Spatio-temporal modeling of *Aedes albopictus* dispersal in Réunion Island. Application to Vector Control.

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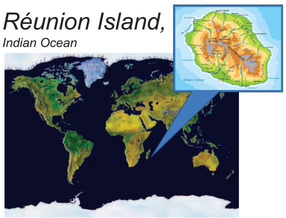
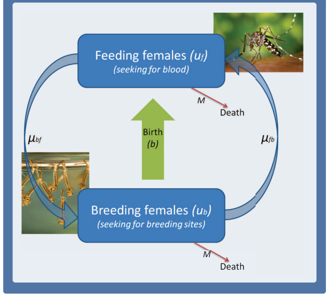
Context



We study the dispersal of female mosquitoes *Aedes albopictus*, responsible of the spreading of the Chikungunya virus in Réunion Island. Dumont and Chiroleu [1] showed that the use of chemical control tools such as adulticides and larvicides, combined with mechanical control, which consists in reducing the number of breeding sites, would have been an efficient solution against the huge epidemics of 2006. Other alternative, like the Sterile Insect Technique (TIS Project, Réunion Island), are in study, but, for the moment, only mechanical and chemical controls are permitted. It is also necessary to improve vector-control, i.e. using as less chemical tools as possible but located in the favorable places in order to have the maximal effects on the wild mosquitoes. We consider a spatio-temporal model, taking into account some entomological knowledges. We also consider two compartments representing females looking for blood and females looking for breeding sites. We assume that mosquitoes follow a random walk. Additional drift terms are considered taking into account the fact that mosquitoes, stimulated by attractants, move preferably in some directions. Wind is also and incorporated. For each breeding or feeding site we construct an area of attraction that depends on Wind speed and Wind direction.

The compartimental model



A system of quasilinear partial differential equations

Set $\Omega = [-1,1]^2$ and $Q_T = \Omega \times (0,T)$. For all $(x,t) \in Q_T$, we consider

$$\begin{cases} \frac{\partial u_f}{\partial t} = \nabla\cdot(D\nabla u_f) - \nabla(C_f(x)\,u_f) + \vec{V}\cdot\nabla u_f - (M + \mu_{bf}\mathbf{1}_{bf})\,u_f + \mu_{fb}\mathbf{1}_{fb}u_b + b, \\ \frac{\partial u_b}{\partial t} = \nabla\cdot(D\nabla u_b) - \nabla(C_b(x)\,u_b) + \vec{V}\cdot\nabla u_b - (M + \mu_{fb}\mathbf{1}_{fb})\,u_b + \mu_{bf}\mathbf{1}_{bf}u_f, \\ \nabla u_f\cdot\vec{n} = \nabla u_b\cdot\vec{n} = 0, \quad x \in \partial\Omega \text{ and } 0 < t < T, \\ u_f(x,0) = u_{0,f}(x) \qquad x \in \Omega, \\ u_b(x,0) = u_{0,b}(x) \qquad x \in \Omega, \end{cases}$$

where C_f represents the attractors due to blood meals, like houses, and C_b represents the attractors due to breeding sites. Each PDE is solved using a splitting technique and an appropriate numerical method for each operator :

$$\frac{\partial u}{\partial t} - \underbrace{\nabla.(D(.)\nabla u)}_{\text{Diffusion}} + \underbrace{\nabla.(C(.)u) + \vec{V}(.).\nabla u}_{\text{Advection}} + \underbrace{f(u,.)}_{\text{Reaction}} = 0$$

Numerical Methods :	Diffusion ↓ TR-BDF	Advection ↓ CTU	Reaction ↓ Non standard scheme

Theoretical results

Assuming the parameters are smooth enough, we can show :

- Existence of a classical nonnegative solution,
- Uniqueness of the solution,
- Existence of a possible equilibrium, ...

Numerical Simulations

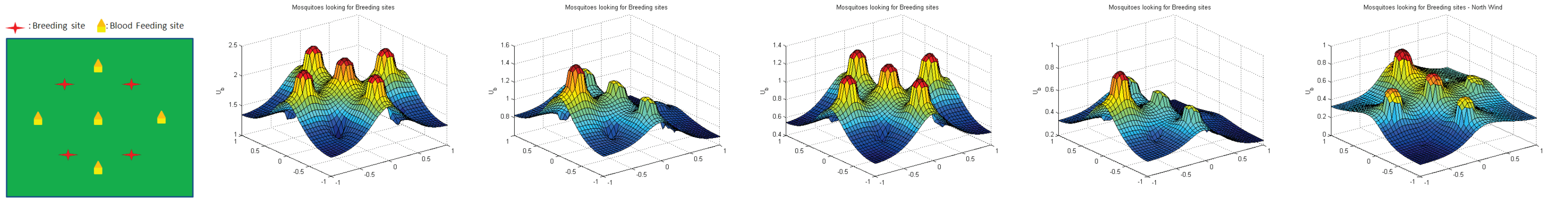
We provide numerical simulations with

- several breeding and feeding sites,
- (or without) landscape roughness,
- (or without) Wind,
- vector control.

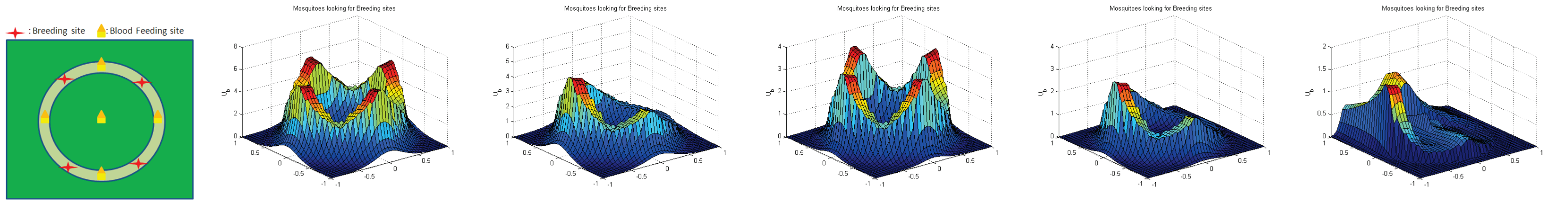
Some Simulations

Massive spraying every 14 days around houses (50 m radius), and destruction of the East Breeding sites after 10 days. At day $t = 60$, the system has reached the steady state solution.

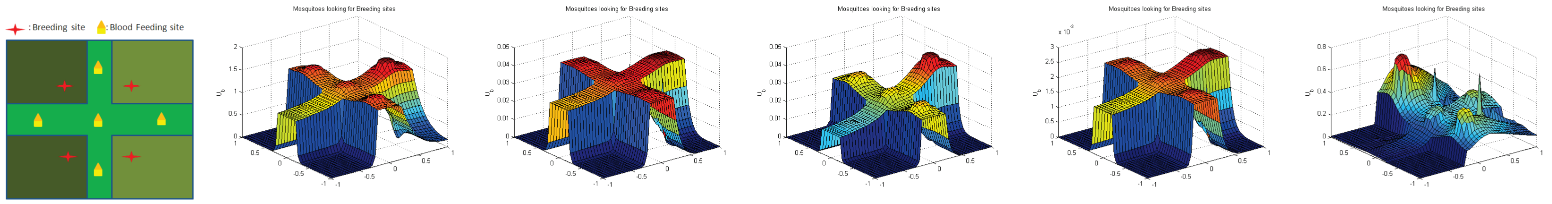
Homogeneous Landscape without Wind Mechanical Control (MC) Massive spraying (MS) MC and MS MC and MS, with North Wind



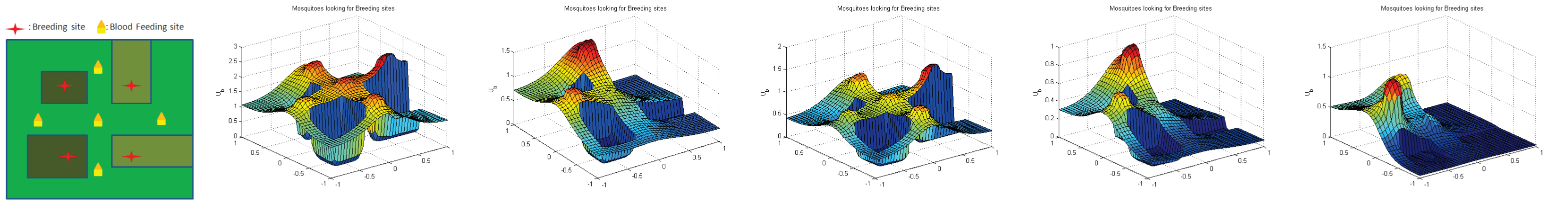
Torus Landscape



Cross Landscape



Complex landscape



Conclusions

The previous examples show that landscapes have a large impact on mosquito spreading and distribution. Additional environmental factors, like Wind, lead to very different results (see example 3, columns 4 and 5). As in the temporal model [1], Mechanical Control and Massive Spraying around houses is the best combination for Vector Control (compare Columns 2, 3 and 4). We conclude that deeper knowledges on landscape modeling and on the relationship between mosquitoes and vegetation would be necessary to improve Vector control.

References

[1] Y. Dumont and F. Chiroleu, Vector control for the chikungunya disease, *Math. Biosc. Eng.*, 7(2) :315–348, 2010.

[2] C. Dufourd and Y. Dumont, Spatio-temporal modeling of mosquito distribution, submitted