# Early warnings of the potential for malaria transmission in Rural Africa using the Hydrology, Entomology and Malaria Transmission Simulator (HYDREMATS)

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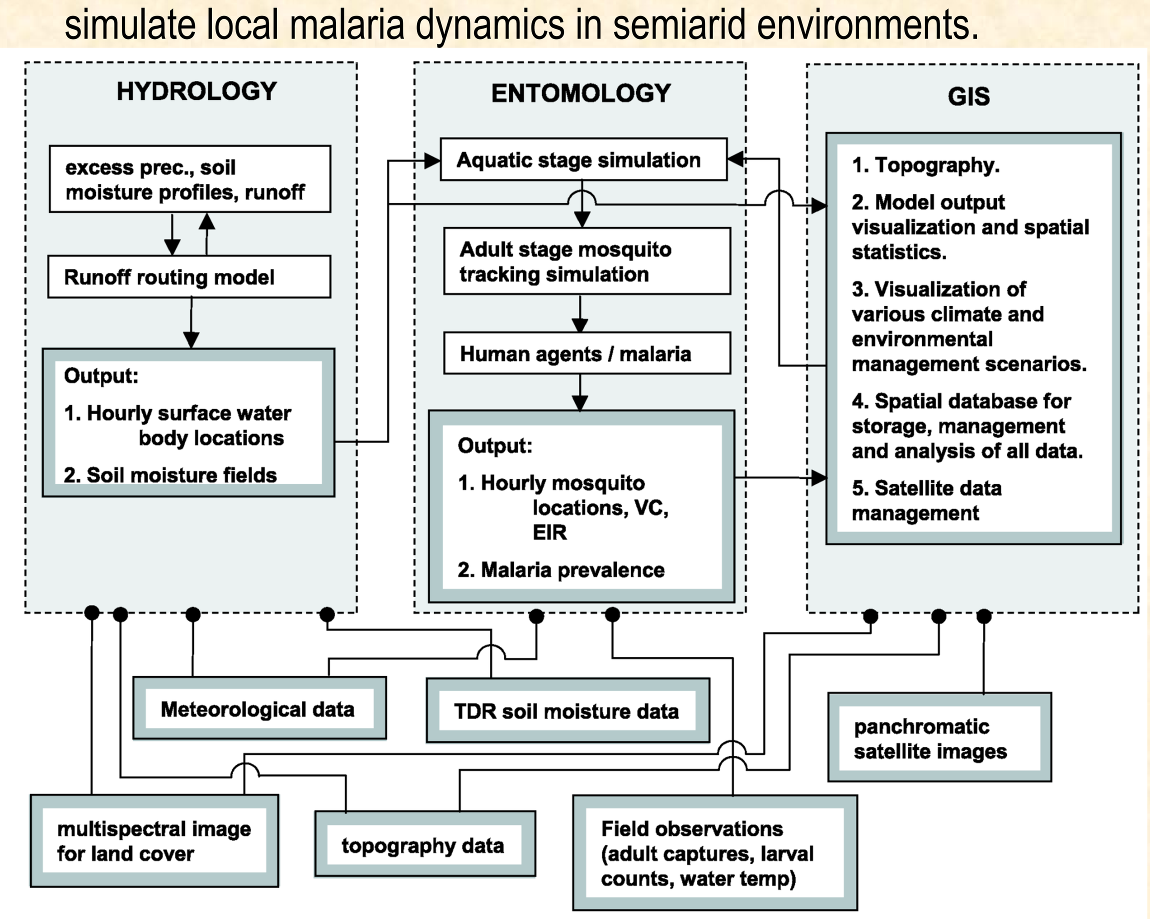
## Abstract

Early warnings of malaria transmission allow health officials to better prepare for future epidemics. Monitoring rainfall is recognized as an important part of malaria early warning systems, as outlined by the Roll Back Malaria Initiative. The Hydrology, Entomology and Malaria Simulator (HYDREMATS) is a mechanistic model that relates rainfall to malaria transmission, and could be used to provide early warnings of malaria epidemics. HYDREMATS is used to make predictions of mosquito populations and vectorial capacity for 2005, 2006, and 2007 in Banizoumbou village in western Niger. HYDREMATS is forced by observed rainfall, followed by a rainfall prediction based on the seasonal mean rainfall for a period two or four weeks after the time the prediction is made. Predictions made using this method provided reasonable estimates of mosquito populations and vectorial capacity, two to four weeks in advance. The predictions were significantly improved compared to those made when HYDREMATS was forced with seasonal mean rainfall alone.

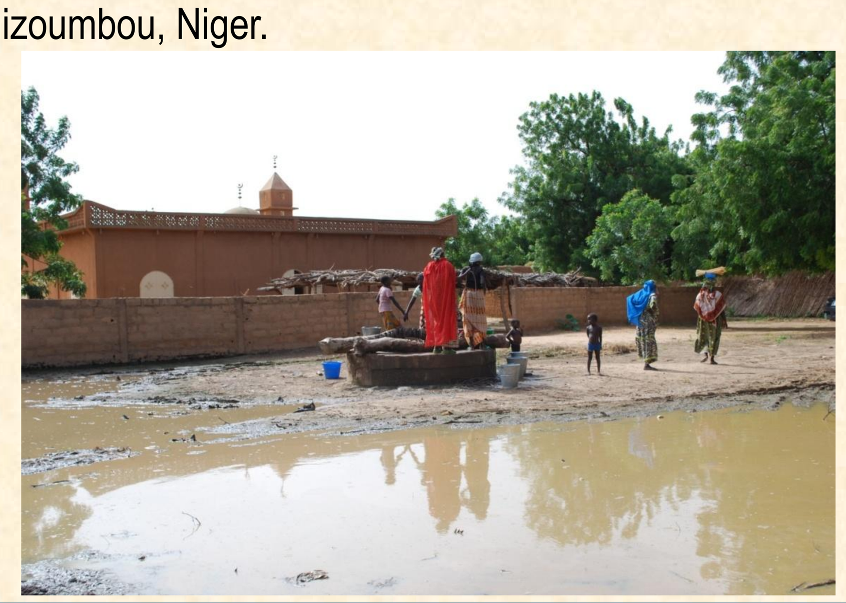
**Primary Question: Can HYDREMATS predict periods of increased malaria transmission 2-4 weeks in advance?**

## Modelling Approach

HYDREMATS is a mechanistic coupled hydrology and entomology model developed by Bomblies et al. (2008) to simulate local malaria dynamics in semiarid environments.

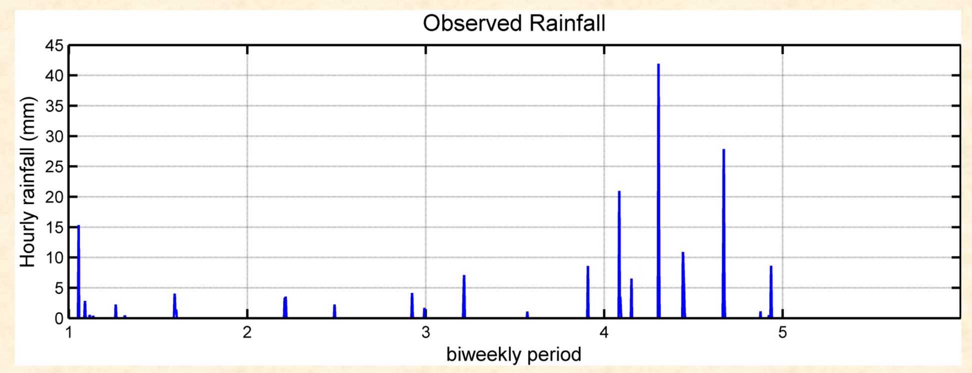



HYDREMATS has been field validated at our study site in Banizoumbou, Niger.

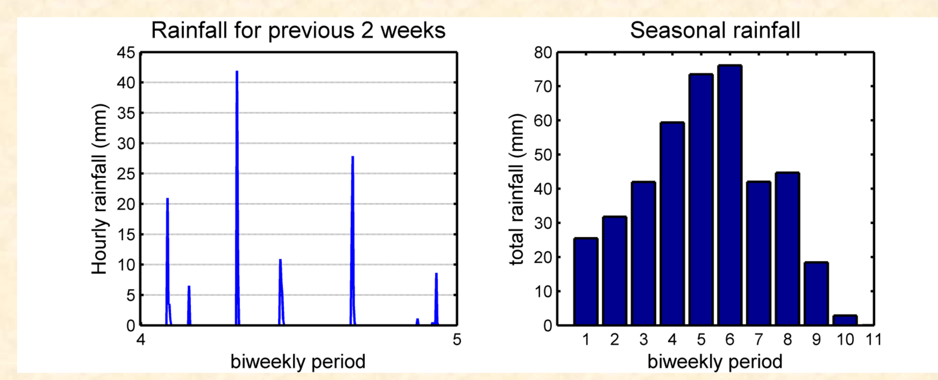


## Using HYDREMATS to predict mosquito populations

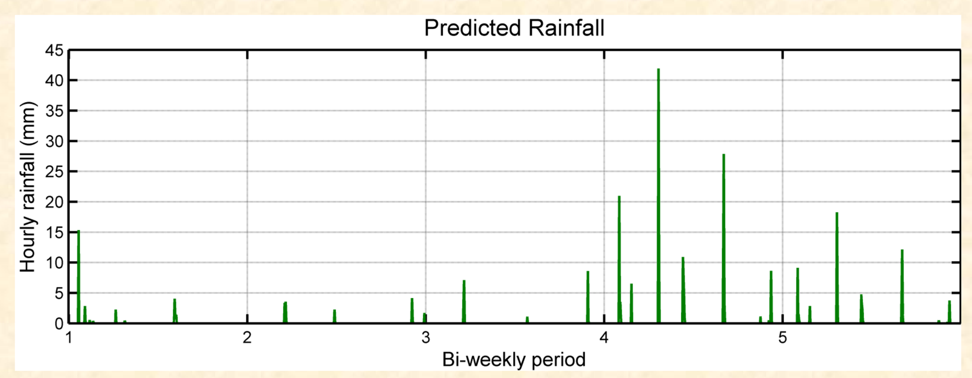
HYDREMATS requires hourly rainfall inputs. In order to run model into the future, estimates for future rainfall must be provided.




**Step 1**: Use observed rainfall up until the time the prediction is made

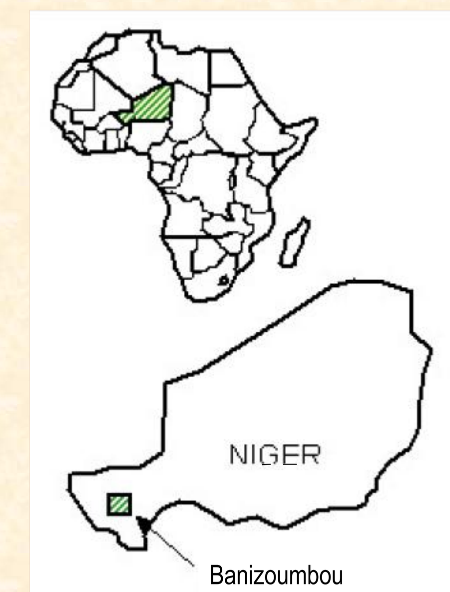



**Step 2:** Take rainfall observed in the previous two weeks and scale it such that the total volume is equal to the seasonal mean volume for that period




**Step 3**: Use this scaled rainfall as the prediction

Rainfall predictions were constructed for each two and four week period for the rainy seasons of 2005-2007 and used as inputs to HYDREMATS. Control simulations were conducted using observed rainfall.

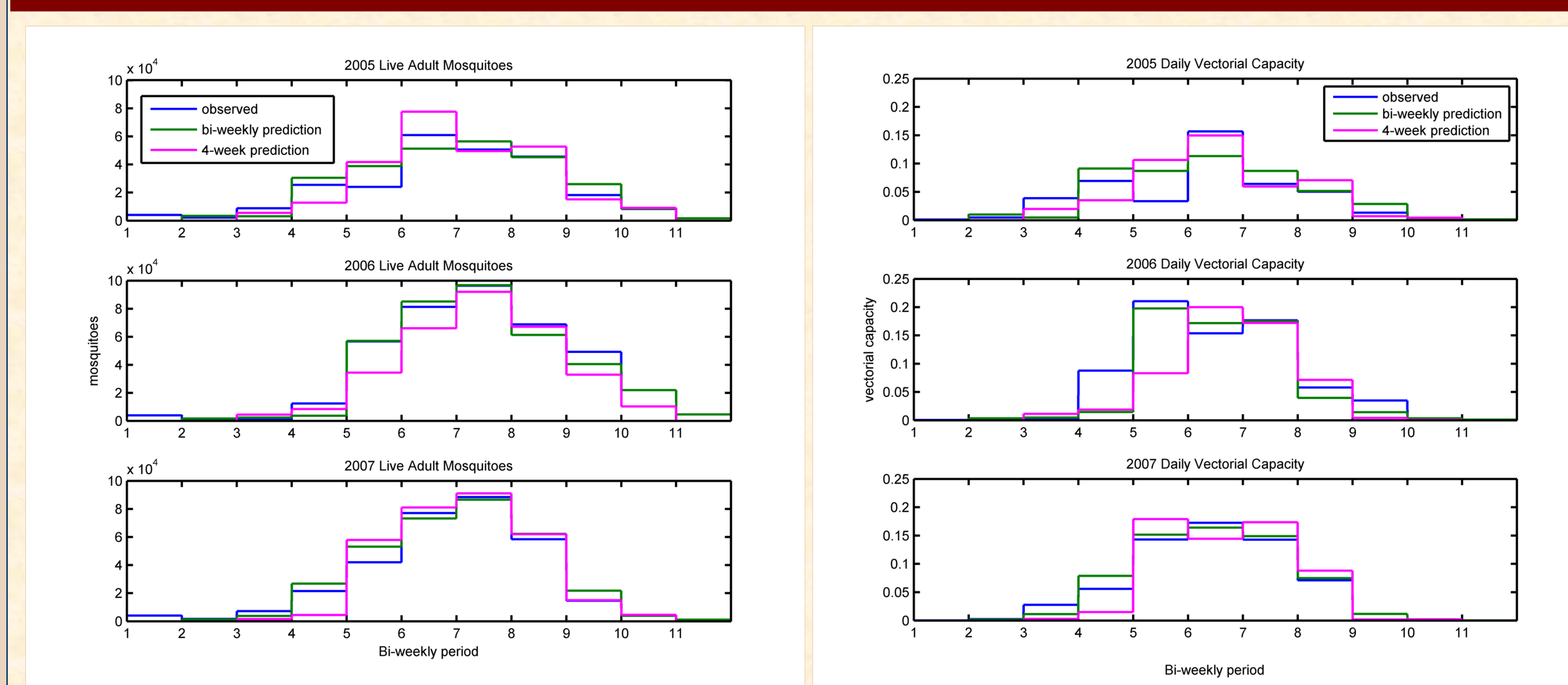



**Study location**

**Anopheles mosquito larvae**

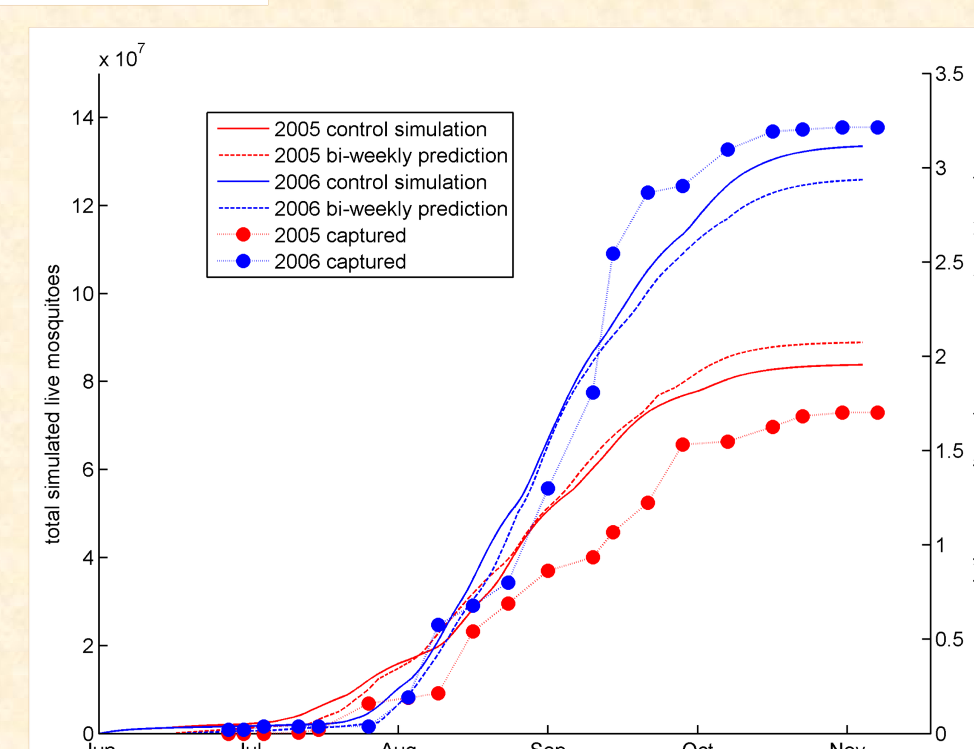
HYDREMATS models hydrological processes including infiltration and surface runoff, routing rainfall into pools used for mosquito breeding, such as the one shown above.

## Results




**(Above) Simulated Adult mosquito populations and vectorial capacity.** *Bi-weekly results are shown for simulations forced by observed rainfall (blue), predictions made two weeks in advance (green), and predictions made four weeks in advance (pink).*

**(Below) Comparison with field observations.** *2005 data are shown in red, and 2006 data are shown in blue. The solid line represents adult mosquitoes modeled in the control simulation, the dashed line shows adult mosquitoes in the bi-weekly prediction simulation. The circles show mosquitoes captured in the field, corrected for moon phase.*




The results showed that HYDREMATS is effective at making short-term predictions of mosquito populations and vectorial capacity. This correctly predicted the relative differences in mosquito populations between years, and the timing of peak transmission. In the early part of the wet season, predictions made 4 weeks in advance are less accurate than those made 2 weeks in advance, but the two are of comparable accuracy in the later half of the season.

## Relating mosquito abundance to malaria transmission

Vectorial capacity is a measure of the mosquito's ability to transmit disease, and is defined as the average number of human inoculations of a parasite originating from a single case of malaria, if all vectors biting the original case were to become infected (Garrett-Jones & Grab, 1964). The equation for vectorial capacity, VC, is:

$$VC = \frac{ma^2p^n}{-\ln p}$$

Where
*m* is the number of female mosquitoes per human
*a* is the average number of bites each mosquito takes per timestep
*p* is the probability the mosquito survives the given timestep
*n* is the extrinsic incubation time of the parasite, which is the time the parasite resides in the vector before it can be transmitted to humans

In our simulations, *p* and *n* are the same between simulations over a given year, as they are primarily a function of air temperature, which does not change between simulations. The mosquito density, *m*, is directly proportional to the number of mosquitoes, as the number of humans in HYDREMATS simulations are held constant. The timestep used to calculate vectorial capacity is one day.

## Conclusions

A method has been demonstrated by which mechanistic modelling of hydrological and entomological processes can be used to make short-term predictions of mosquito populations and malaria transmission. This method is an improvement over methods based on direct monitoring of rainfall or statistical correlations relating rainfall to malaria transmissions, as it explicitly represents the mechanistic relationships between observed rainfall, mosquito populations, and the subsequent response in malaria transmission.

With a two or four-week lead time, health officials can prepare for an epidemic by redistributing limited medical staff and supplies, applying insecticides, raising public awareness, and preparing medical facilities for prompt case detection and treatment.

## References

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Bomblies, A., Duchemin, J. B., & Eltahir, E. A. B. (2008). Hydrology of malaria: Model development and application to a sahelian village. *Water Resour.Res, 44*

Garrett-Jones, C., & Grab, B. (1964). The assessment of insecticidal impact on the malaria mosquito's vectorial capacity, from data on the proportion of parous females. *Bull Wld Hlth Org, 31*, 71-86.