HYDREMATS: The Hydrology, Entomology and Malaria Transmission Simulator

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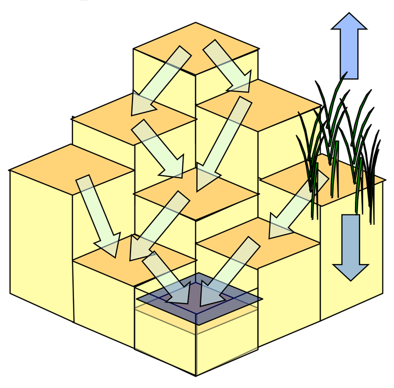
Advantages of HYDREMATS

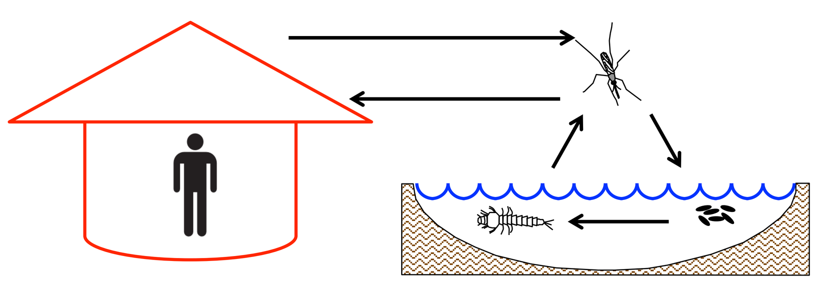
Hydrology

- Very high resolution
  - 10 meter x 10 meter, hourly timestep
- Land surface model simulates the physical processes by which water pools form and recede[1].
- Captures the importance of different patterns of rainfall[3,4]
  - high intensity rainfall leads to greater pool formation than the same amount of rainfall distributed over a longer time
  - water pools must persist for over one week to be productive breeding sites
  - Duration of rainy season important for transmission
- Gives location of water pools relative to households
- Gives water temperature, which determines larval development rate
- Can use predictions from climate models to analyze impacts of climate change[5]
- Accounts for permanent breeding sites such as river banks and ponds[6]
- Model outputs compared to data on pool location, temperature and depth, soil moisture[1]



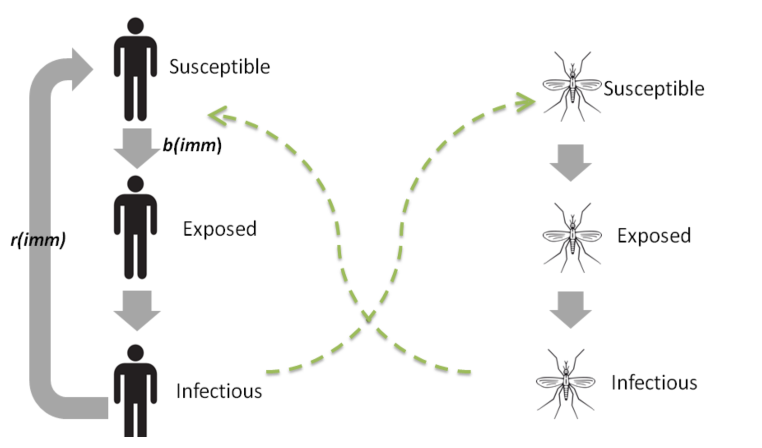
Entomology

- An ecological model simulates the entire lifecycle of Anopheles mosquitoes.
- Allows an accurate representation of the seasonality and interannual variability of vector activity and transmission
- Identify mosquito hotspots
- Directly simulate the effects of vector control activities, such as bednets, indoor spraying, or larvicide[7]
- Compare model output to data on captured mosquitoes, human biting rate, EIR[1,6]

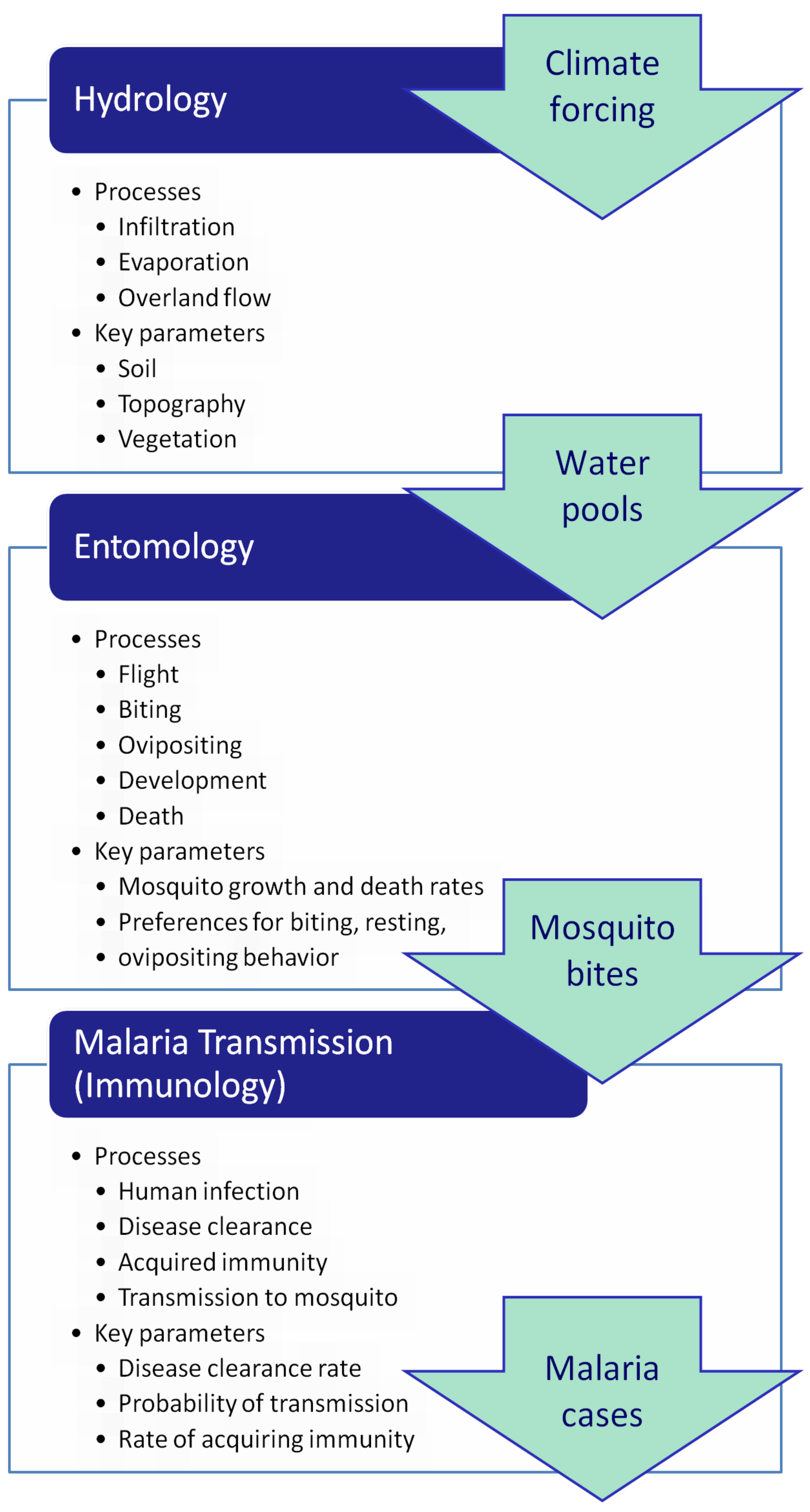


Malaria transmission & immunology

- Tracks the malaria parasite as it travels among the mosquito and human agents
- Records all infectious bites in each human agent, and builds immunity over time
- Compare to data on malaria incidence, prevalence[2]



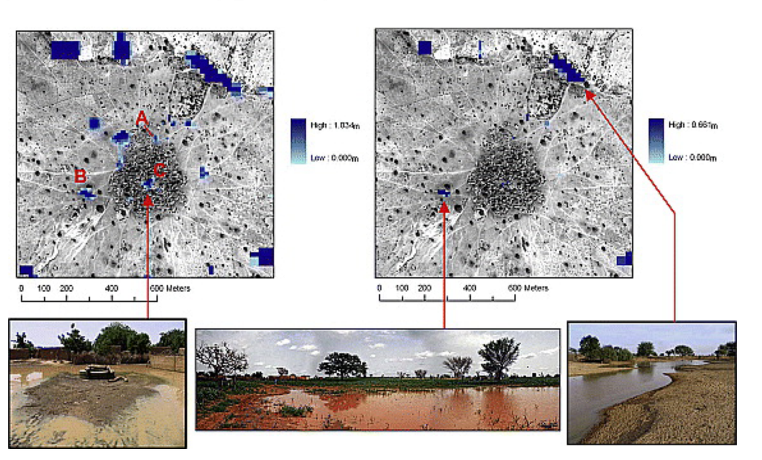
Model Overview



The relationships between environment and malaria transmission are complex and highly non-linear. We simulate these relationships using a powerful computational tool: HYDREMATS[1].

HYDREMATS is unique in that it mechanistically simulates water pools that serve as mosquito breeding sites, the life cycle of individual mosquito agents, and transmission of the malaria parasite between human agents[2].

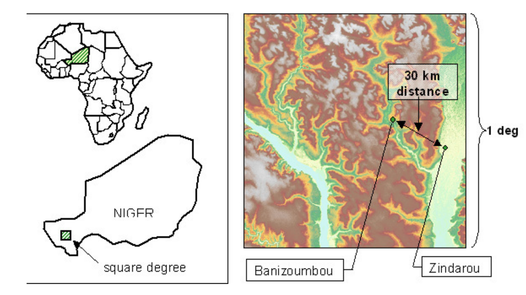
With extremely high spatial and temporal resolution, agent-based approach, and explicit representation of physical and biological process, we capture many aspects of the transmission cycle that are typically lost in malaria models.

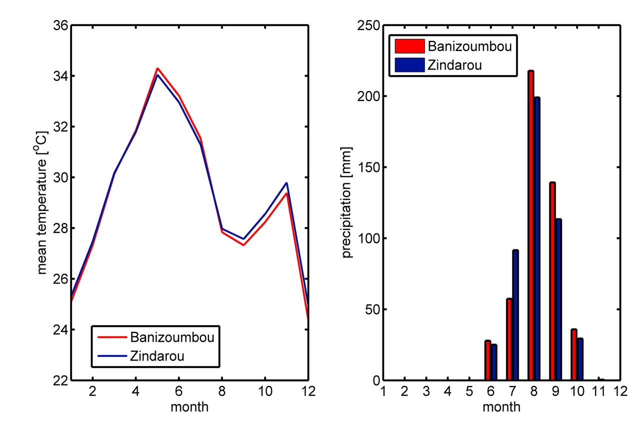


Modelled and observed water pools in Banizoumbou, Niger[1]

Comparison to data

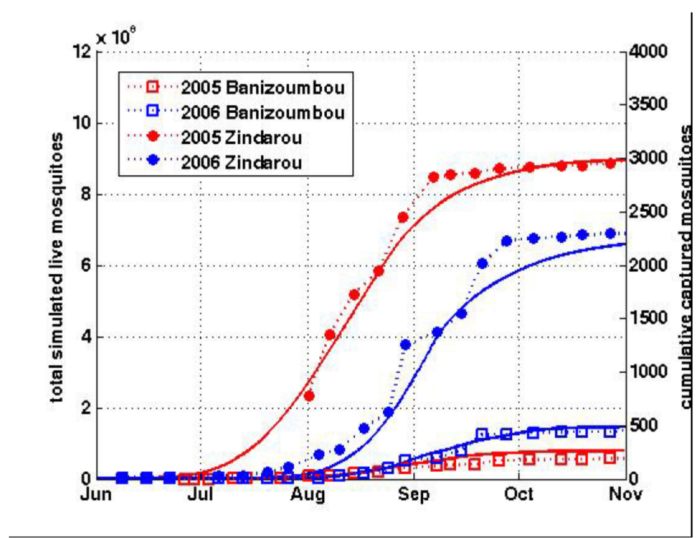
This example shows how different components of the model compare to data in Banizoumbou and Zindarou. two neighboring villages in Niger.





Temperature and rainfall in Banizoumbou (red) and Zindarou (blue) in 2006.[2]

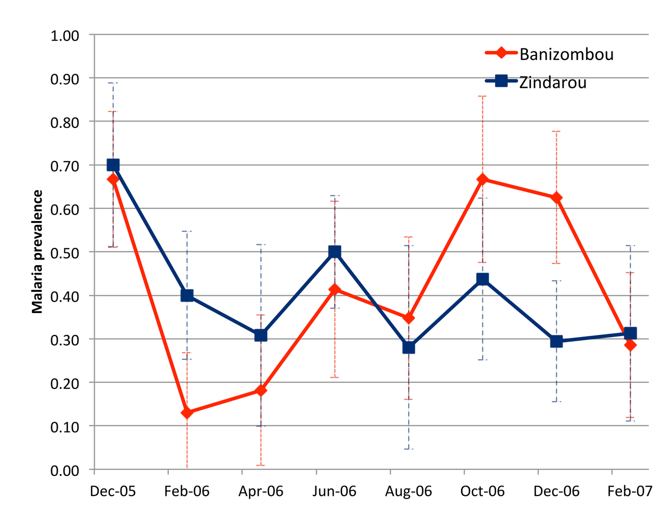
While their climate is very similar, Zindarou has many more mosquitoes than Banizoumbou because it has a shallow water table[6]. Because HYDREMATS includes data on topography and soil moisture, it is able to simulate this difference.



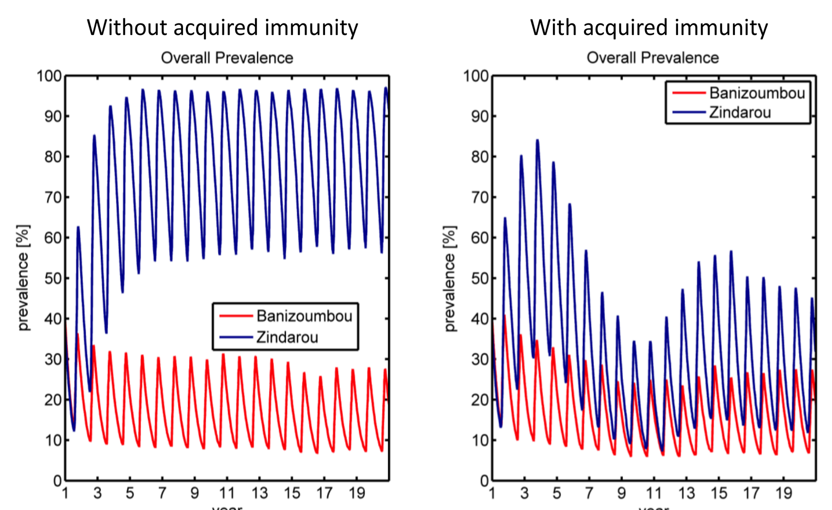
Modeled and observed An. gambiae abundance in Banizoumbou and Zindarou.[6]

Despite the order of magnitude difference in mosquito populations, and therefore vectorial capacity, the malaria prevalence rate was similar in the two villages.

Observed malaria prevalence in Banizoumbou and Zindarou.[2]



We found this could be explained at least in part by the effects of acquired immunity.



Simulated malaria prevalence over a 20 year simulation with and without the effects of acquired immunity[2]

References

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