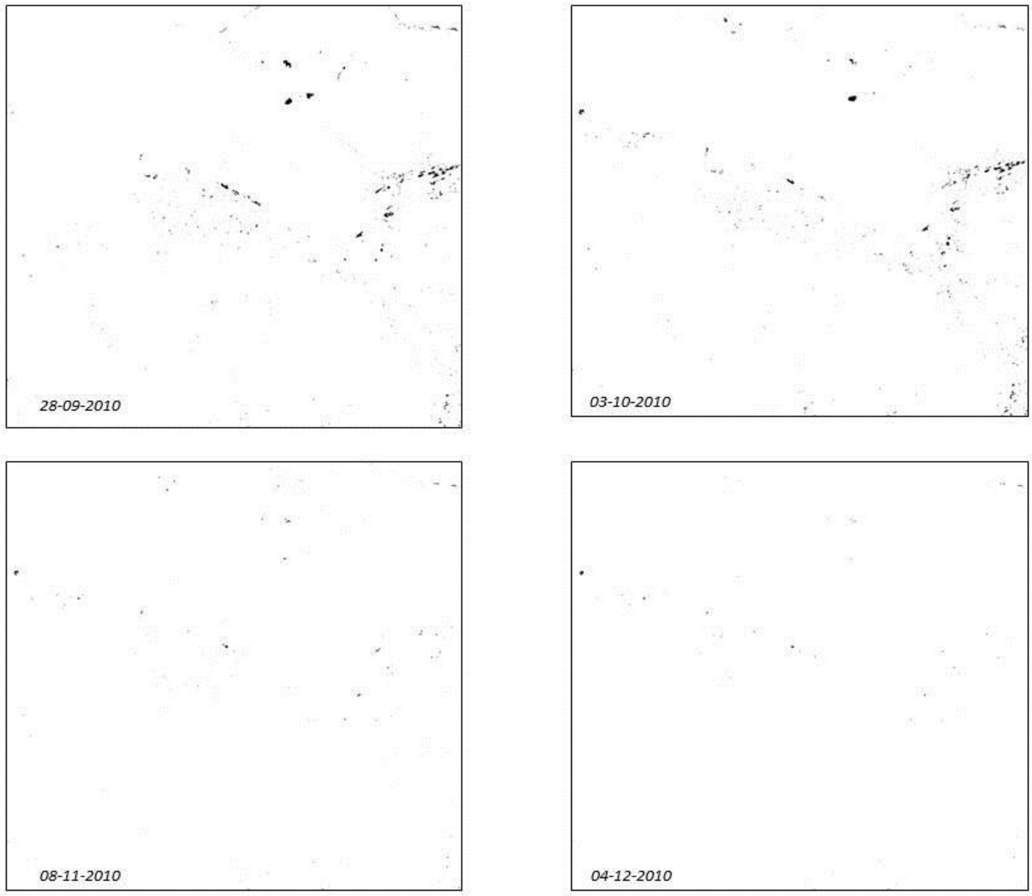

Figure 3: Water bodies mapping at different dates during the 2010 rainy season (*28/09/2010: 481.62 ha for 425 water bodies; 03/10/2010: 462.08 ha for 460 water bodies; 08/11/2010: 79.95 ha for 104 water bodies; 04/12/2010: 40.25 ha for 53 water bodies*)

At this stage, the goal is to first use operational and high-spatial resolution remote sensing images/data to detect all ponds (including their levels of turbidity with and without vegetation) for potential mosquitoes' presence and breeding sites. Temporary ponds are often of small size (< 0.1ha), it is essential to have images with high-spatial resolution. Thus, SPOT-5 multi-spectral high-spatial resolution images (10 m or 2.5m) are well adapted. This is accomplished by developing brand-new indices derived from SPOT-5 images using middle infrared (MIR) and the green and red channels, i.e. the NDPI (Normalized Difference Pond Index), which permits ponds' detection, and the NDTI (Normalized Difference Turbidity Index) which estimates pond turbidity as a measure of vector behaviour (Lacaux et al, 2007). The 'classic' NDVI (Normalized Vegetation Difference Index) allows the assessment of the vegetation cover within the ponds. This technology makes it possible to locate also small ponds with accuracy. The resulting ZPOM is obtained from entomological field-studies and mapped using flying ranges and spatial distribution of vectors. The second step is to establish dynamic maps of mosquitoes' density called Zones Potentially Occupied by Mosquitoes (ZPOM) starting from regular data of the rainfall events. This work is carried out by integrating results of studies on mechanisms of emergence, proliferation and diffusion of the vectors. The ZPOM are defined by taking into account (i) the distribution of rainfall events (frequency and intensity) (ii) the flying range of mosquitoes (iii) their aggressiveness.

2.1.2- Vulnerability map (hosts' evaluation)

The objective here is to determine the zones where hosts (cattle/human) can be found. Those zones represent the vulnerable place where hosts could be in contact with the vectors. If no data/information exists elsewhere, those zones could be detected by processing remote sensing data. The map of vulnerability could be established by photo-interpretation or classification of satellite images. The recognition of those zones could be done based on a precise knowledge of some zones identified during a ground survey.

2.1- Malaria

With regards to malaria, the problem is very more complicated… This is due to the fact that, the breeding sites of malaria vectors are various; we can find malaria vectors as well as in ponds around different human settlements. On the other hand, we can find other breeding sites that cannot be detected by remote sensing data due to the fact of their small size, etc. Lastly, some political and medical interventions like bednet distribution can impact also on the vulnerability assessment.

The table below gave the cases of malaria in the BHEO.

	2009	2010	2011	2012	TOTAL
Barkedji	147	4	83	88	322
Niakha	3	*NAN*	6	6	15
Ngao	2	*NAN*	3	6	11
Fourdou	0	*NAN*	0	0	0
Kangalédji	1	*NAN*	3	6	10
Beli Boda	0	*NAN*	1	1	2

With regards to these data, Barkedji village seemed to be the most vulnerable. Beyond the high value recorded in Barkedji, these facts highlight also another problem that is related to the address issue. Often, when you asked to people addresses, "*they say that they are living in Barkedji*", and the Health Center is based in Barkedji… In fact, they often gave the address of their parents or relatives in Barkedji even if they are living the villages around Barkedji. Niakha, Ngao and Kangaledji are scarcely at the same level. Beli Boda is less affected by malaria.

Conclusion

The results of the relevant studies conducted so far indicate a clear vulnerability with regards to RVF and malaria in Barkedji. These results can be considered as good inputs into African health information systems, agencies; they can rely on panoply of additional products based on remote sensed approach in support of appropriate measures to apply in regions under vulnerability threats. Finally, this should improve health early warning systems linked to vector borne epidemics. In developing countries, there are strong needs to be supported by a solid base of evidence and knowledge of the health effects and vulnerability resulting from a changing environment, based on quantitative and qualitative methods of assessing human health vulnerability and public health adaptation to climate change.

References

Ba Y., Diallo D., Kebe C.M.F., Dia I., Diallo M., 2005. Aspects of bioecology of two Rift Valley Fever virus vectors in Senegal (West Africa): *Aedes vexans* and *Culex poicilipes* (*Diptera: Culicidae*), *Journal of Medical Entomology*, 42(5): 739-750.

Bates I., Fenton C., Gruber J. et al., 2004a. Vulnerability to Malaria, Tuberculosis, and HIV/AIDS Infection and Disease. Part 1: Determinants Operating at Individual and Household Level, Lancet Infectious Diseases 4(5): 267-277.

Bates I., Fenton C., Gruber J. et al., 2004b. Vulnerability to Malaria, Tuberculosis, and HIV/AIDS Infection and Disease. Part 2: Determinants Operating at Environmental and Institutional Level, Lancet Infectious Diseases 4(6): 368-375.

Berdica K., 2002. An introduction to road vulnerability : what has been done, is done and should be done ?, *Transport Policy*, vol. 9, no 2, p. 117-127.

Bohle H.-G., 2001. Vulnerability and Criticality. Perspectives for Social Geography, Update IHDP (2): 1-5.

Caminade C., Ndione J-A., Jones A., Kébé C.M.F., Danuor S., Tay S., Tourre Y-M., Lacaux J-P., Duchemin J-B., Jeanne I., Morse A.P., 2011.Mapping Rift Valley fever and malaria risk over West Africa using climatic indicators. *Atmospheric Sciences Letter*, 12: 96-103.

Chambers R., 1989. Editorial Introduction: Vulnerability, Coping and Policy, IDS Bulletin 20 (2): 1-7.

Chardon A.-C., 1996. *Croissance urbaine et risques « naturels ». Évaluation de la vulnérabilité à Manizales, Andes de Colombie*, thèse de doctorat, Université Joseph Fourier – Grenoble, 387 p.

CIESIN (Center for International Earth Science Information Network). 2007. *Changes in the incidence of vector-borne diseases attributable to climate change*, http://www.ciesin.columbia.edu/TG/HH/veclev2.html (accessed October 18, 2007).

D'Ercole R. et Metzger P., 2005. « Repenser le concept de risque pour une gestion préventive du territoire » / « Rethinking the concept of risk for preventive land management », *Pangea*, juin-décembre, p. 19-36.

Digoutte J.-P., Peters C.J., 1989. General aspects of the 1987 Rift Valley fever epidemic in Mauritania. *Research in virology*, 140: 27-30.

El Mamy A.B.O., Baba M. O., Barry Y., Isselmou K., Dia M.L., Ba H., Diallo M.Y., El Kory M.O.B., Diop M., Lo M.M., Thiongane Y., Bengoumi M., Puech L., Plee L., Claes F., de La Rocque S., Doumbia B., 2011. Unexpected Rift Valley Fever Outbreak, Northern Mauritania. *Emerging Infectious Diseases*, 17 (10), 1894-1896

Fontenille D., Traore-Lamizana M., Diallo M., Thonnon J., Digoutte J.-P., Zeller H.G., 1998. Nouveaux vecteurs de la fièvre de la vallée du Rift en Afrique de l'Ouest. *Emerging Infectious Diseases*, 4: 289-293.

Hoogstraal H., Meegan J.M., Khalil G.M., Adham F.K., 1979. The Rift Valley fever epizootic in Egypt 1977-1978. 2. Ecological and entomological studies, *Trans. R. Soc. Trop. Med. Hyg.*, 73: 624-629

Jouan A., Le Guenno B., Digoutte J.-P., Philippe B., Riou O., Adam F., 1988. An RVF epidemic in Southern Mauritania, *Annales de l'Institut Pasteur / Virologie*, n°139, pp. 307-308.

Jupp P.G., Kemp A., Grobbelaar A., Leman P., Burt F.J., Alahmed A.M., Al Mujalli D., Al Khamees M., Swanepoel R., 2002. The 2000 epidemic of Rift Valley fever in Saudi Arabia: mosquito vector studies. *Medical and Veterinary Entomology*,1: 245-252.

Kelly-Hope L., Thomson M.C., 2008. Climate and Infectious Diseases. In *Seasonal Forecasts, Climatic Change and Human Health, Health and Climate,* Series *Advances in Global Change Research,* Vol. 30(I): 31-70, Thomson M.C., Garcia-Herrera R., Beniston M. (Eds.) 234 p.

Lacaux J.-P., Tourre Y.-M., Vignolles C., Ndione J.-A., Lafaye M., 2007. Ranking Ponds from High-Resolution Remote Sensing: application to Rift Valley Fever Epidemics in the Ferlo Region (Senegal). *Remote Sensing of Environment*, 106: 66-74.

Lemasson J.-J., Fontenille D., Lochouarn L., Dia I., Simard F., Ba K., Diop A., Diatta M., Molez J.-F., 1997. Comparison of behaviour and vector competence of *An. gambiae* and *An. arabiensis* (*Diptera*: *Culicidae*) in Barkedji, a sahelian area of Senegal. *Journal of Medical Entomology,* 34(4): 396-403.

Linthicum K.J., Assaf A., Compton J.T., Kelley P.W., Myers M.F., Peters C.J., 1999. Climate and satellite indicators to forecast Rift Valley Fever epidemics in Kenya. *Science*, 285: 397-400.

Meegan J.M., Hoogstraal H., Moussa M.I., 1979. An epizootic of Rift valley fever in Egypt in 1977.*Vetenary Record*, 105(6): 124-5.

Miller B.R., Godsey M.S., Crabtree M.B., Savage H.M., Al-Mazrao Y., Al-Jeffri M.H., Abdoon A.M., Al-Seghayer S.M., Al-Shahrani A.M., Ksiazek T.G., 2002. Isolation and genetic characterization of Rift Valley fever virus from *Aedes vexans arabiensis,* Kingdom of Saudi Arabia. *Emerging Infectious Disease,* 8: 1492-1494.

Nabeth P., Kane Y., Abdalahi M.O., Diallo M., Ndiaye K., Ba K., Schneegans F., Sall A.A.,Mathiot C., 2001. Rift Valley fever outbreak in Mauritania in 1998: seroepidemiologic,virologic, entomologic, and zoologic investigations.*Emerging infectious diseases,* Nov-Dec. 7(6):1052-1054.

Ndione J.-A., Besancenot J.-P., Lacaux J.-P., 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,* vol. 2, n°3, pp. 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,* vol. 4, n° 2, S5-S10.

Ndione J.-A., Diop M., Lacaux J.-P., Gaye A.Th., 2008. Variabilité intrasaisonnière de la pluviométrie et émergence de la fièvre de la vallée du Rift (FVR) dans la vallée du fleuve Sénégal : nouvelles considérations, *Climatologie*, vol. 5, pp. 83-97.

Ndione J.-A., Lacaux J.-P., Tourre Y.-M., Vignolles C., Lafaye M., Güell A., Gaye A.Th., Diallo M., Dia I., Ba Y., Kébé C.M.F., Faye A., 2011. Com. Orale In *Climate, environment and health: recent achievements in Senegal. Climate & Health in Africa: 10 years On* », 4-6 April 2011, Addis-Abeba (Ethiopia).

Ndione J.-A., Lacaux J.-P., Tourre Y.-M., Vignolles C., Fontannaz D., Lafaye M., 2009. Mares temporaires et risques sanitaires au Ferlo : contribution de la télédétection pour l'étude de la fièvre de la vallée du Rift entre août 2003 et janvier 2004.*Sécheresse,* vol. 20, n°1, pp. 153-160.

Sabatier P., Fontaine B., Roucou P., Bicout D., 2008. Analyse du Changement du Climat et de ses impacts sur l'eau et la santé. Com. Orale In Atelier RIPIECSA *« Changement climatique et Paludisme au Sahel »*, Bamako, Mali, 29 novembre-1erdécembre 2008.

Sissoko D., Giry C., Gabrie P. *et al*., 2009b. Rift Valley fever, Mayotte, 2007-2008. *Emerging Infectious Diseases*, 15: 568-570.

Tourre Y.-M., Lacaux J.-P. 1, Güell A., Lafaye M., Sabatier P., Coëffier E., Braak L., 2008a. The RedGems Information System: Climate, Environment and Public Health, pp. 135-141, In Thomson M.C., Garcia-Herrera R., Beniston M. [Editors], *Seasonal Forecasts, Climatic Change and Human Health*. 232 p.

Tourre Y.-M., Lacaux J.-P., Vignolles C., Ndione J.-A., Lafaye M., 2008b. Mapping of zones potentially occupied by mosquitoes (ZPOMs) *Aedes vexans* and *Culex poicipiles*, the Main Vectors of Rift valley fever in Senegal, *Geospatial Health*, 3(1): 69-79.

Tourre Y.-M., Lacaux J.-P., Vignolles C., Ndione J.-A., Lafaye M., 2010. Rift Valley Fever (RVF) risks in Senegal using high-resolution remote sensing. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Science*, XXXVIII (Part 8, Kyoto, Japan 2010), 343-348.

Zeller, H. G., D. Fontenille, M. Traore´-Lamizana, Y. Thiongane, and J. P. Digoutte. 1997. Enzootic activity of Rift Valley fever virus in Senegal. Am. J. Trop. Med. Hyg. 56: 265Ð272.

Weichselgartner J., 2001. « Disaster mitigation : the concept of vulnerability revisited », *Disaster Prevention and Management*, vol. 10, no 2, p. 85-94.

WHO (World Health Organization). 2004a. *Global strategic framework for integrated vector management*. Geneva: World Health Organization, http://www.emro.who.int/rbm/PDF/ GlobalStratFrameIVM.pdf (accessed October 18, 2007).

Woods C.W., Karpati A.M., Grein T., McCarthy N., Gaturuku P., Muchiri E., Dunster L., Henderson A., Khan A.S., Swanepoel R., Bonmarin I., Martin L., Mann P., Smoak B.L., Ryan M., Ksiazek T.G., Arthur R.R., Ndikuyeze A., Agata N.N., Peters C.J., 2002. An outbreak of Rift Valley fever in Northeastern Kenya, 1997-1998. *Emerging Infectious Diseases*, 8: 138-144.