Towards a Predictive Theory of Malaria: Connections to Spatio-temporal Variability of Climate and Hydrology

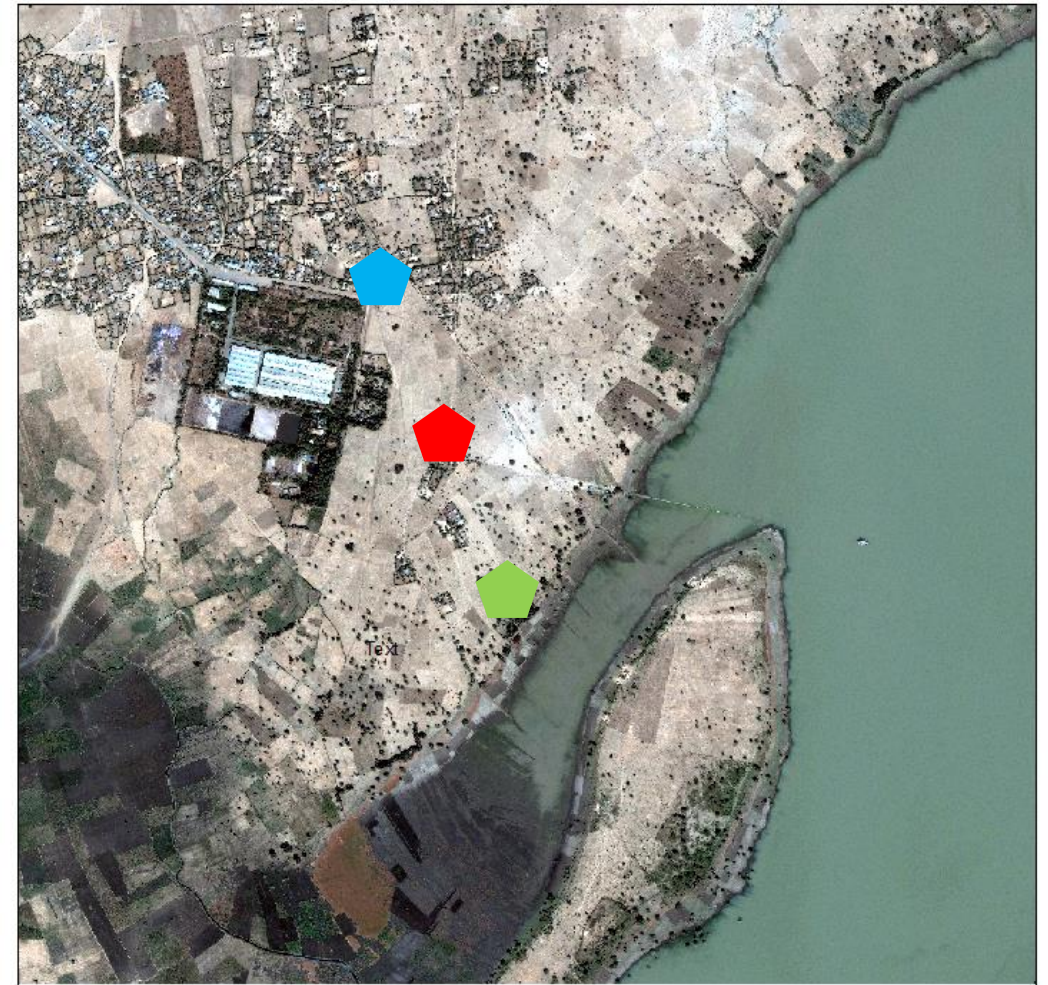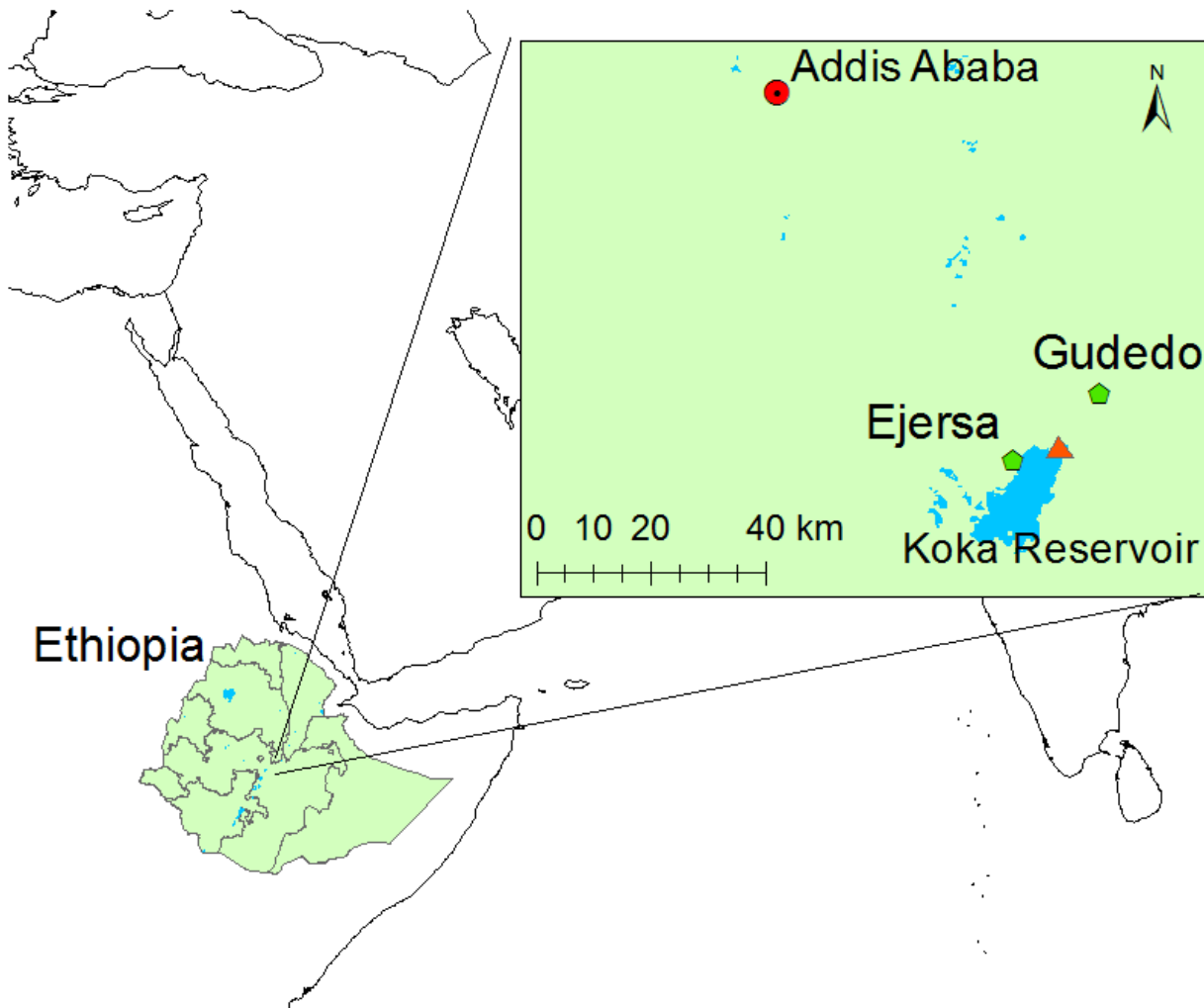Hydrology and Malaria

@Eltahir group

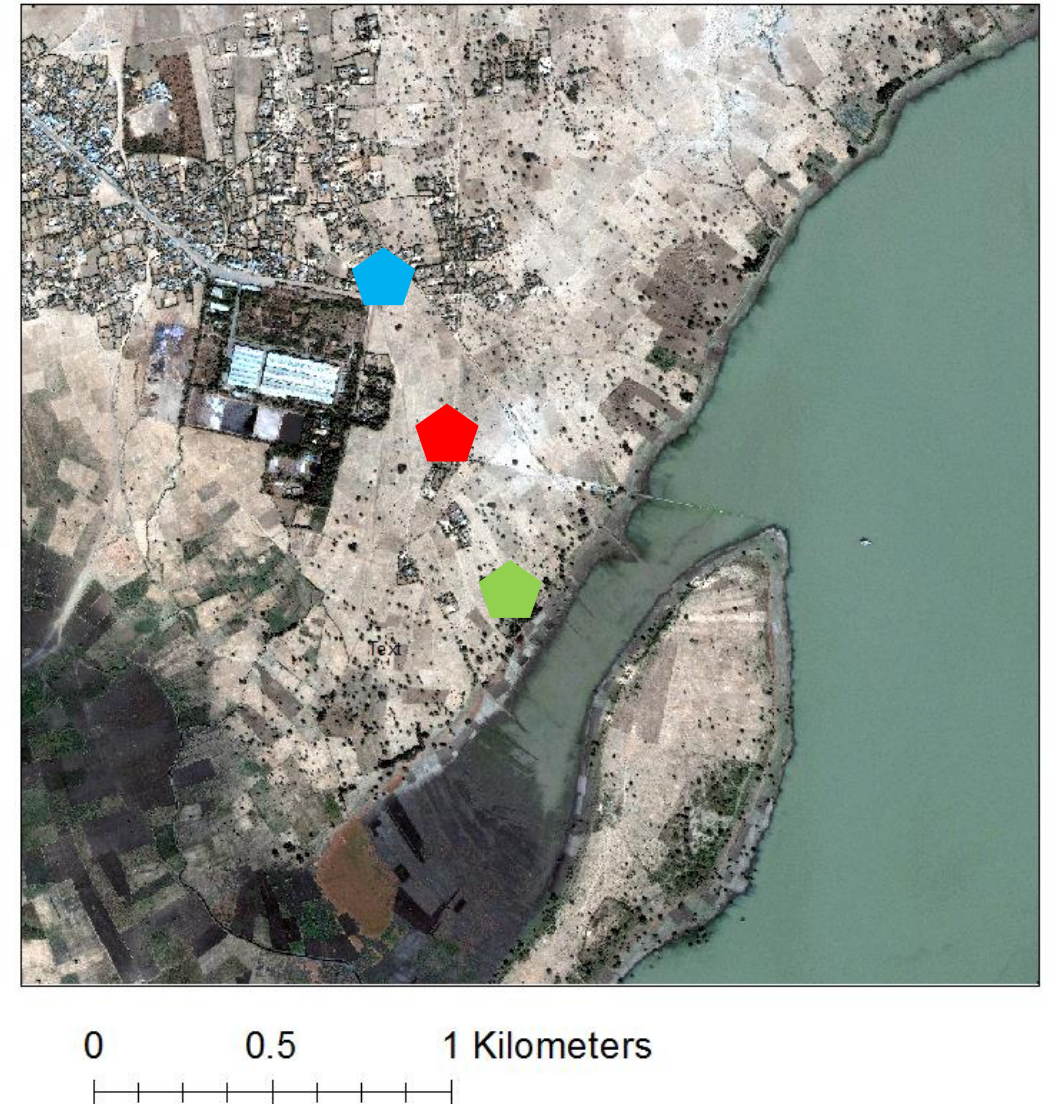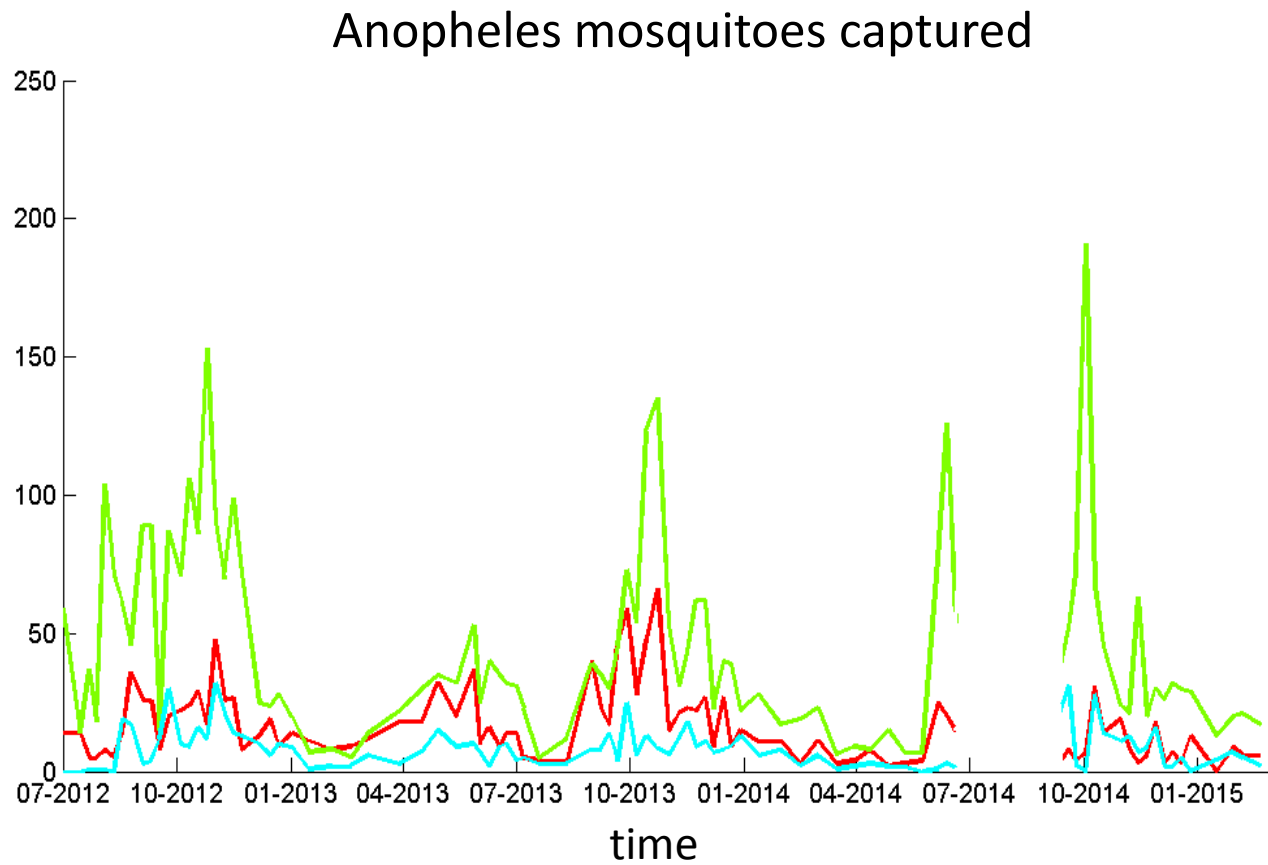Noriko Endo
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Importance of the spatial distribution of houses

Importance of the spatial distribution of houses
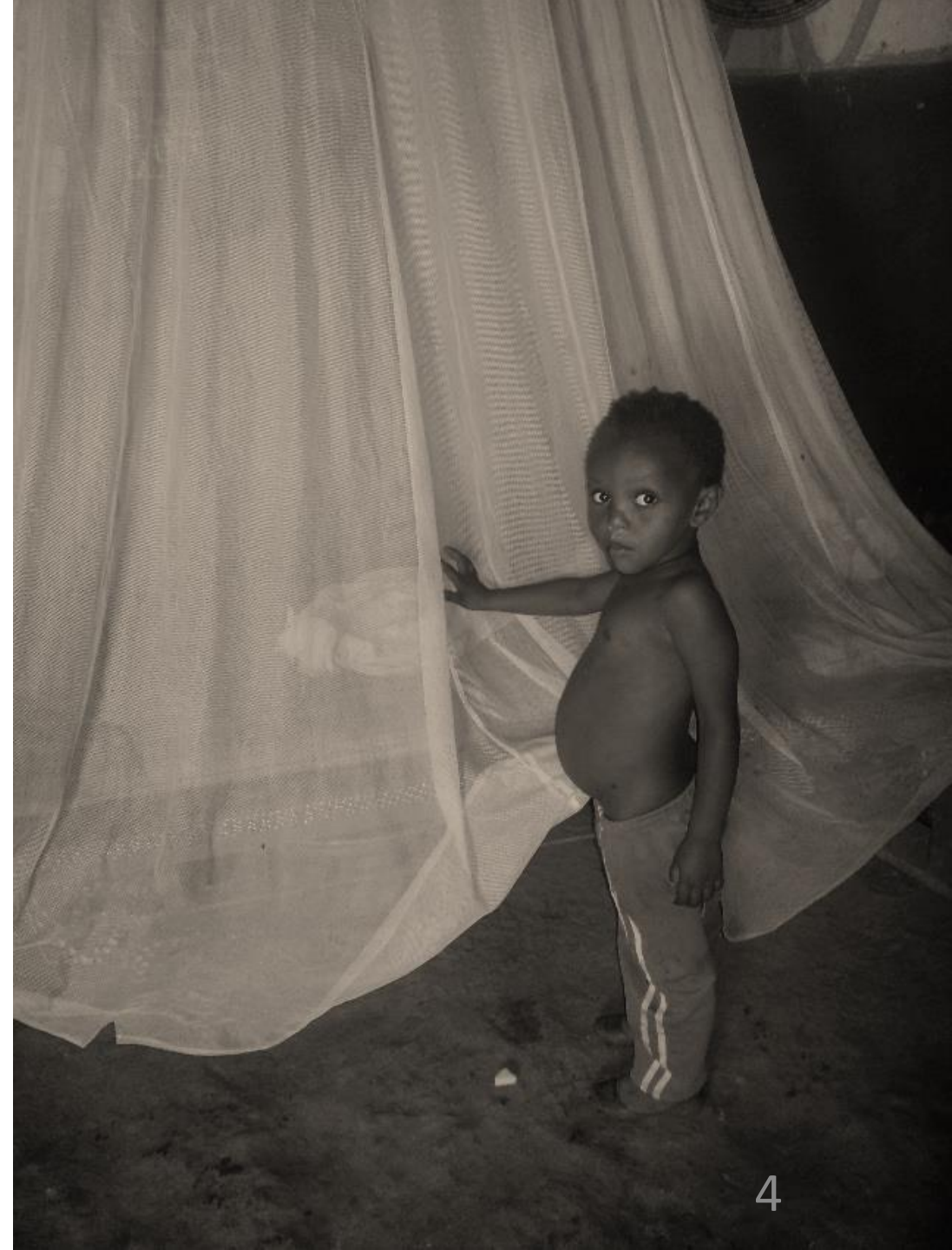
Anopheles mosquitoes captured

Towards a
Predictive Theory of Malaria...

1. Simulation under hypothetical settings
2. Introduction of a malaria time scale and two dimension-less values
3. Testing against observations

Simulation tool:
HYDRology, Entomology, Malaria Transmission Simulator (HYDREMATS)
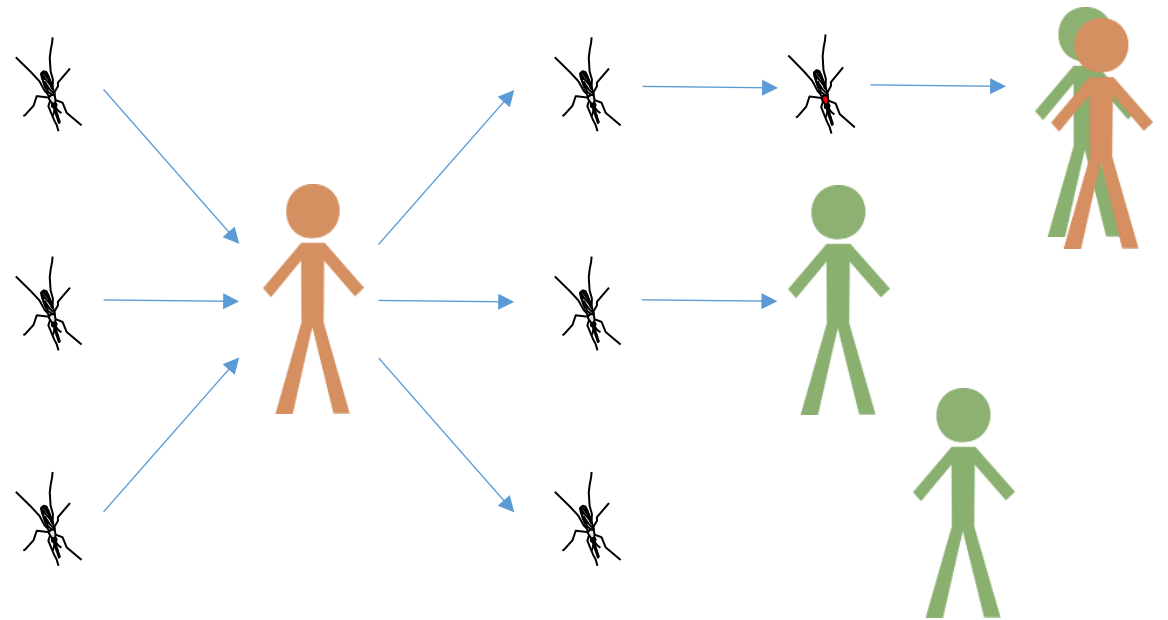
Bomblies et al., 2008; Yamana 2015
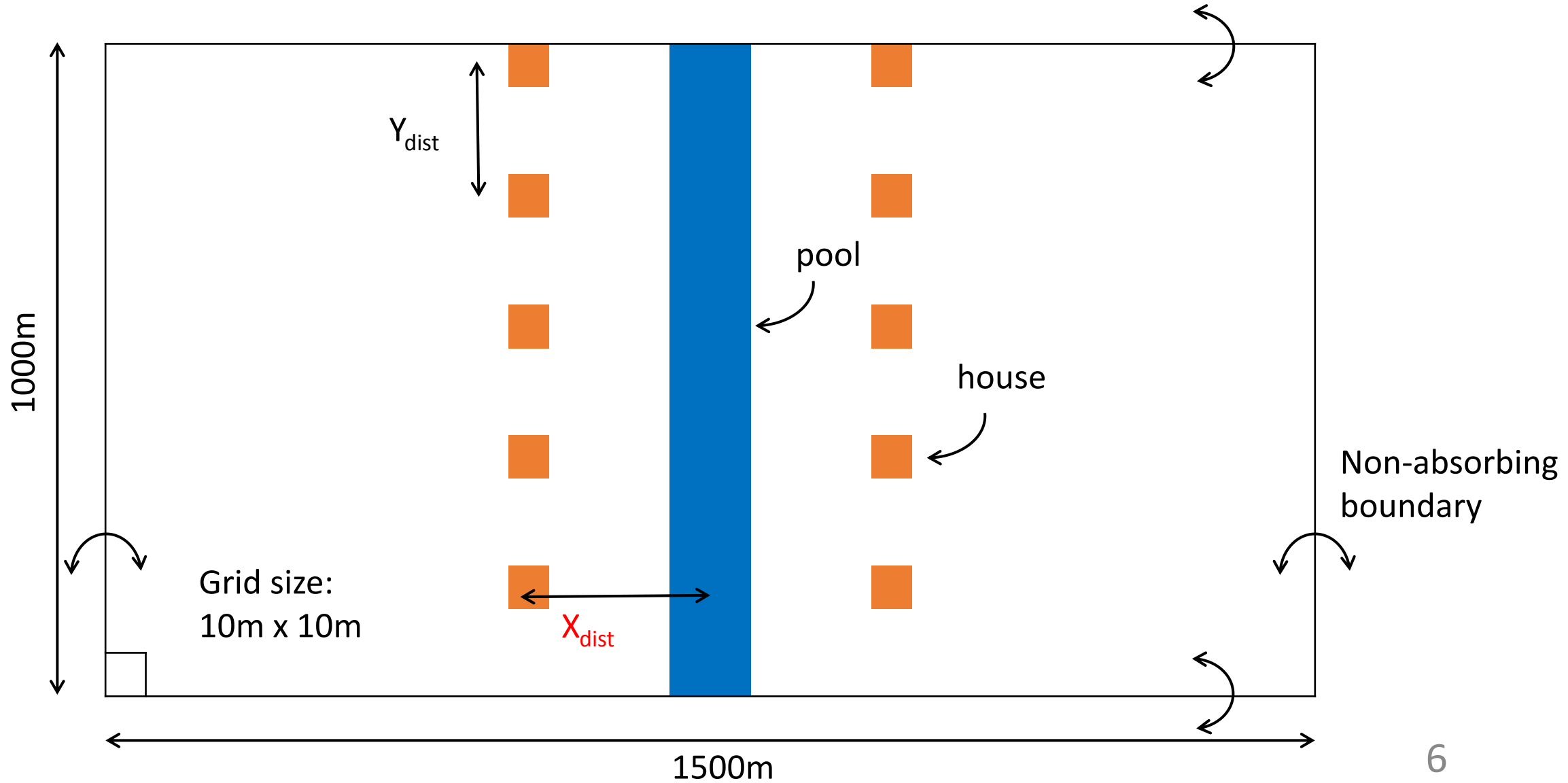
Basic Reproduction Rate (R_o)

`` how many people get infected from one infectious person ''
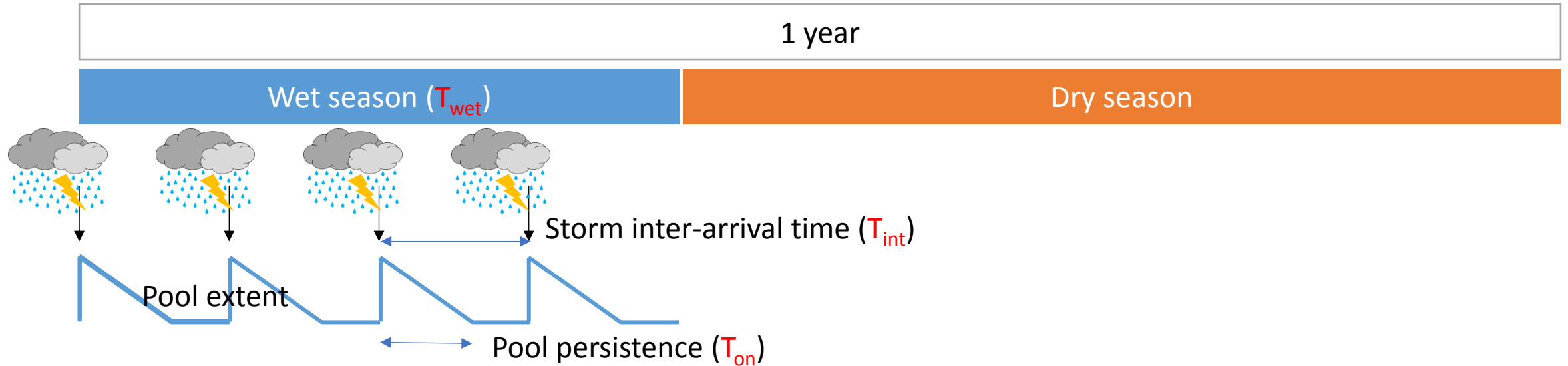
$R_o \geq 1$ ... sustain malaria

Exact meaning of R_o calculated
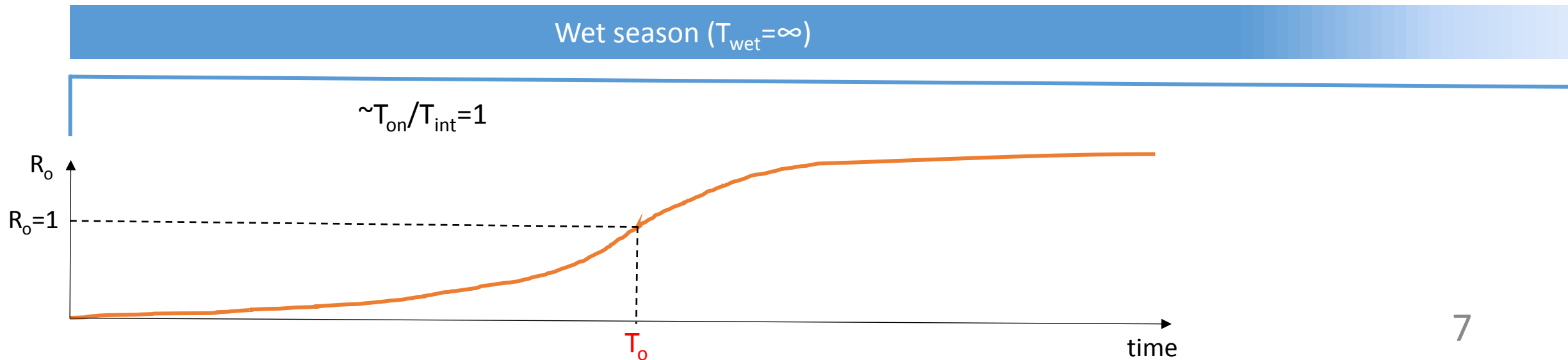even under dynamic conditions
in HYDREMATS

Spatial set up

Y$_{dist}$

pool

house

Non-absorbing boundary

1000m

Grid size:
10m x 10m

X$_{dist}$

1500m

Temporal setup: Hydroclimatological assumption

1 year

Wet season (T_{wet})

Dry season

Storm inter-arrival time (T_{int})

Pool extent

Pool persistence (T_{on})

\<Hydrologically-saturated condition\>

Wet season ($T_{wet}=\infty$)

$\sim T_{on}/T_{int}=1$
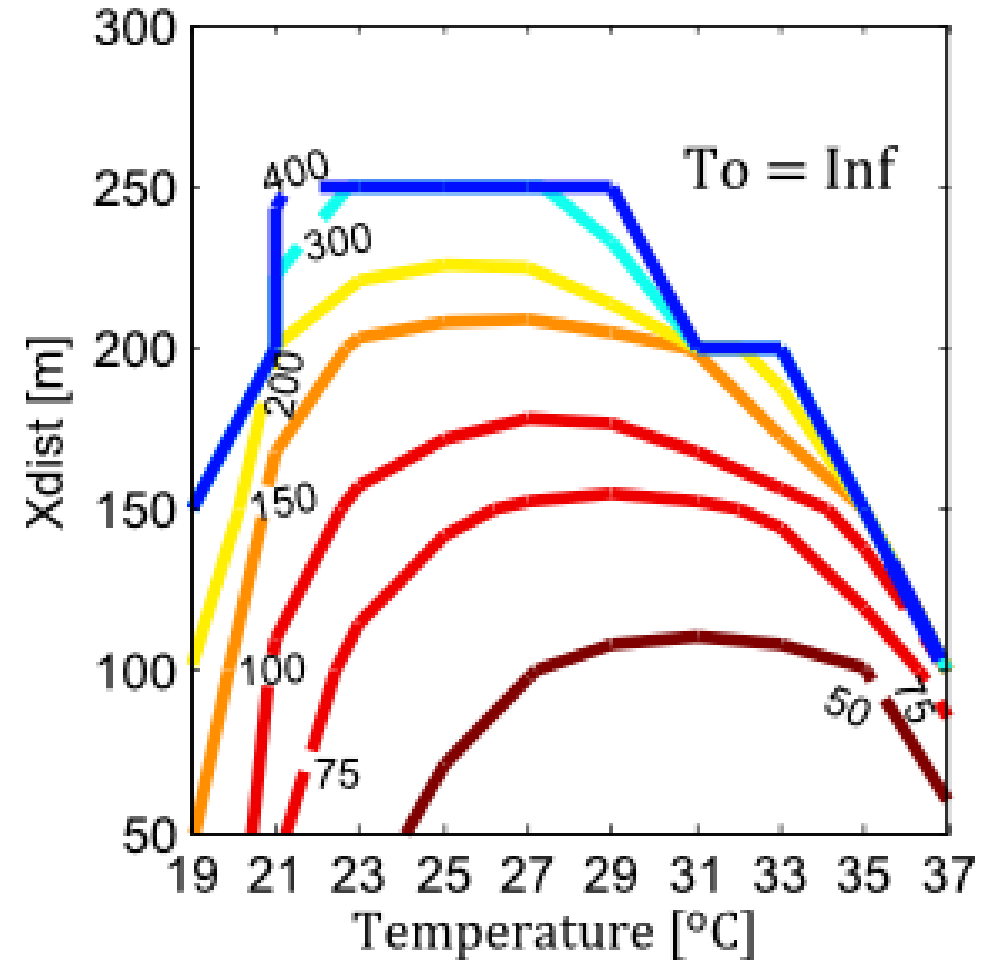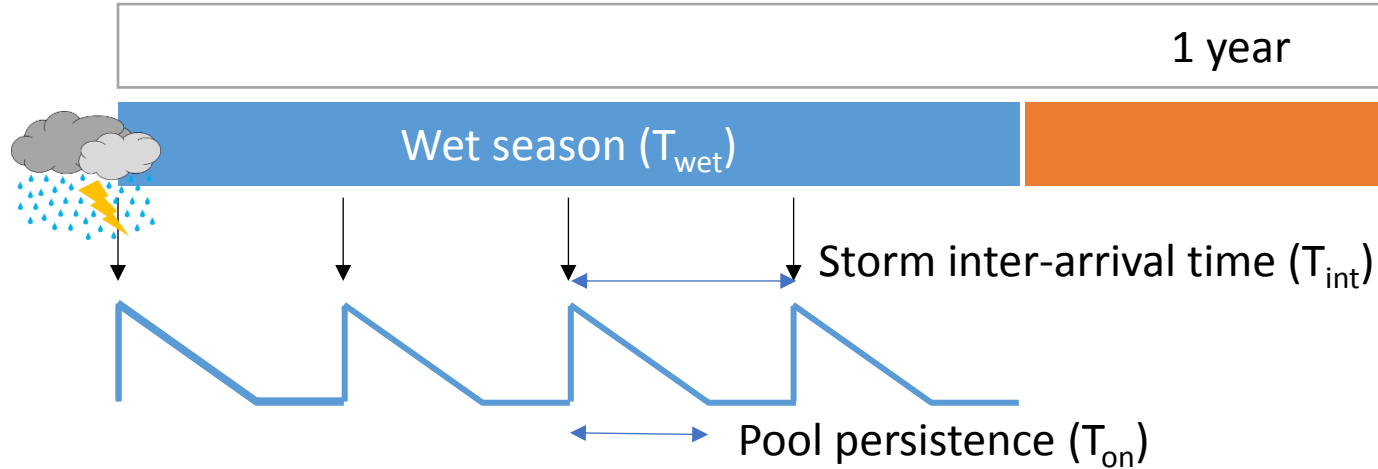
R_o

$R_o=1$

T_o

time

malaria time scale: T_o

- T_o is independent of T_{wet}, T_{on}, and T_{int}.
- T_o is dependent on X_{dist} and temperature.

Two dimension-less numbers

\<Normal setup\>

1 year

Wet season (T_{wet})

Storm inter-arrival time (T_{int})

Pool persistence (T_{on})
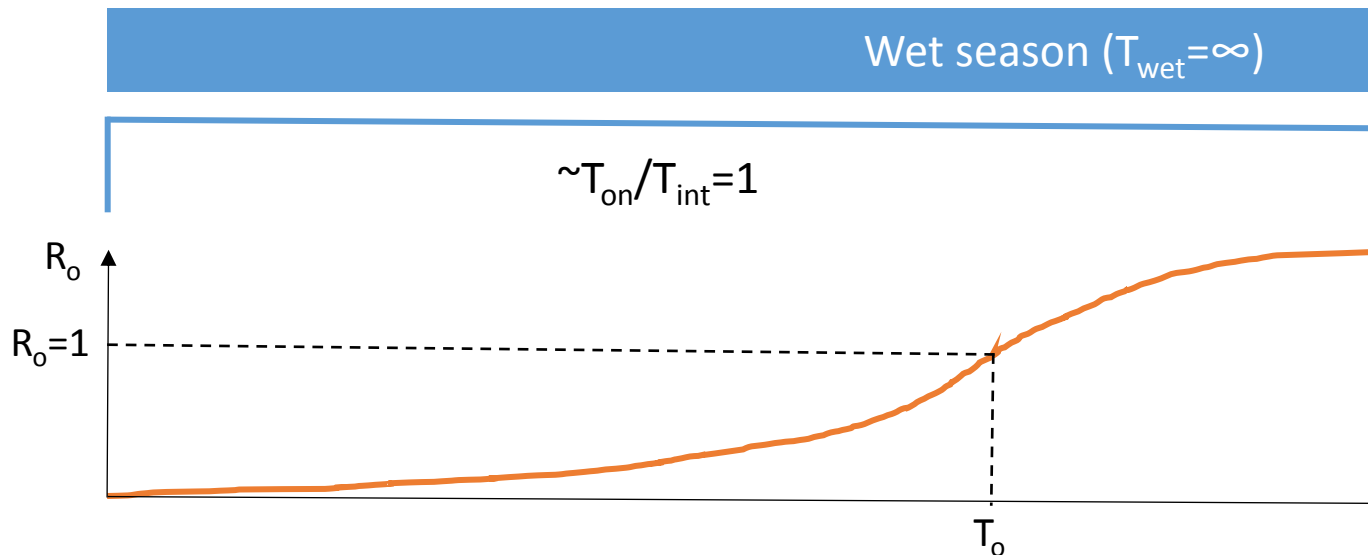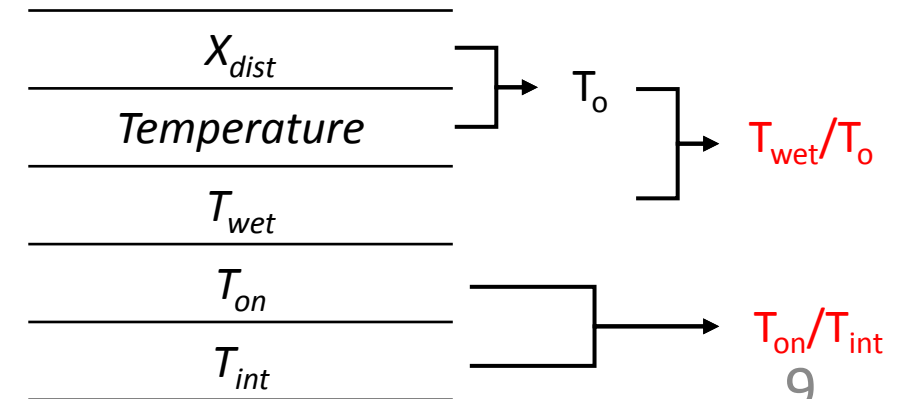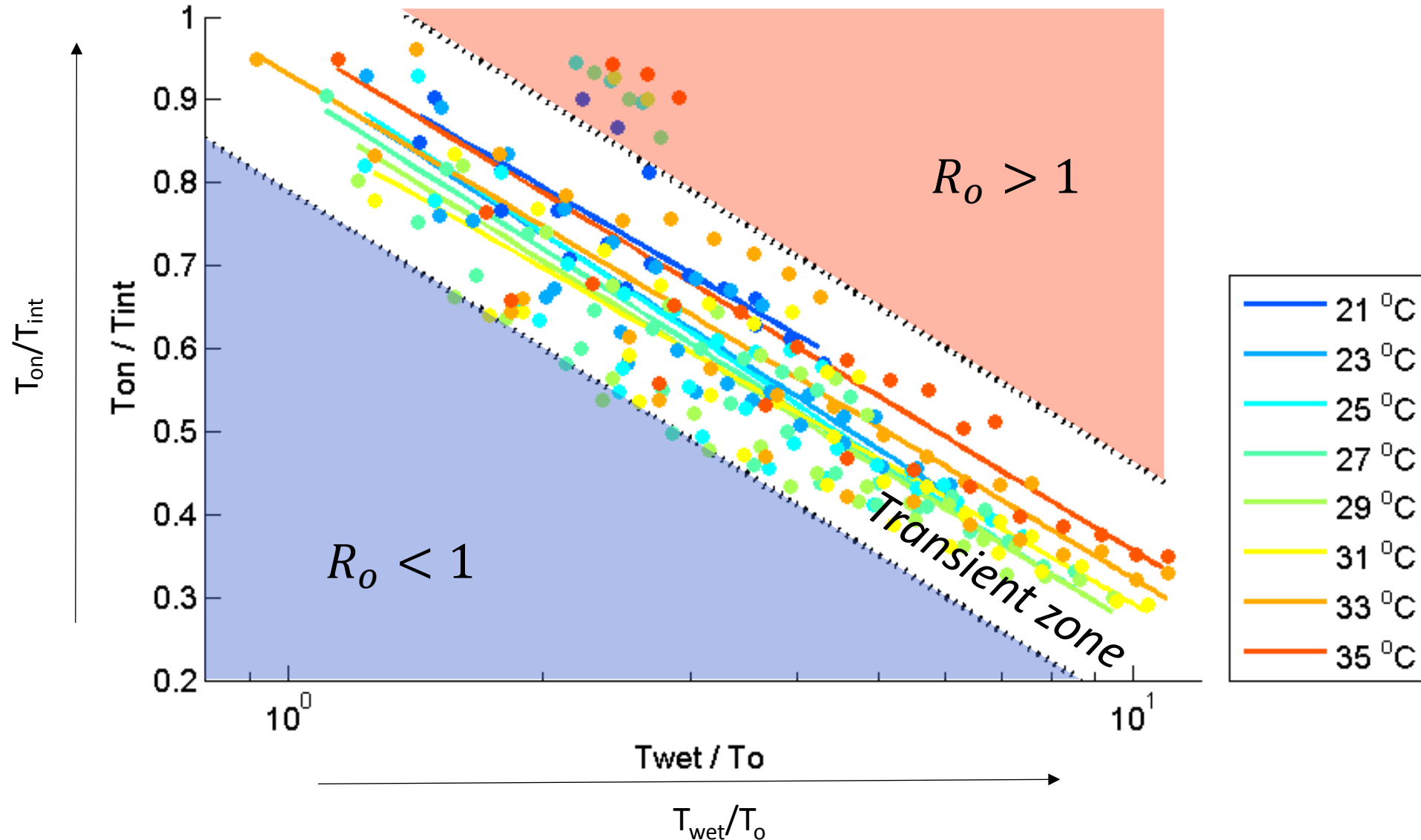
- If $T_{wet} > T_o$ or $T_{wet}/T_o > 1$ under the hydrologically saturated condition, you have $R_o > 1$.

- $T_{on} = T_{int}$ or $T_{on}/T_{int} = 1$ at the hydrologically saturated condition, and T_{on}/T_{int} shows the deviation from it.

- If $T_{wet}/T_o = 1$ and $T_{on}/T_{int} = 1$, $R_o = 1$.

\<Hydrologically-saturated condition\>

Wet season ($T_{wet} = \infty$)

$\sim T_{on}/T_{int} = 1$

R_o

$R_o = 1$

T_o

\<Parameters\>

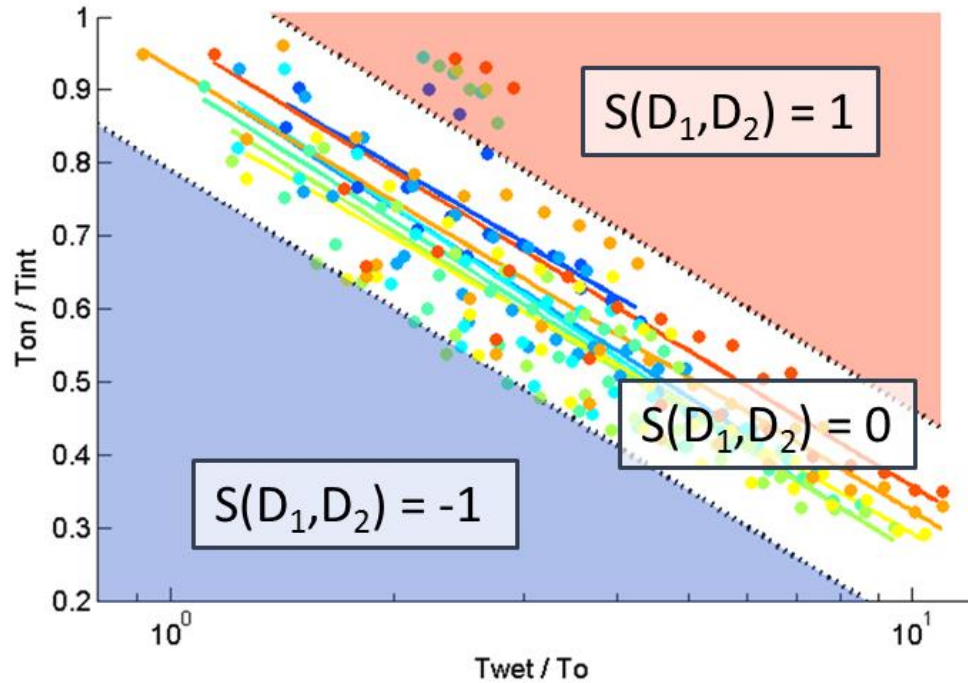|	
X_{dist}	
Temperature	T_o
T_{wet}	T_{wet}/T_o
T_{on}	
T_{int}	T_{on}/T_{int}

Conditions for $R_o=1$

Malaria transmission SCORE

$$s\left(D_1 = \frac{T_{on}}{T_{int}}, D_2 = \frac{T_{wet}}{T_o}\right) \text{ for a year}$$
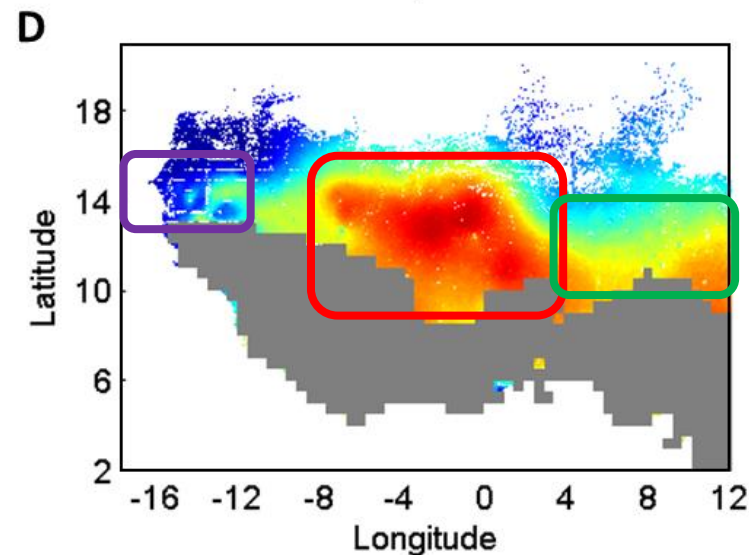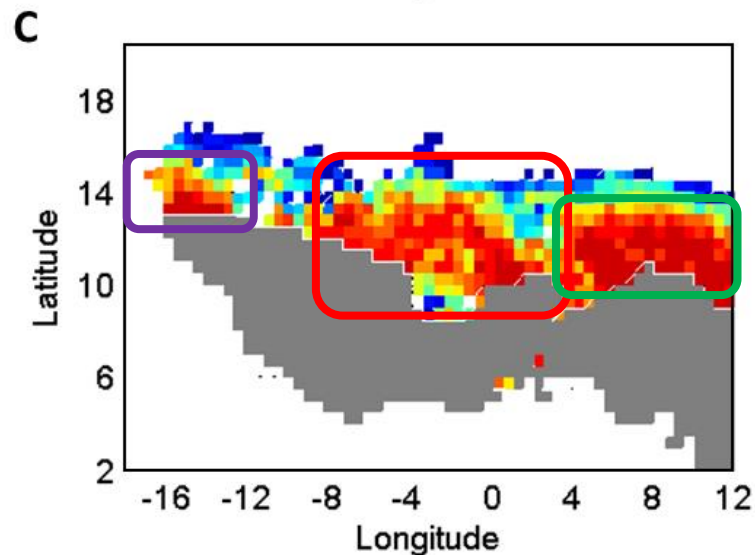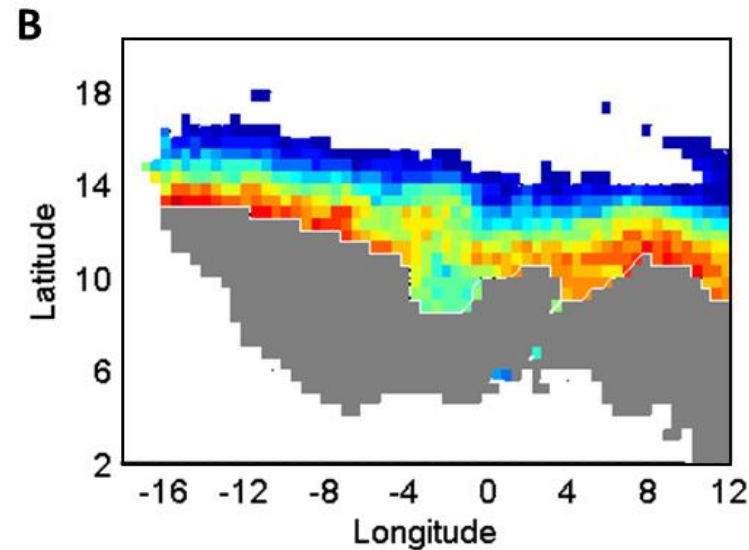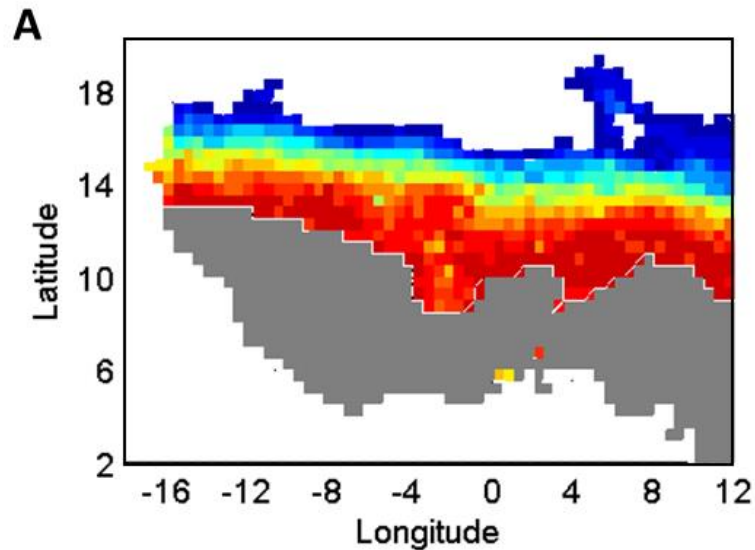
$SCORE$ as the ten-year average of $s(D_1, D_2)$ from 2001 to 2010

<Parameters>	<data source>
X_{dist}	*Fixed or inferred from population density*
temperature	*CRU*
T_{wet}	*CRU*
T_{on}	*HYDREMATS*
T_{int}	*CRU*

T_o

T_{wet}/T_o

T_{on}/T_{int}

11

Predicted malaria transmission intensity

A: SCORE for X_{dist} = 100m
B: SCORE for X_{dist} = 200m
C: population-adjusted SCORE
D: observation of parasite rate
from MAP
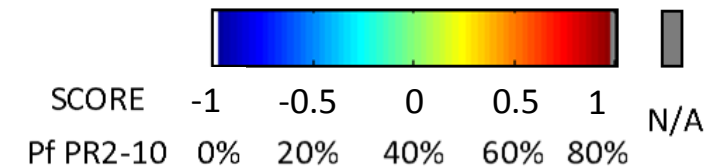
Conclusions

- A malaria time scale, T_o, and simple metrics, T_{wet}/T_o and T_{on}/T_{int}, were developed to predict malaria transmission potential.

- The result compared well with observations in West Africa when X_{dist} was adjusted for population density.

- Close description of hydrology improved the quality of the estimates.

- Spatial distribution of houses is important in predicting malaria transmission potential. Alternatively, the spatial collocation of pools and houses can be modified to prevent malaria.