GeoHealth: A Surveillance and Response System Resource for Vector Borne Disease in the Americas

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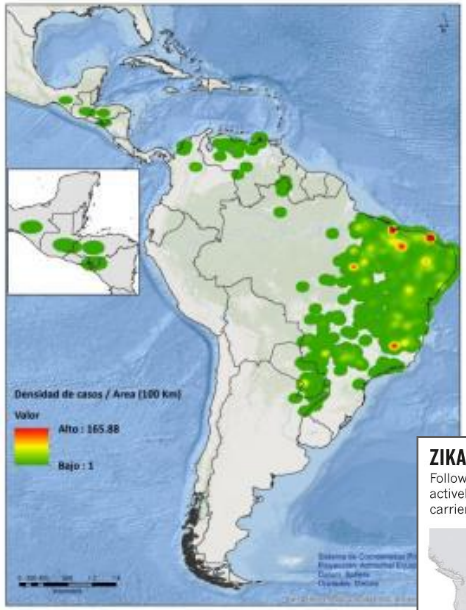
Objectives

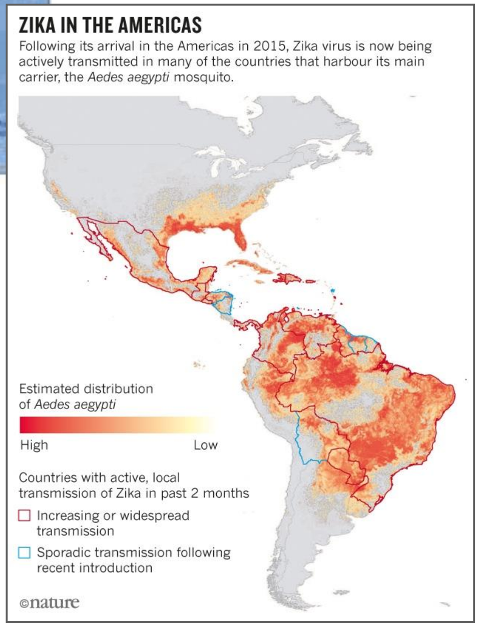
- Construct a geospatial health resource data portal (GeoHealth) compatible with GEOSS

- Map and model the epidemiological risk of two prototype vector borne diseases: Visceral leishmaniasis and *Aedes* borne arboviruses

- Process big data to discover 'hidden' associations of disease for ecological niche modeling vs hypothesis-driven statistical analysis

- Implement dissemination and training programs to promote geospatial mapping and modeling for VBD as envisioned in GEOSS.





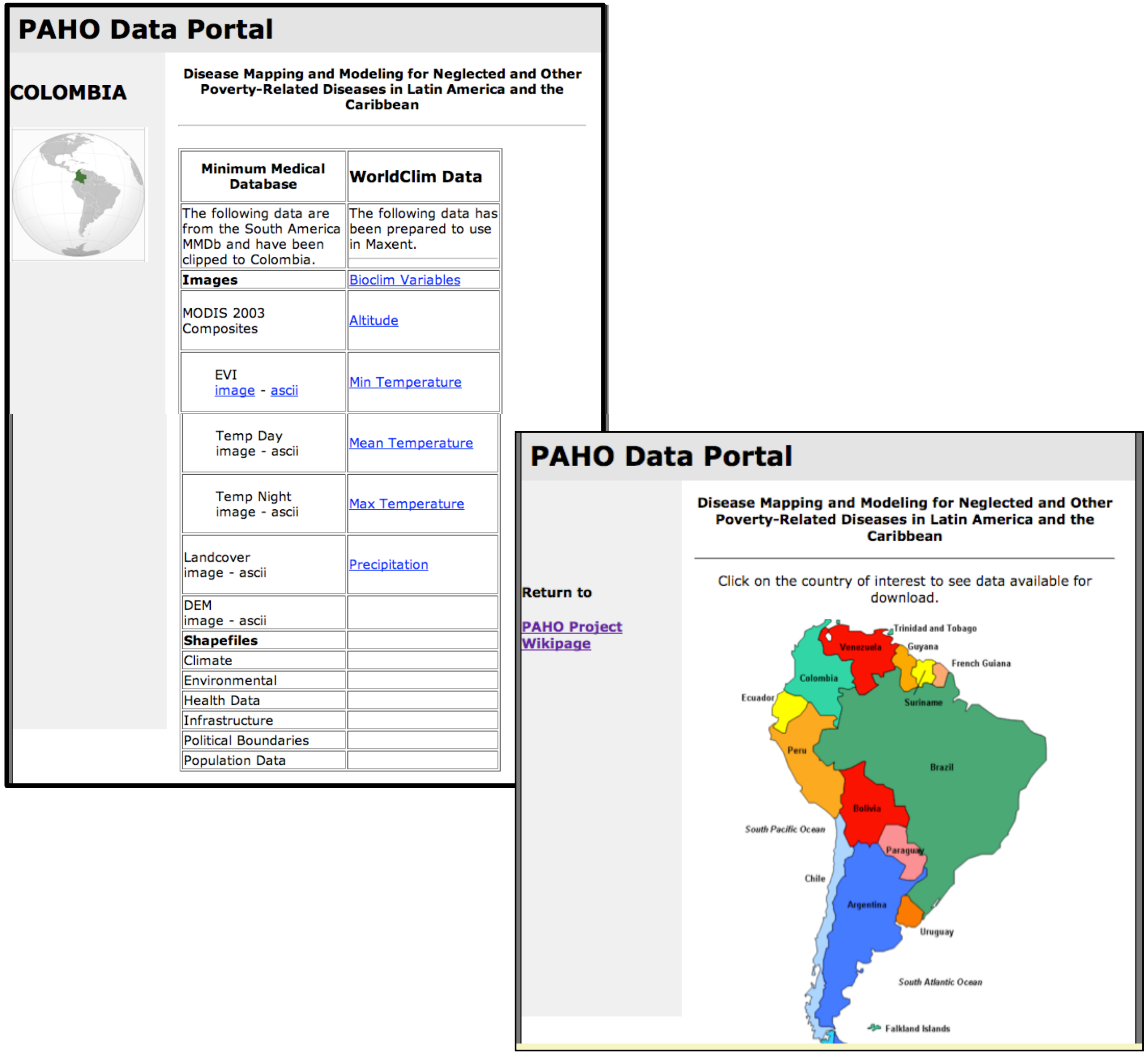
- All data clipped to the country boundary; WGS84 projection, 1 km spatial resolution; in ASCII format for Maxent or Bayesian modeling

- This example shows the data available for Colombia

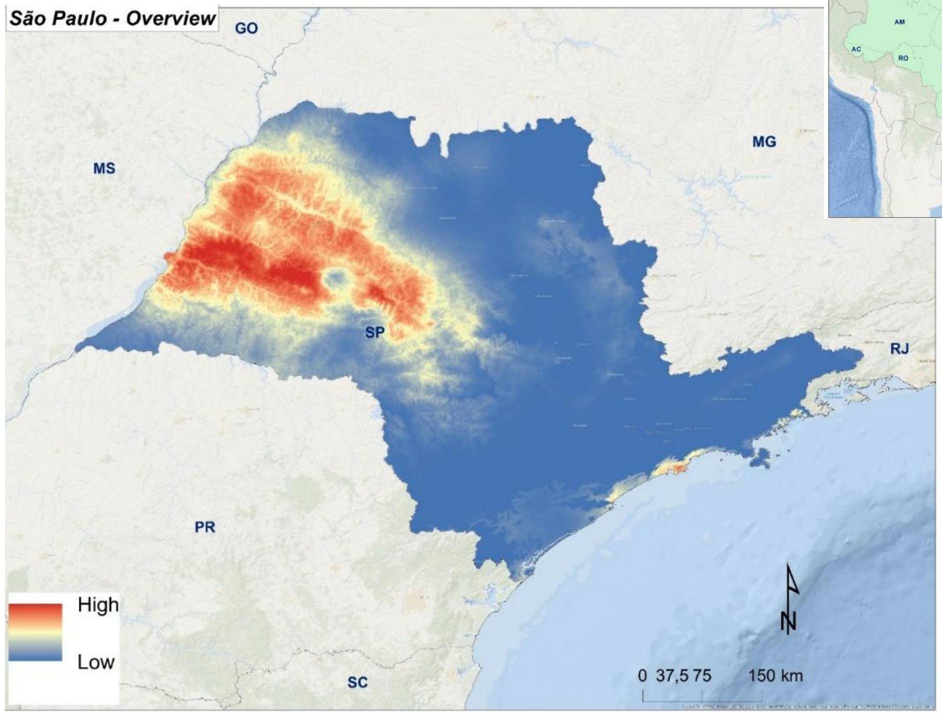
- Worldclim (global coverage, Ikm resolution) used for ecological Niche modeling and by climate change community

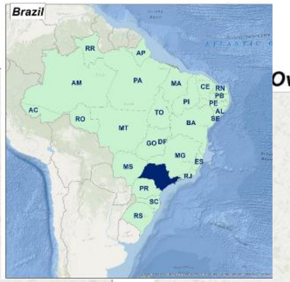
- MODIS EVI, LST annual composites for 2005-2009

- Socioeconomic Data at the Municipality level

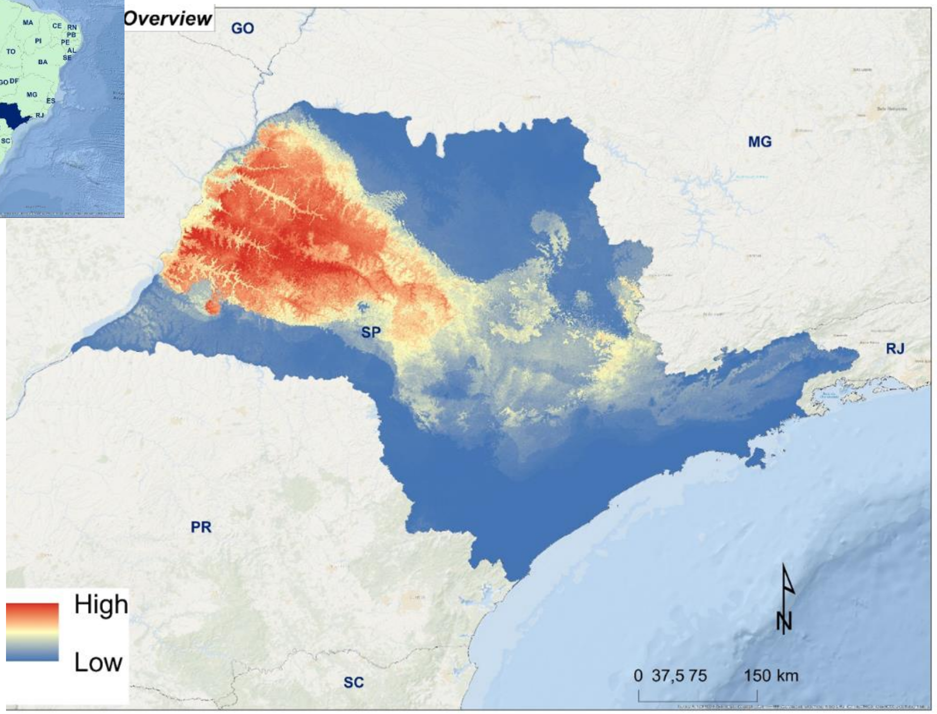


WorldClim 2.0
Visceral Leishmaniasis





BioClim
Lutzomyia longipalpis

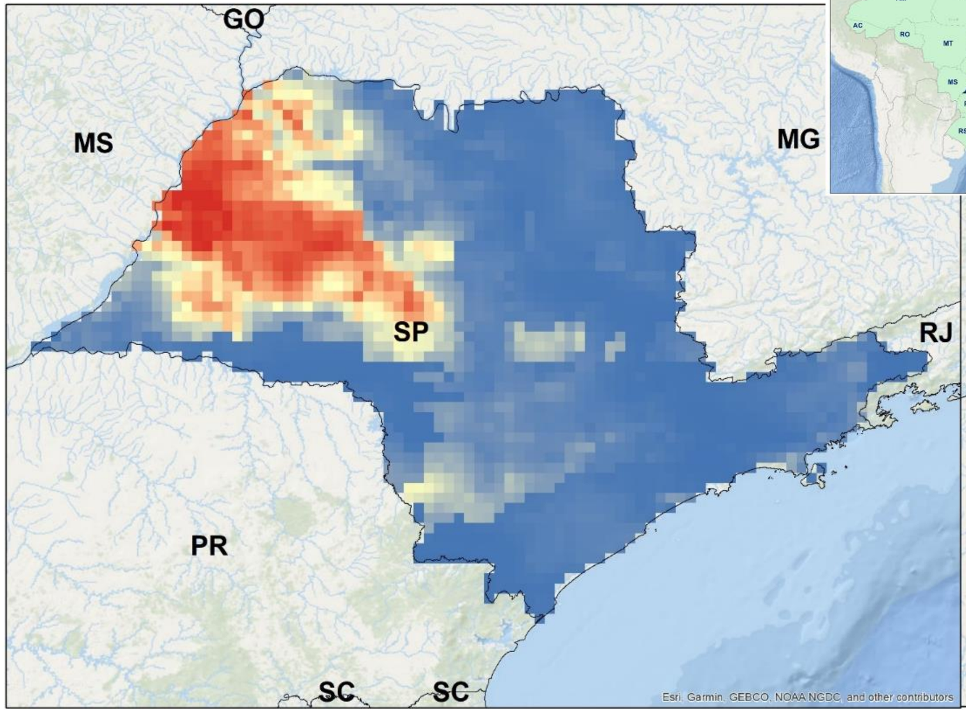


AUC VL Worldclim – 0.882
Tmax12 35.7%
Prec06 19.7%
Tmax01 13.9%

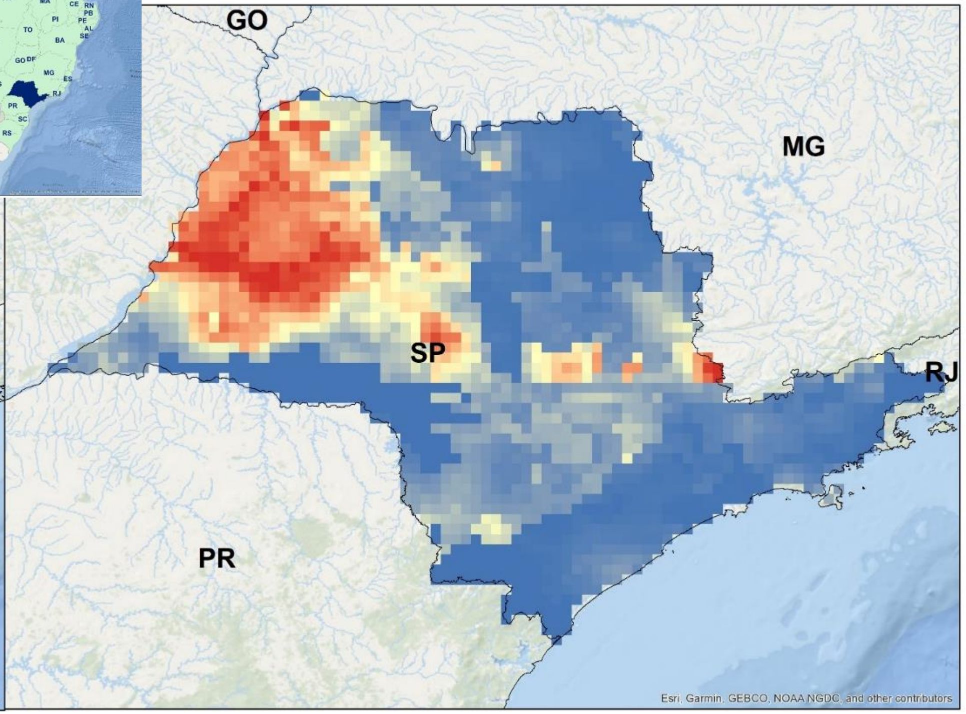
AUC LL BioClim – 0.835
Bio 14 21.3% - Prec Driest Mo
Bio 15 13.8% - Prec Seasonality
Bio 16 16.9% - Prec Wettest Q

Results suggest *Direct* earth observing satellite measurement of soil moisture by SMAP can be used *in lieu* of models calculated from classical thermal and precipitation climate station data to assess VL disease risk and to guide control program interventions.

Visceral Leishmaniasis

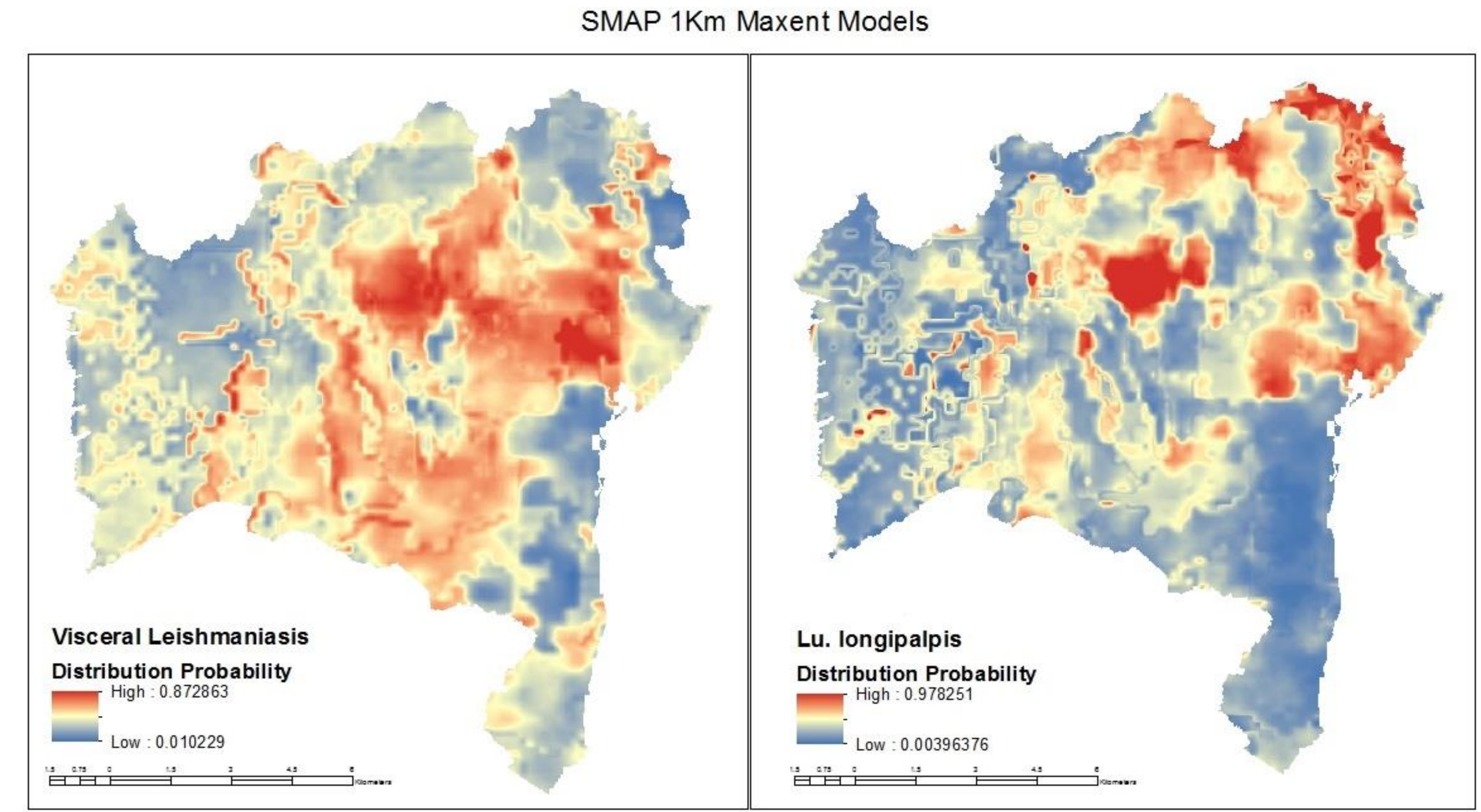


Lutzomyia longipalpis



AUC VL SMAP – 0.884	
Oct	27.1%
Aug	24.8%
Sept	20.4%

AUC LL SMAP – 0.793	
July	37.4%
Dec	17.0%
March	14.5%


SMAP 1Km Maxent Models
Visceral Leishmaniasis
Distribution Probability
High : 0.872863
Low : 0.010229
1.5 0.75 0 1.5 3 4.5 6
Kilometers
Lu. longipalpis
Distribution Probability
High : 0.978251
Low : 0.00396376
1.5 0.75 0 1.5 3 4.5 6
Kilometers

Surveillance and Response Systems for Visceral Leishmaniasis

Global 1km Scale

WorldClim 2.0 Models
30-Year Climate Station Data

Tmax/Tmin/Prec →
Water Budget (Prec/PET)

Biology-Based GDD-WB Generations/year

Satellite Climatology Models
2017- 2019 Data

***VIIRS**-8d LST
***GPM** →
***SMAP**
GOES-16

Community/Agricultural Field Scale (30m)

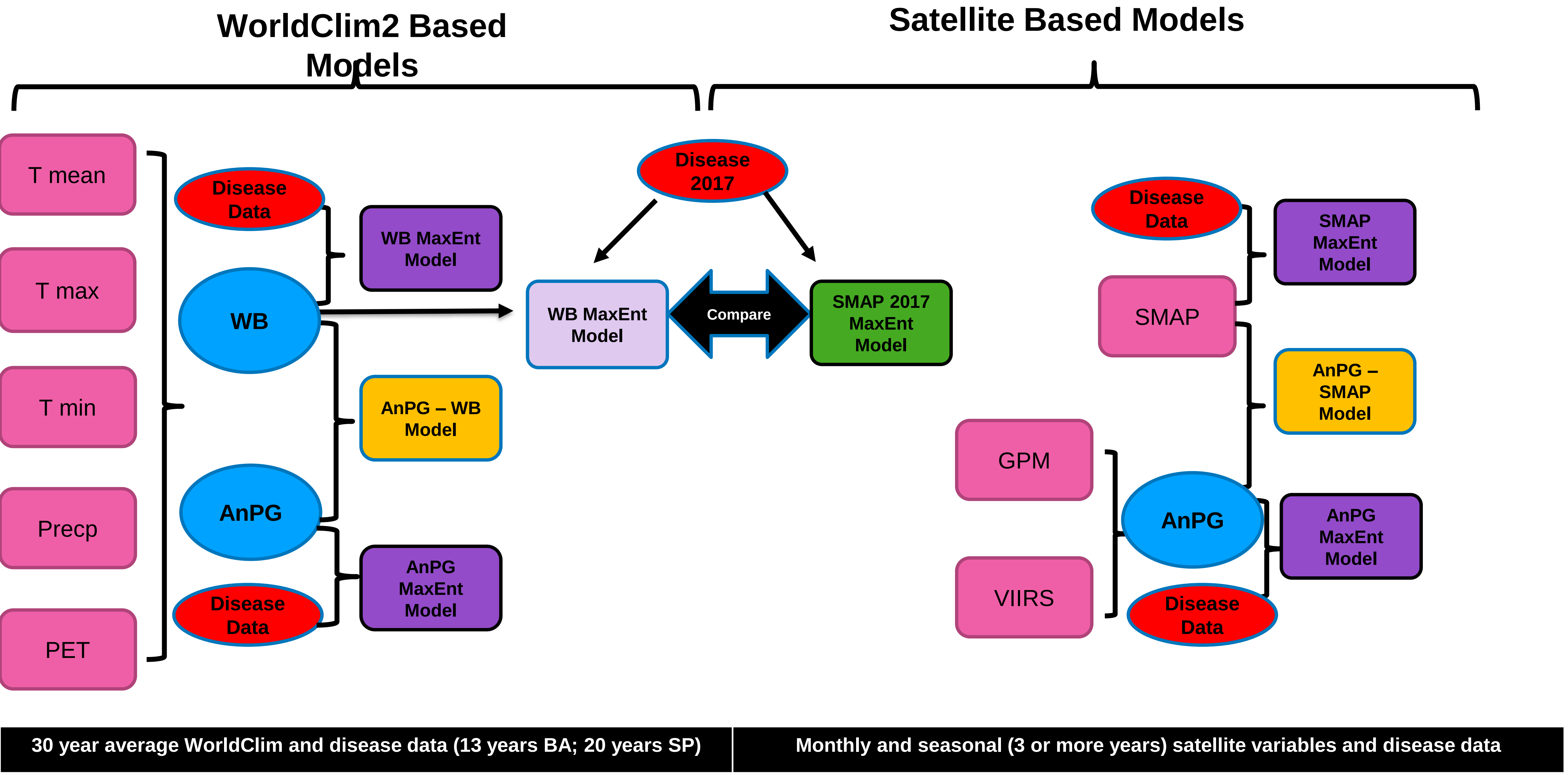
***Landsat 8**; Landsat Legacy
***ASTER**
***ECOSTRESS**

Habitat-Household Scale (<1m)

(Household = Epidemiologic Unit)

***Worldview** 2,3
***GeoEye**

***Lutzomyia longipalpis* Gen/yr**
Base temperature = 16
GDD one generation = 414
WB = $\leq$0.8
(Nieto et al., 2006)

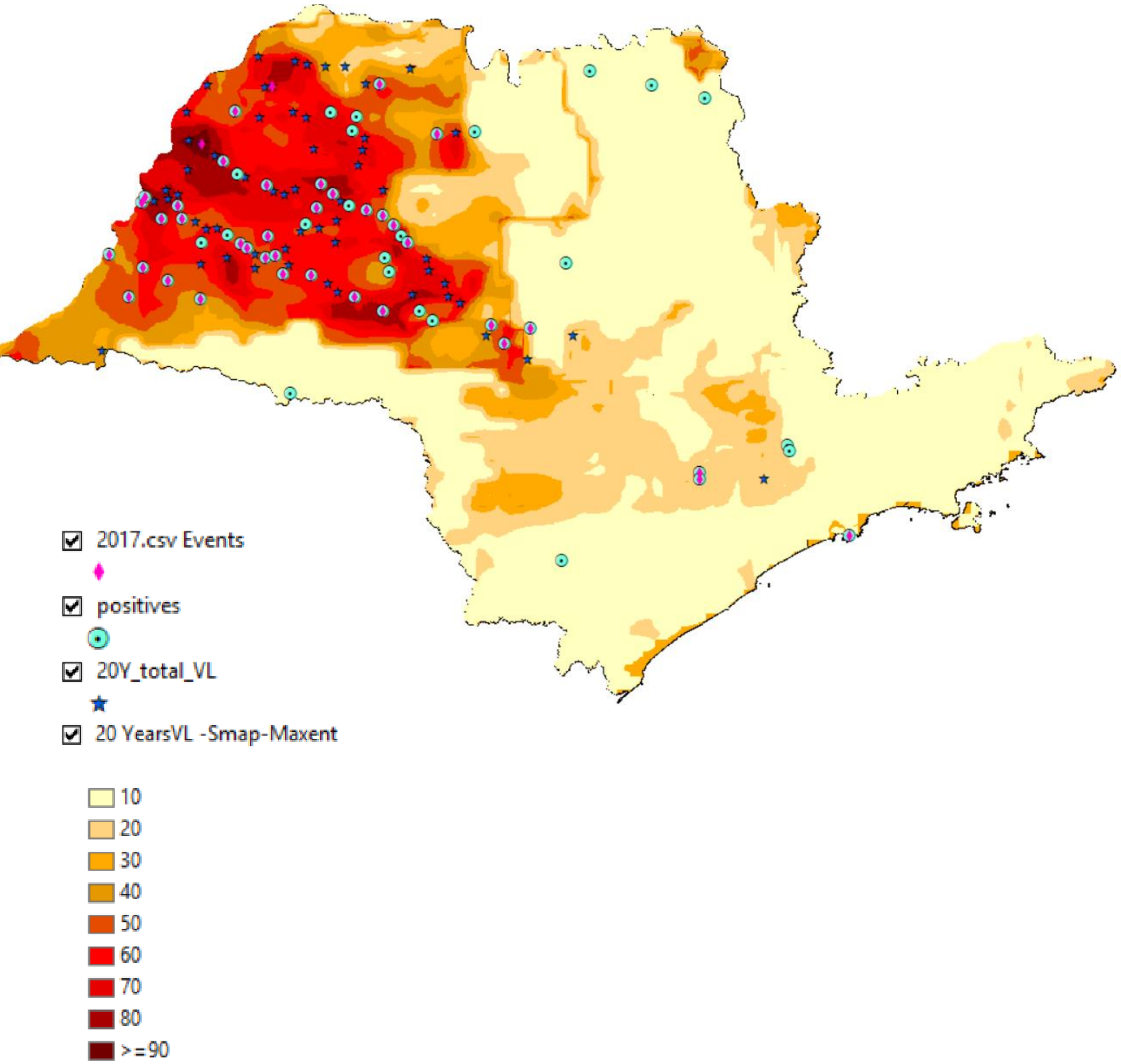


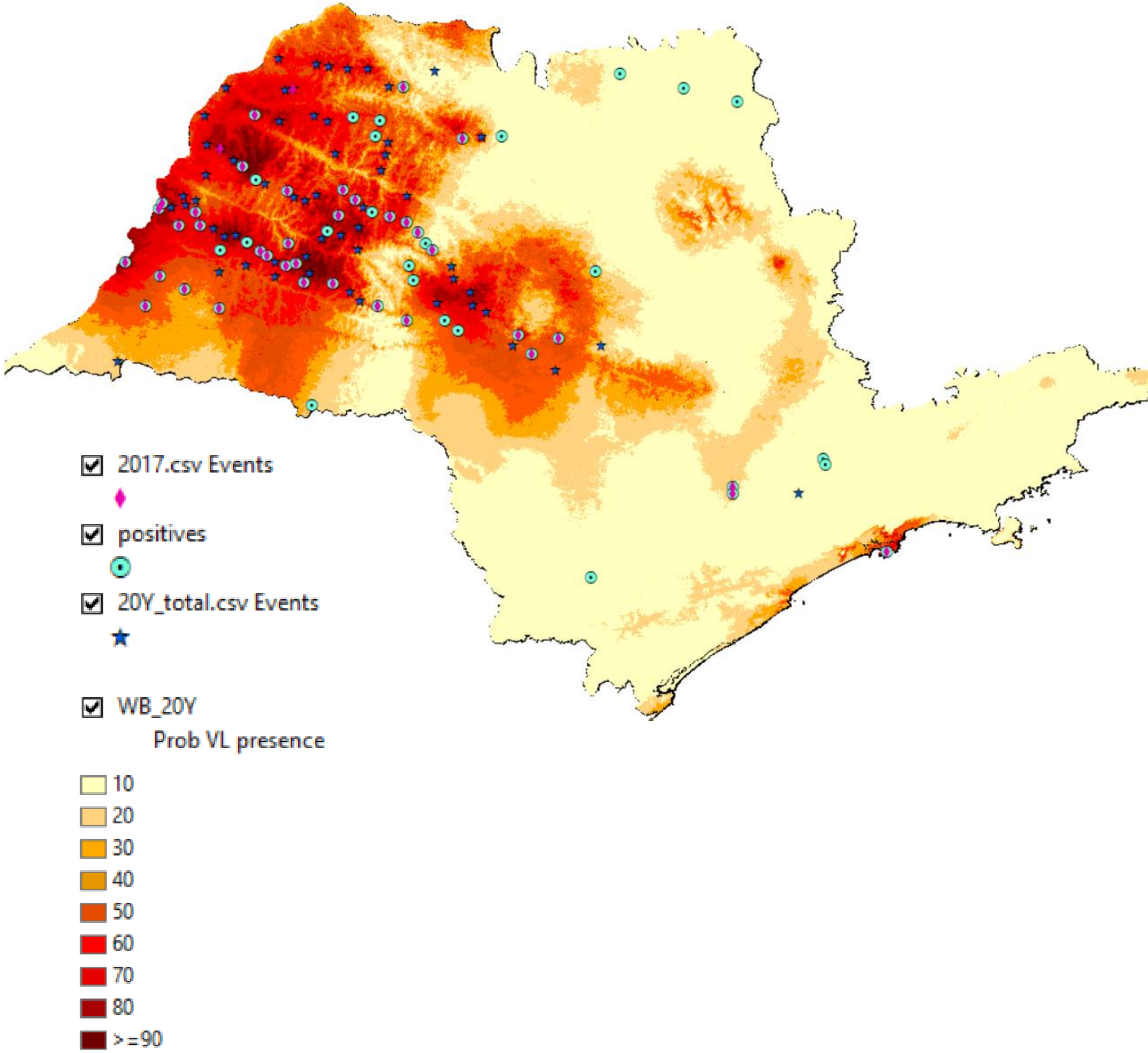
WorldClim2 Based Models
Satellite Based Models
T mean
T max
T min
Precp
PET
Disease Data
WB
AnPG
Disease Data
WB MaxEnt Model
AnPG – WB Model
AnPG MaxEnt Model
Disease 2017
WB MaxEnt Model
Compare
SMAP 2017 MaxEnt Model
Disease Data
SMAP
SMAP MaxEnt Model
AnPG – SMAP Model
GPM
VIIRS
AnPG
Disease Data
AnPG MaxEnt Model
30 year average WorldClim and disease data (13 years BA; 20 years SP)
Monthly and seasonal (3 or more years) satellite variables and disease data

SMAP SP Maxent
20 years Incidence VL

Incidence VL São Paulo

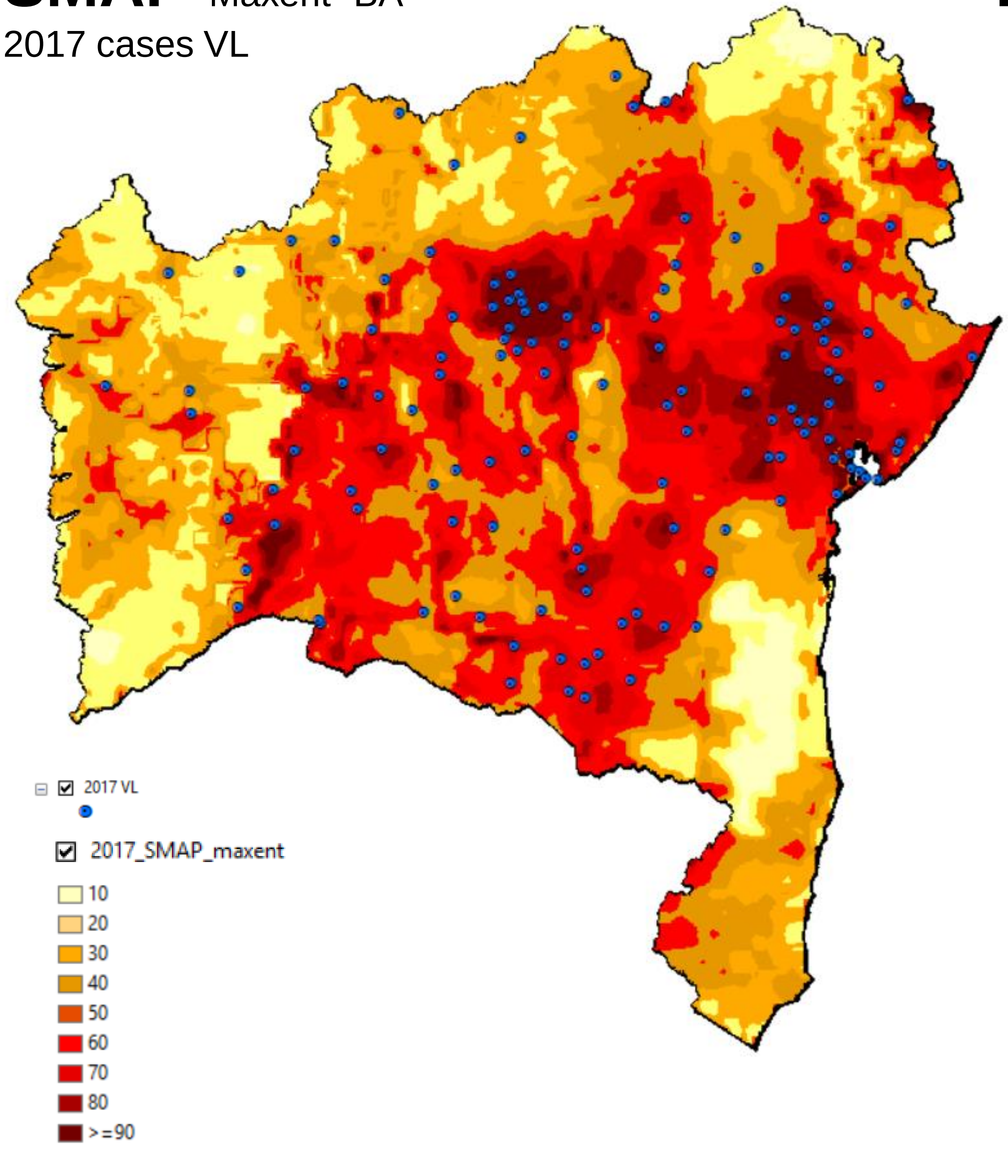
WB SP Maxent
20 years Incidence VL



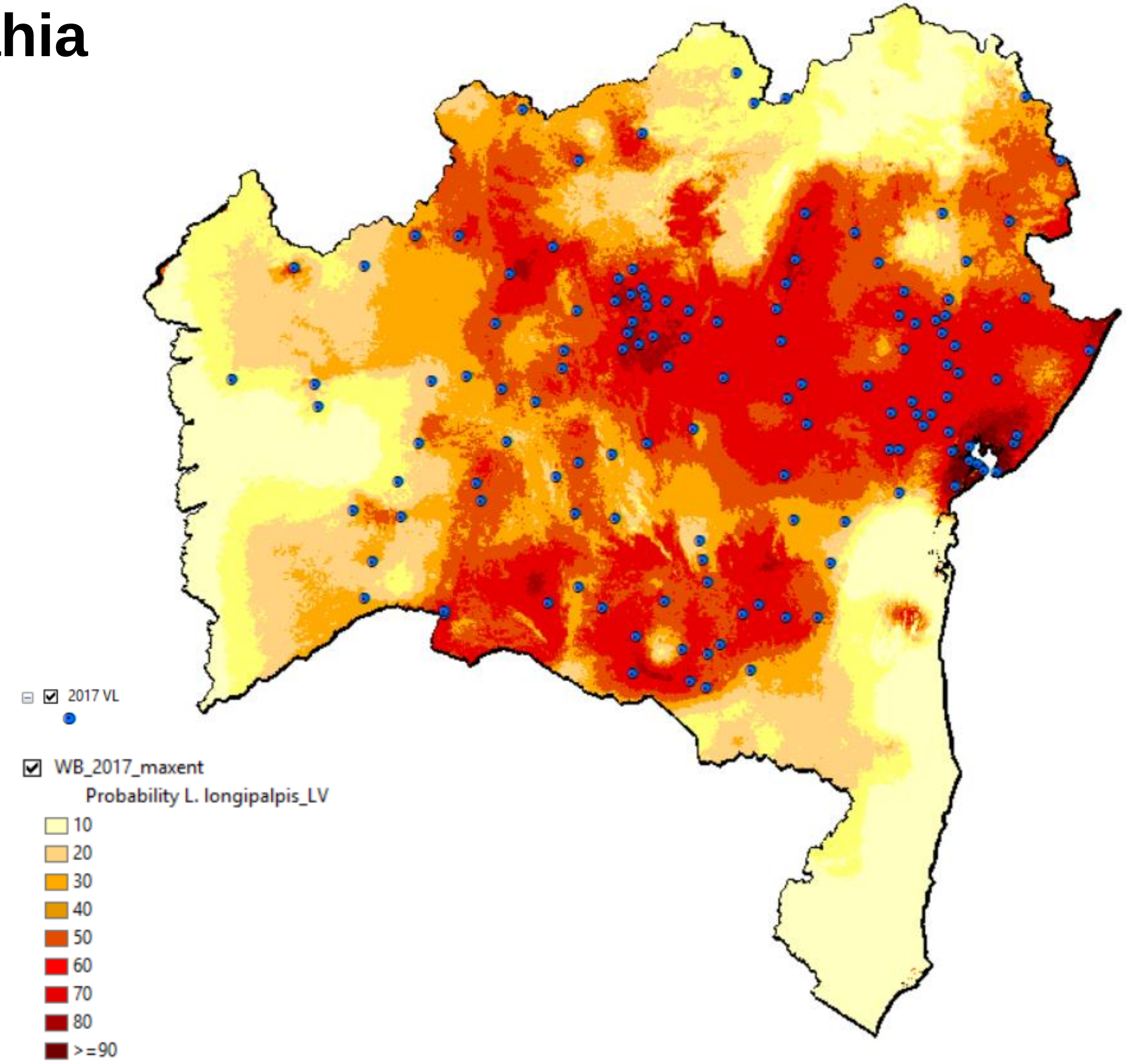


2017 - VL cases Bahia

SMAP Maxent- BA
2017 cases VL



WB Maxent- BA
2017 cases VL



Neural Network Models

DISEASE Data

- Disease data per month (12) * (3 years) and
- Disease data per season (moving 3 month average) 12 each year *(3 years).
- (point* and polygon 1Km)

SMAP IMAGES

- SMAP data 2 per mo (24) * (3 years)=72 images
- SMAP per season (moving 3 month average)= 24 per year * (3 years)=72 images
- 10 km and resampled 1km resolution
- If each 3 day, 10/mo) x 36 = 360 images

AnPG VIIRS/GPM Images

- AnPG (per month (12) * (3 years)= 36 images
  AnPG per season (moving 3 month average)= 12 per year *(3 years)=36 images
- 1km resolution
- If/ea 8day = 48 x 3 yr=144 images AnPG

- Disease points
- SMAP images
- AnPG images

- 12 months
- Seasonal (moving 3 mo avg)
- 3 years **

=

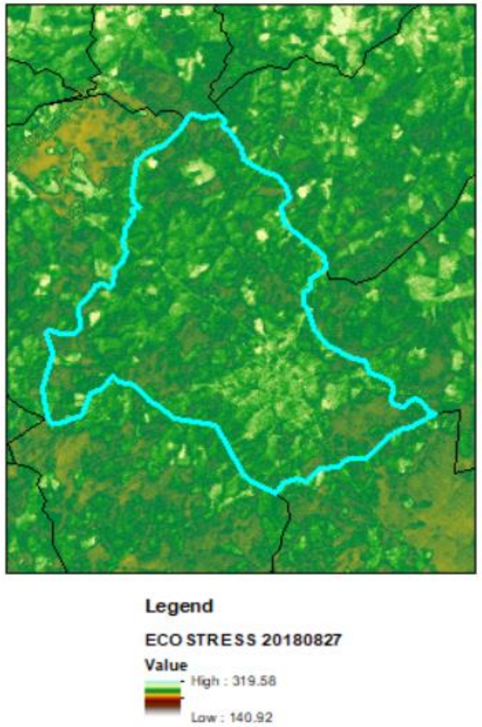
**96 Images and Disease data

→ **Neural Network Models**

**This number will increase as we get more than 3 years of data and/or if we use bimodal seasonality .

Biological Drivers and Limiting Factors

Collaborators
Adolfo Lutz Institute, Sao Paulo
UNESP Presidente Prudente-Geography



ECOSTRESS IMAGE CATALOG

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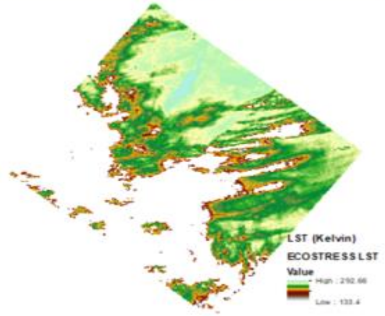
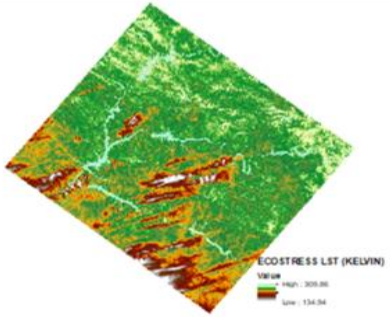
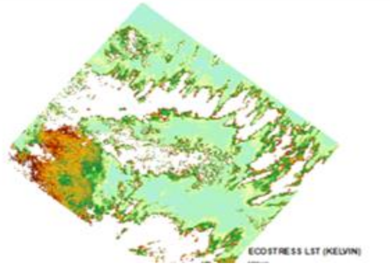
ECOSTRESS_L2_LSTE_00616_005_ 20180815T100949_0501_02_LST_UTM.tif	August 15, 2018 7:09:49 AM		
ECOSTRESS_L2_LSTE_00616_006_ 20180815T101041_0501_02_LST_UTM.tif	August 15, 2018 7:10:41 AM		
ECOSTRESS_L2_LSTE_00723_005_ 20180822T071955_0501_02_LST_UTM.tif	August 22, 2018 4:19:55 AM		

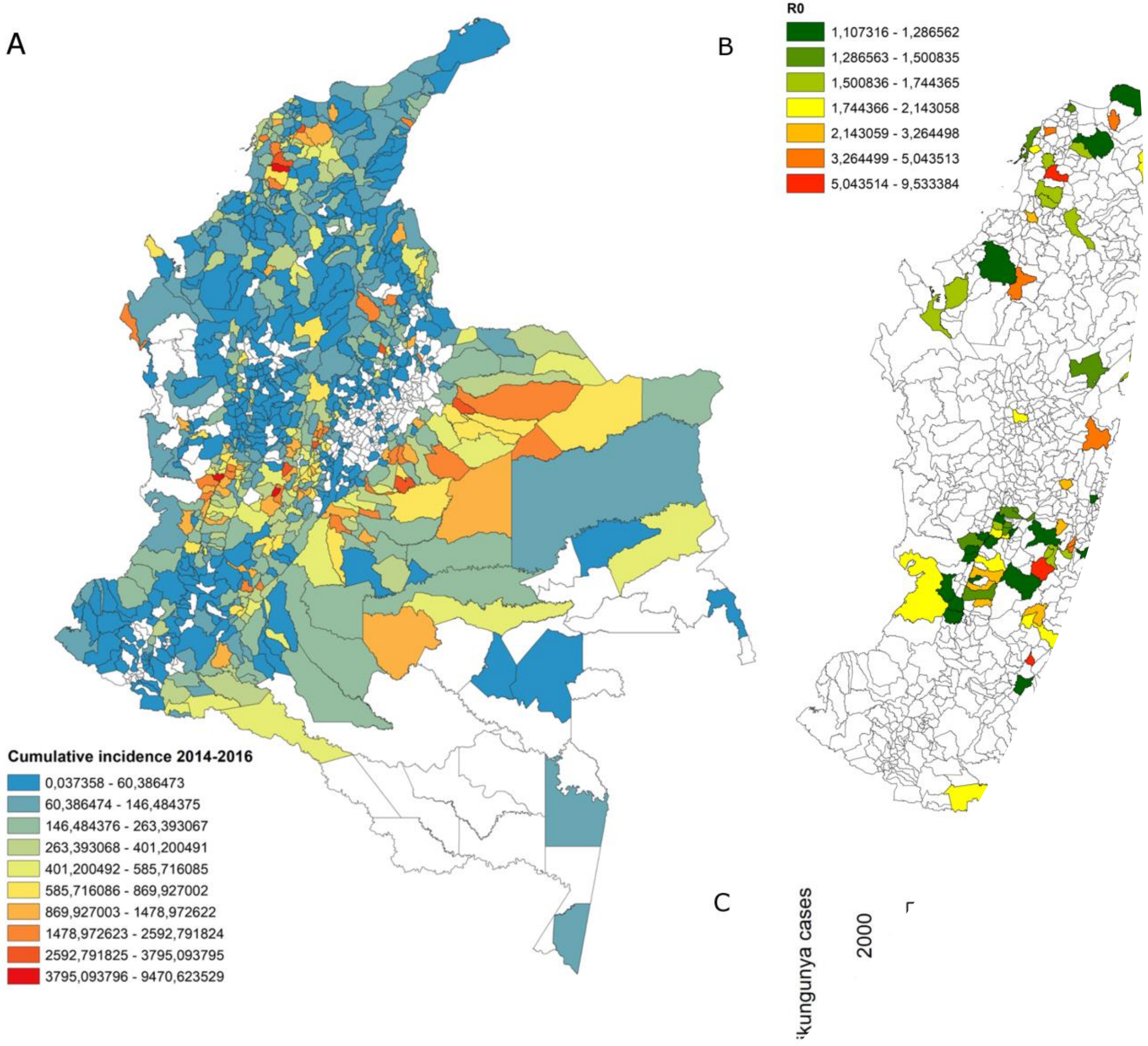
Eco-environmental variables and Chikungunya basic reproduction number (R_0)

Víctor Hugo Peña-García, RC Christofferson

- Aim: Investigate the correlation of temperature with chikungunya incidence in Colombia

- Model WorldClim and administrative-level data from Colombian Ministry of Health. (Paper submitted to PLoS NTD July, 2019)

- Hypothesis: VIIRS satellite surveillance LST data can be used to develop risk assessment models *in lieu* of classic climate station data



Characterization of micro- and macro-environment of mosquitoes

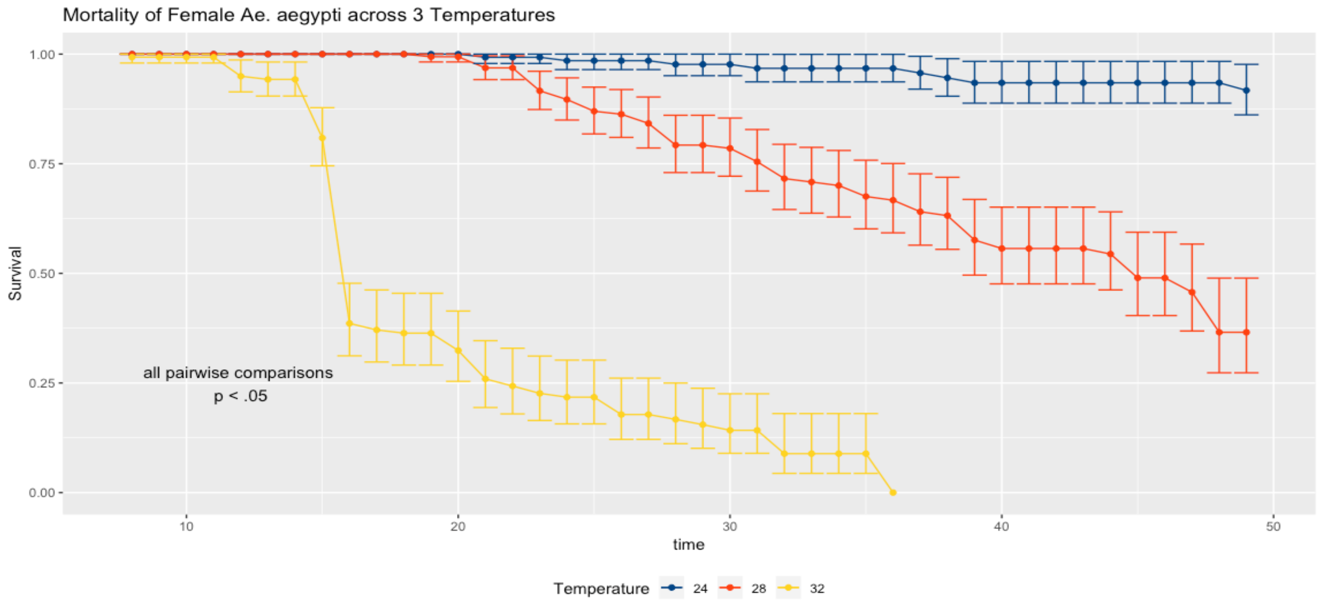
- The timing of mosquito development is altered:
  - Average time to pupation from egg
  - Average time to adult emergence from egg
  - Average time to female adult emergence from egg

EVENT	TEMP	AVG TIME TO EVENT
Pupation	24	8.35 days
	28	6.09 days
	32	6.29 days
Total adult emergence	24	10 days
	28	8.02 days
	32	7.93 days
Female adult emergence	24	10 days
	28	8.08 days
	32	8.13 days

Characterization of micro- and macro-environment of mosquitoes

Temperature	Minimum Time to Virus in the Saliva (transmission)
24°C	27 days
28°C	18 days
32°C	5 days

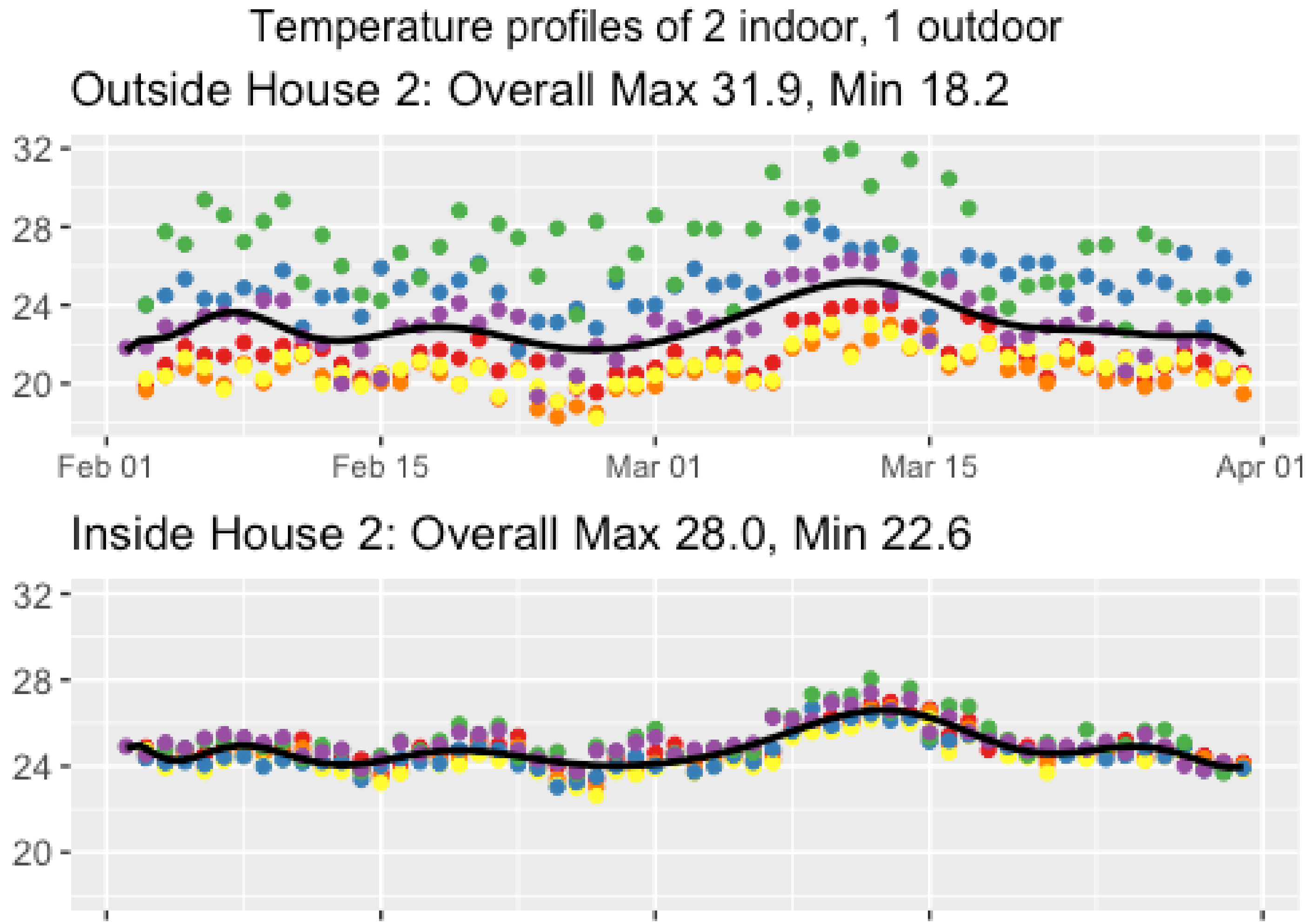
- Mosquito infection is faster at higher temperatures
- Mosquitoes die much faster at higher temperatures
- **The advantage to the virus is lost by the cost to the vector**



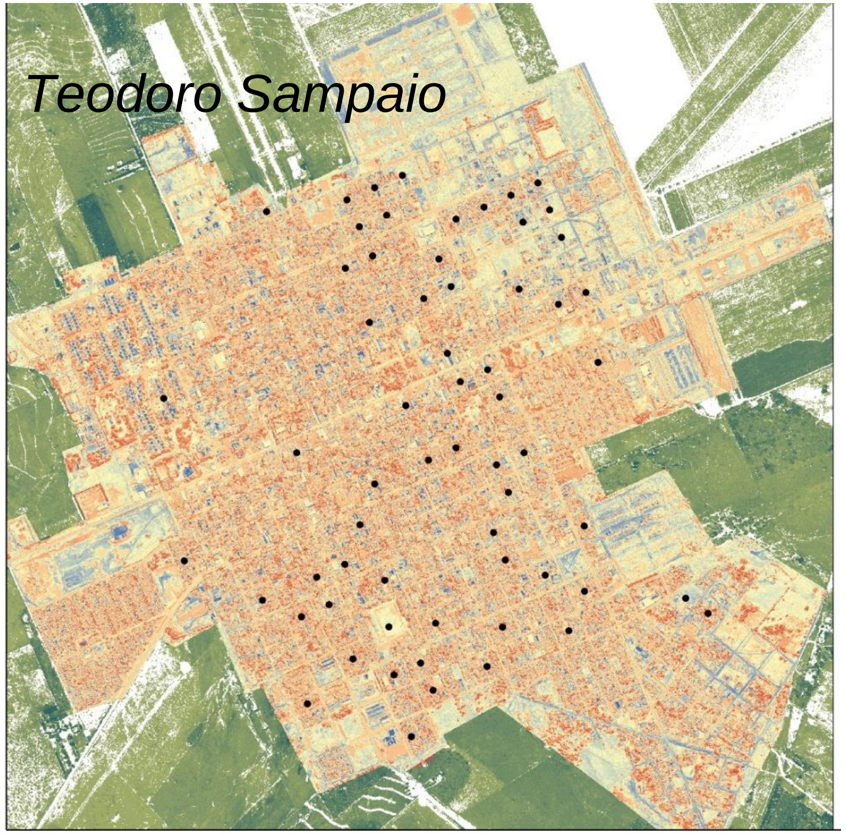
- Deployed 30 HOBO digital temperature loggers in Colombia – paired inside and outside houses

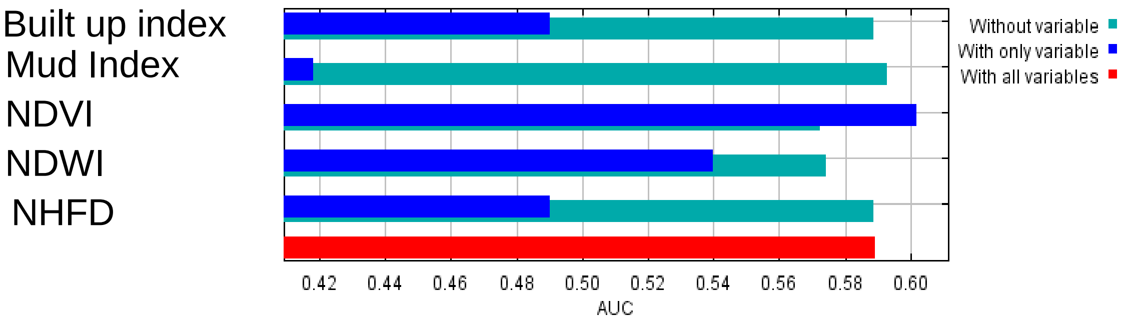
- Goal: Determine the relative relationships between indoor/outdoor temperatures using VIIRS 8d, 2017-2019 satellite data

- Expectation: Discover we can easily determine some mathematical relationship (likely non-linear and non-uniform) that will enable translation of satellite temperature data to capture micro-environmental temperatures of mosquitoes (i.e. indoors)



Models - Habitat-Household level





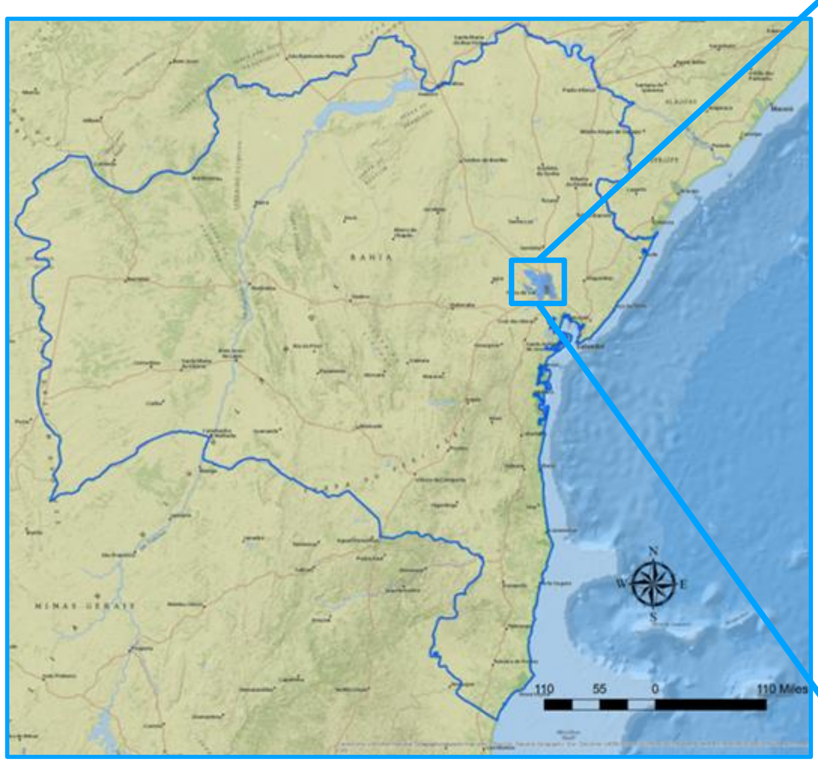
A Comparison of Household-Habitat Scale Ecological Niche Models Using WorldView-2, GeoEye-1, and Landsat 8 Satellite Products to Determine Ecological Distribution of Soil-Transmitted Helminth Infections in three Representative Communities of Feira de Santana, Brazil (Ryan H Avery, Phd Dissertation, LSU, Aug, 2019)

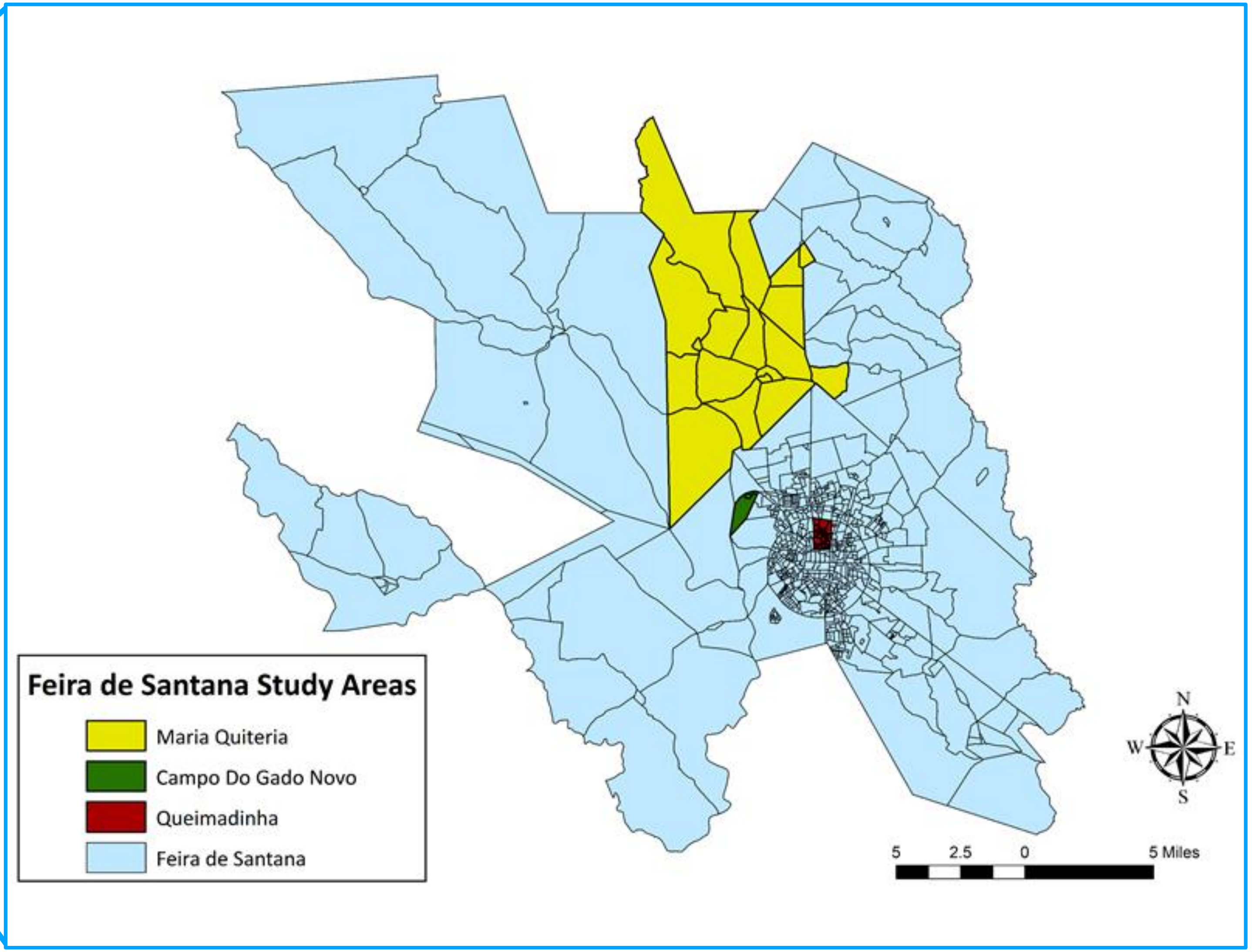
Objectives

I. Evaluate whether WorldView-2 (WV2) and GeoEye-1 (GE1) satellite imagery can be used for production of effective and reliable STH ecological niche models (ENM) for households and their surrounding environments, and compare to ENMs created using Landsat 8 satellite imagery.

ii. Determine the important environmental variables(s) driving the ecological distribution of STH and whether these differ depending on the type of community (rural, peri-urban, urban) evaluated.

Feira de Santana, Bahia, Brazil





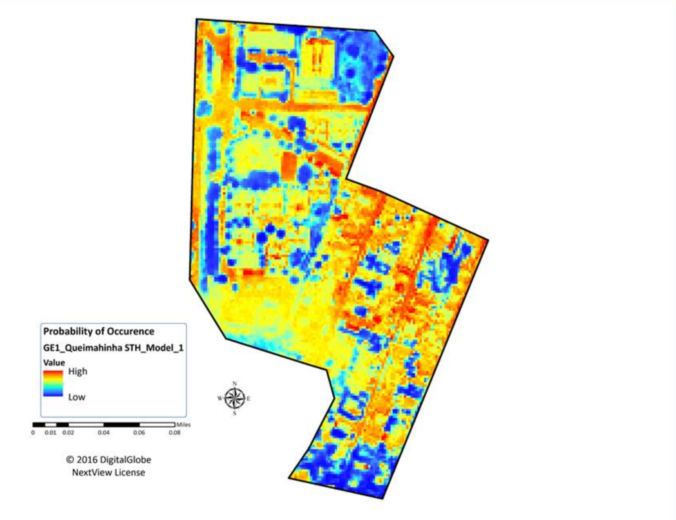


Figure 1.3. The GE1 STH ENM 1, where NDVI was the main contributing variable.

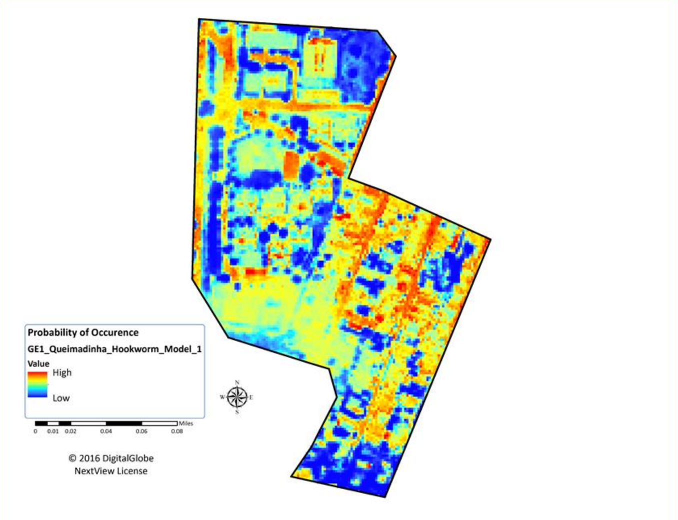


Figure 1.4. The GE1 hookworm ENM 1, where NDVI was the main contributing variable.

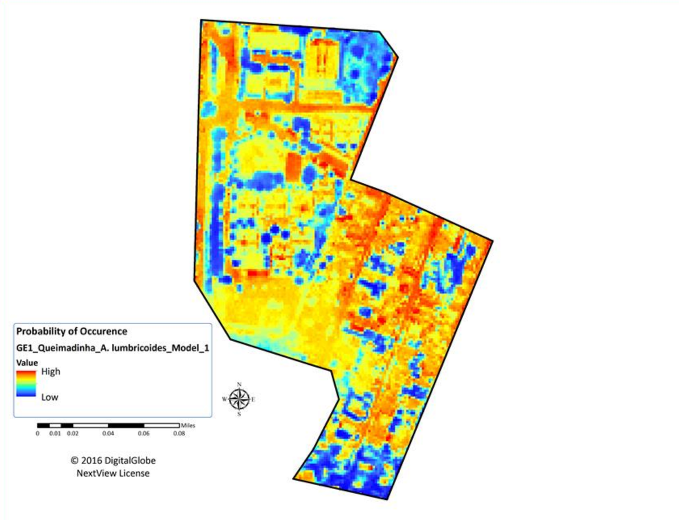


Figure 1.5. The GE1 *A. lumbricoides* ENM 1, where NDVI was the main contributing variable.

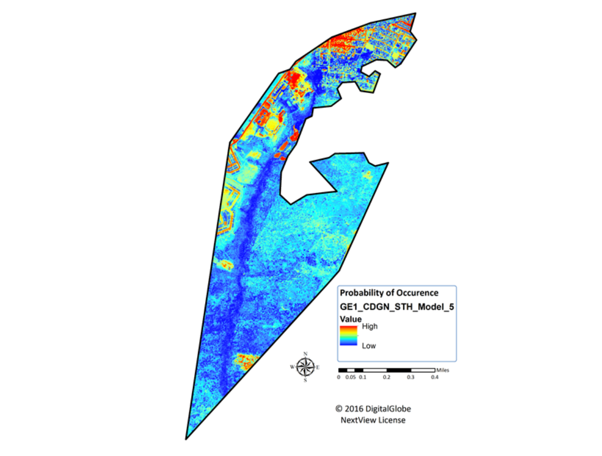


Figure 1.6. The GE1 STH ENM 5, where NDWI was the main contributing variable.

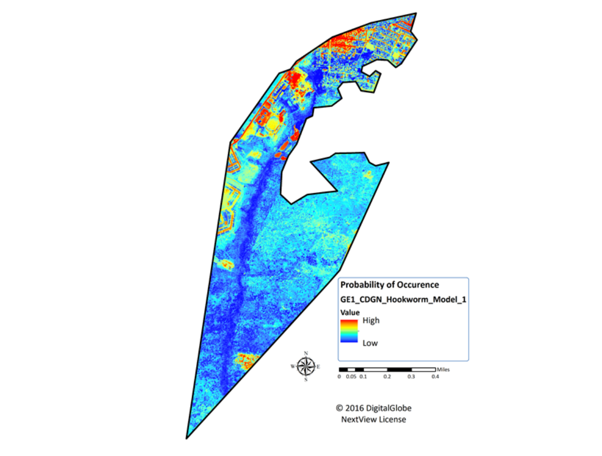


Figure 1.7. The GE1 hookworm ENM 1, where NDWI was the main contributing variable.

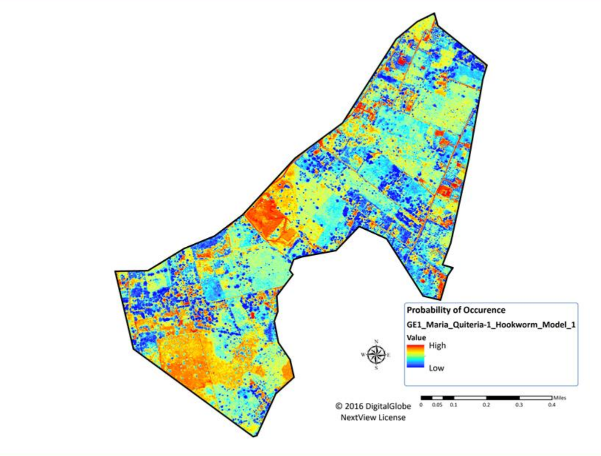


Figure 1.8. The GE1 hookworm ENM 1, where NDVI was the main contributing variable.

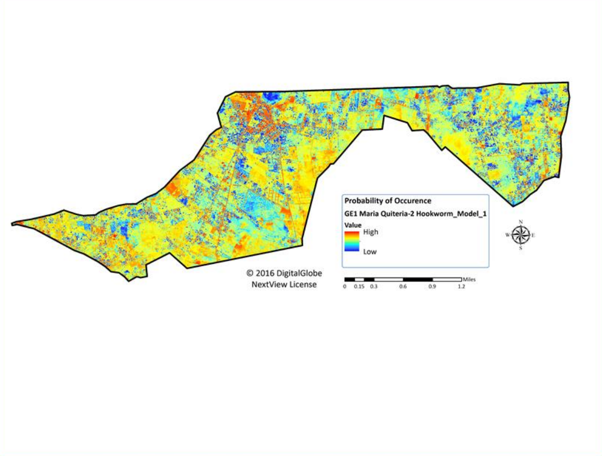


Figure 1.9. The GE1 hookworm ENM 1, where NDVI was the main contributing variable.

GE1 AND WV2 COMPARISON RESULTS

- Overall, the GE1 images consistently produced the best performing ENMs for STH and hookworm across all study areas

Table 1.3. The top ecological niche model(s) for each soil-transmitted helminth from the comparison of GE1 and WV2 across all study areas, the AICc score, and the top contributing environmental variable.

Parasite	Satellite/Area	Model	AICc score	Top Variable	Percentage
STH	GE1 Queimadinha	1	171.599248	NDVI	100
Hookworm	GE1 Queimadinha	1	95.49679642	NDVI	100
A. lumbricoides	WV2 Queimadinha	13,22	116.1267087	WVSI	100
T. trichiura	WV2 Queimadinha	9,22,13	80.73185793	WVSI	100
STH	GE1 CDGN	5	146.1031124	NDWI	100
Hookworm	GE1 CDGN	1, 2	122.1542984	NDVI, SAVI	95.4
Hookworm	GE1 Maria Quiteria-1	3	124.3804917	NDWI	100
Hookworm	GE1 Maria Quiteria-2	1	325.1545496	NDVI	92

Start ARL 2
Current ARL 3
Goal ARL 6

Challenges/Risks to Project Schedule:

Year 3 post-doc personnel budget funding only partial year

- Possible mitigation by additional personnel funding by LSU, eg Grad students, instructor
- Colombia/Brazil government funding of additional students and post docs, eg. FAPESP
- Industry supplemental funding, eg CEVA Pharmaceutical end user
- USAID PEER Program