Characterization of Tick-borne Disease Risk in Alabama using NASA Earth Observation Systems

NASA Applied Sciences'
DEVELOP National Program

Marshall Space Flight Center/University of Alabama at Birmingham

Presenter: Steve Padgett-Vasquez

Project Methodology

Community Concerns

- Currently, many state officials and physicians do not recognize the presence of Lyme disease and STARI in Alabama.
- The general public is not aware of the basic measures to prevent Tick-borne Illnesses (TBI).
- Objectives: Increase awareness of TBI and identify likely tick infested areas.

NATIONAL APPLICATION AREAS

Public Health

Ecological Forecasting

Science Mission Directorate

Earth Science Division

Applied Sciences Program

DEVELOP

Project Methodology

Partners

- Dr. Robert Carter (JSU)
- Birmingham Lyme
- Camp Coleman
- UAB's Outdoor Pursuits
- Dr. Leslie McClure (UAB School of Public Health)

Study Area & Period

- Talladega National Forest, Fort McClellan, and Birmingham, Alabama
- 5 terms, Summer 2009-Fall 2010

Satellite Imagery Utilized

- Landsat TM
- ASTER (Terra)

Science Advisor

Jeffrey C. Luvall, Ph.D.

NASA Marshall Space Flight Center

Lab Location

Lab of Global Health Observation

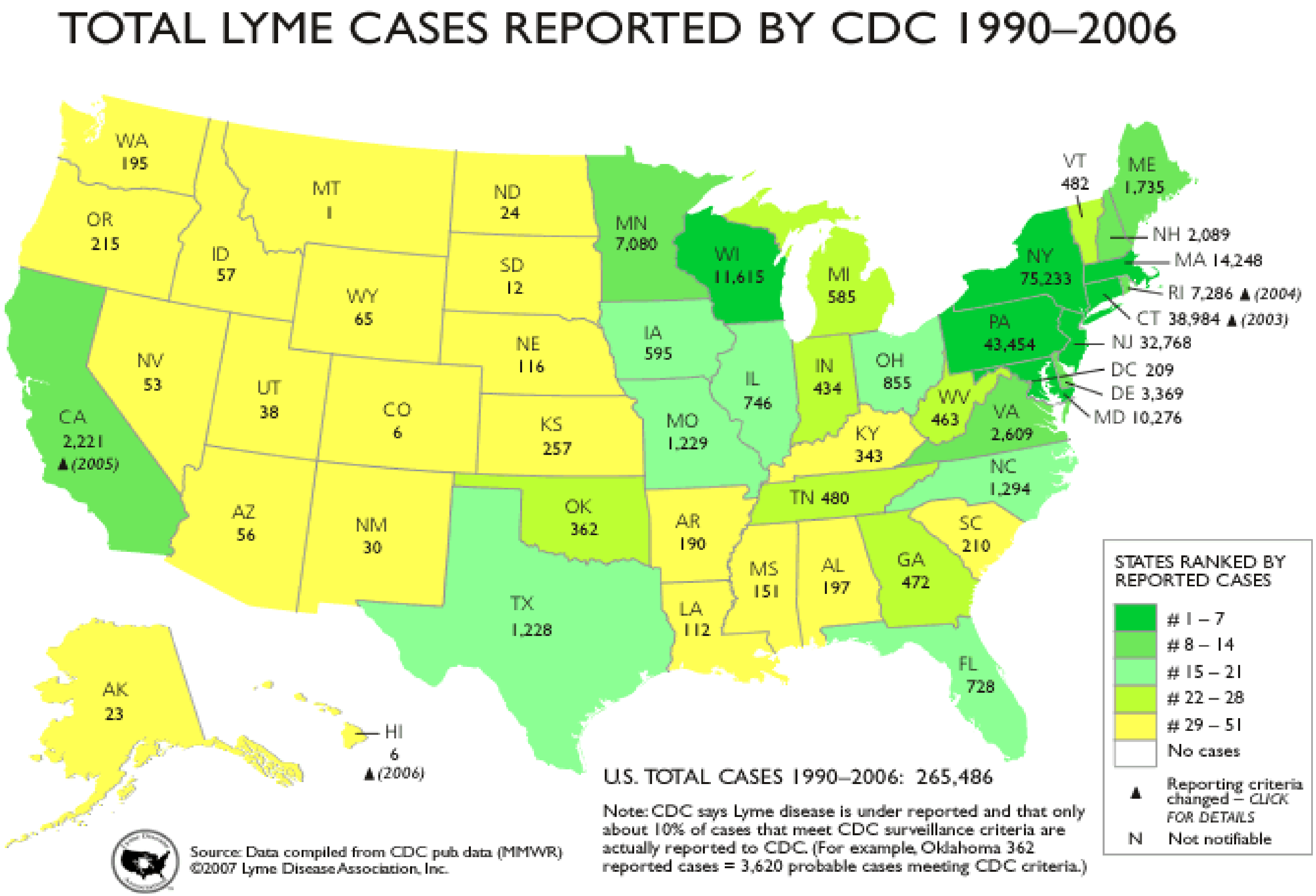
Director: Sarah H. Parcak, Ph.D.

University of Alabama at Birmingham

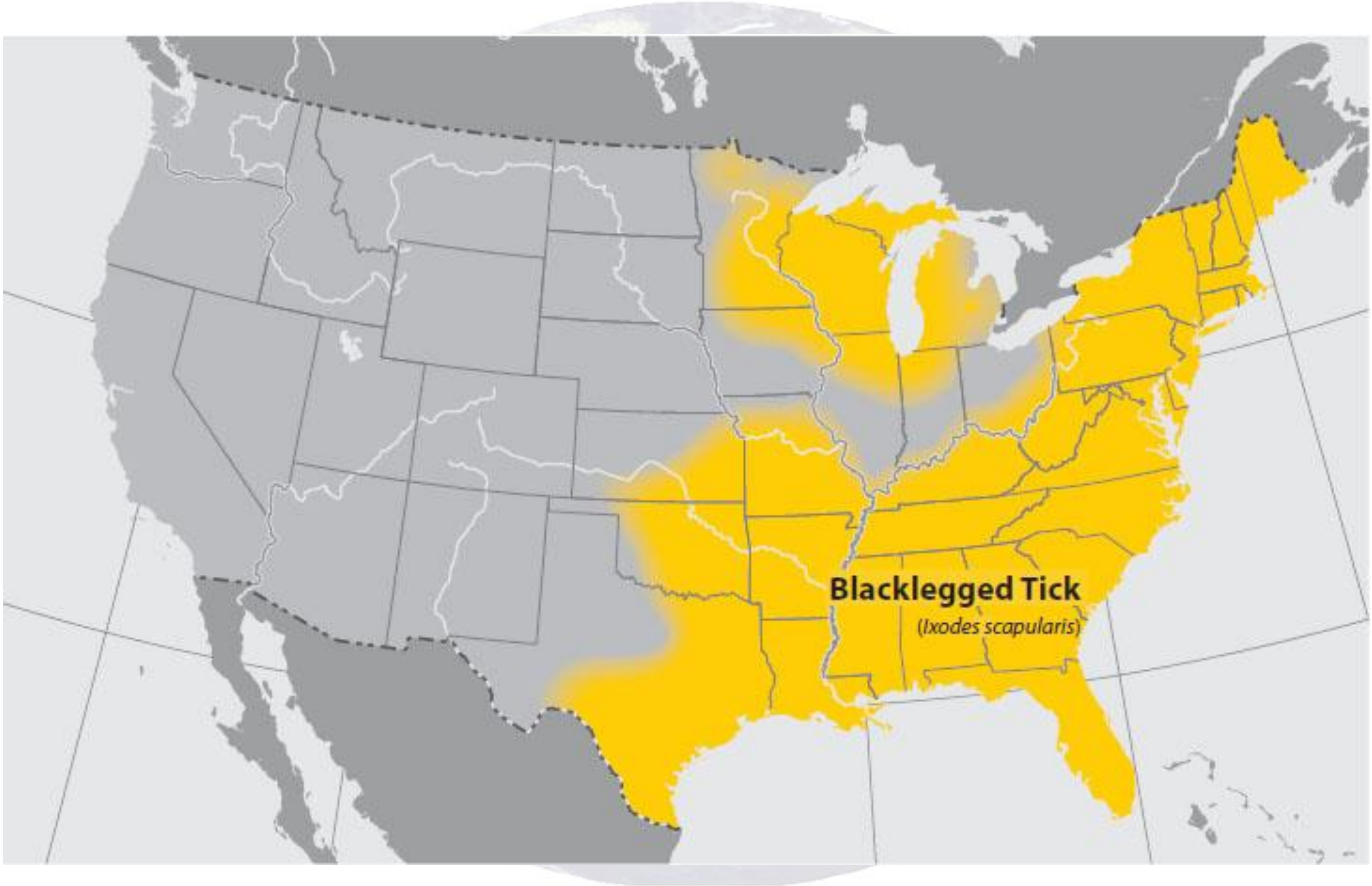
Lyme Disease (LD)

- 1975-clustering of children ill with possible juvenile rheumatoid arthritis seen in Lyme, Connecticut .
- Common symptoms: Erythema migrans, fever, fatigue and headache.
- 1982-Willy Burgdorfer found spirochetes in midgut of ticks sent from Shelter Island, NY, a place with endemic LD.
- The etiologic agent was named *Borrelia burgdorferi.*
- If left untreated, may result in long term effects: arthritis, neurocognitive difficulties or fatigue.
- First documented case of LD in Alabama was reported in 1986.

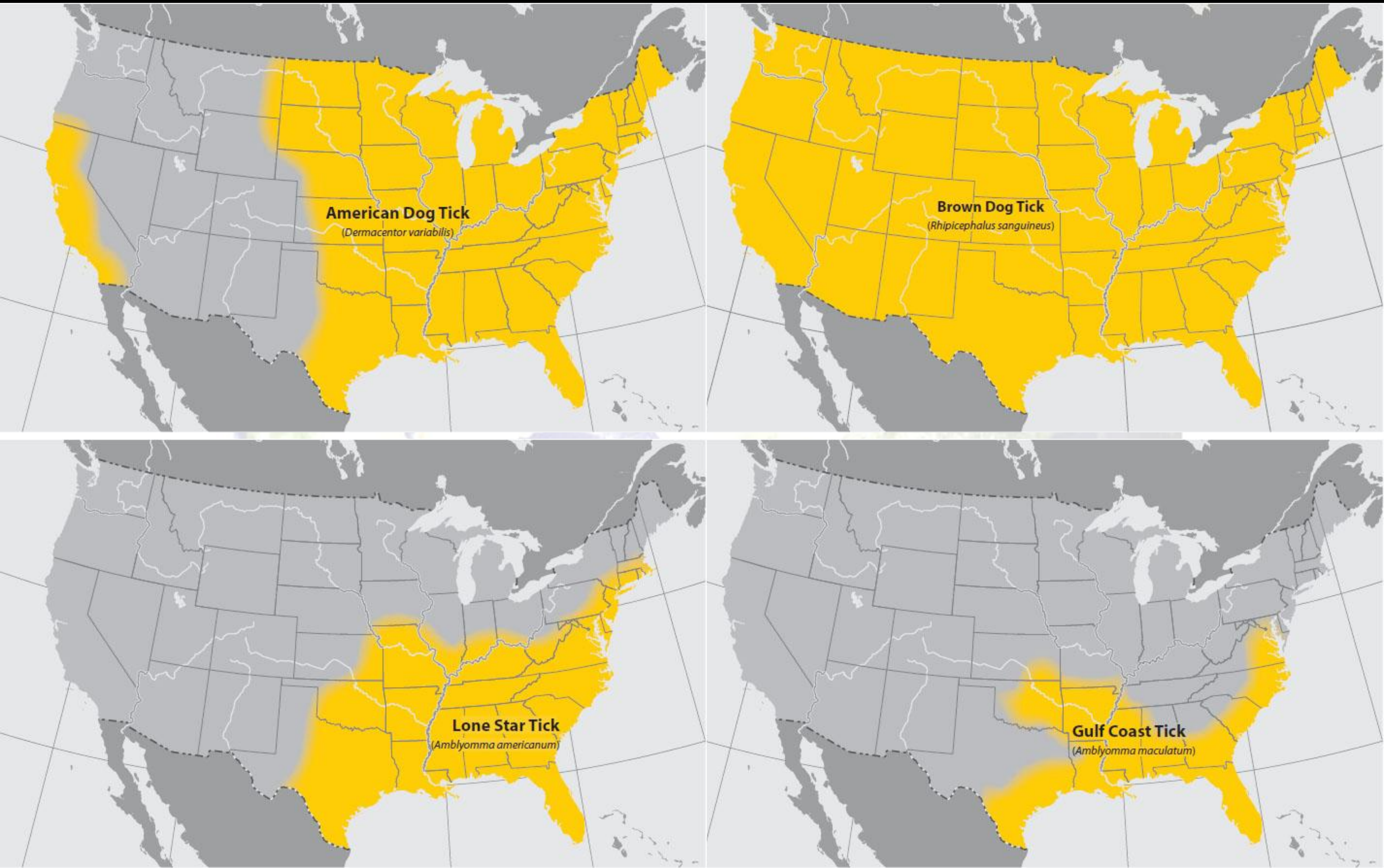
CDC Case Map


TOTAL LYME CASES REPORTED BY CDC 1990–2006
WA 195
OR 215
CA 2,221 ▲(2005)
NV 53
ID 57
MT 1
WY 65
UT 38
AZ 56
CO 6
NM 30
ND 24
SD 12
NE 116
KS 257
OK 362
TX 1,228
MN 7,080
IA 595
MO 1,229
AR 190
LA 112
WI 11,615
IL 746
MI 585
IN 434
OH 855
KY 343
TN 480
MS 151
AL 197
GA 472
FL 728
SC 210
NC 1,294
VA 2,609
WV 463
PA 43,454
NY 75,233
VT 482
ME 1,735
NH 2,089
MA 14,248
RI 7,286 ▲(2004)
CT 38,984 ▲(2003)
NJ 32,768
DC 209
DE 3,369
MD 10,276
AK 23
HI 6 ▲(2006)
STATES RANKED BY REPORTED CASES
1 – 7
8 – 14
15 – 21
22 – 28
29 – 51
No cases
▲ Reporting criteria changed – CLICK FOR DETAILS
N Not notifiable
U.S. TOTAL CASES 1990–2006: 265,486
Note: CDC says Lyme disease is under reported and that only about 10% of cases that meet CDC surveillance criteria are actually reported to CDC. (For example, Oklahoma 362 reported cases = 3,620 probable cases meeting CDC criteria.)
Source: Data compiled from CDC pub data (MMWR)
©2007 Lyme Disease Association, Inc.

Blacklegged tick distribution



Distribution of other tick species



Other tick-borne Illnesses (TBI)

Confirmed Vector

- Blacklegged Tick
- Lone Star Tick
- American Dog Tick
- Brown Dog Tick
- Gulf Coast Tick

TBI

- Anaplasmosis
- Babesiosis
- Erlichiosis
- Rickettsiosis
- Rocky Mountain Spotted Fever
- STARI
- Tularemia

Primary Prevention

- Reducing exposure to ticks is the best defense against TBI.

- Primary personal protection methods:
  – Wear protective clothing
  – Wear light colored clothing
  – Apply tick (insect) repellants
  – Perform tick checks
  – Avoid or reduce time spent in high risk areas

CDC Prevention Recommendation

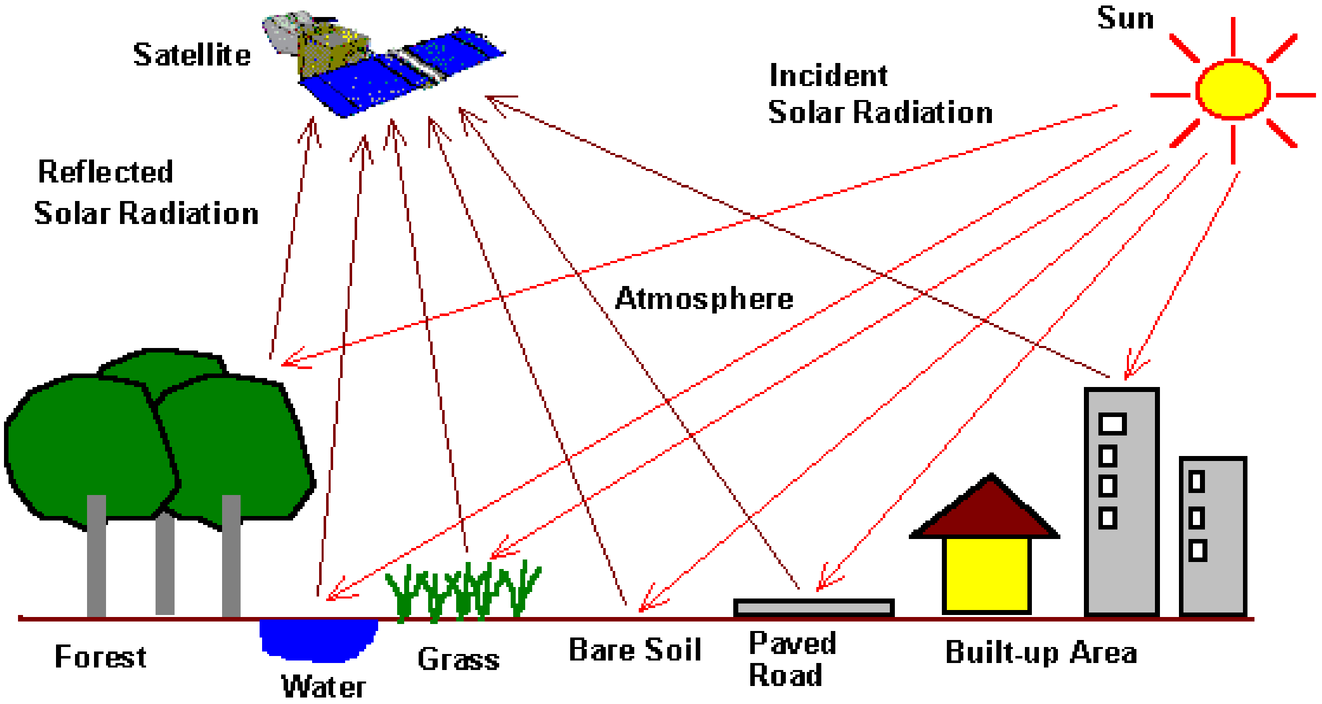
- The CDC Lyme disease prevention webpage states: "Ask your local health department and park or extension service about tick infested areas to avoid."

- However, NO local health department and park or extension service in the state of Alabama provide information about tick infested areas.

State of Alabama Courtesy of Google Earth

Introduction: Remote Sensing

Remote sensing is a technique used to analyze emitted and reflected energy from earth, in multiple parts of the electromagnetic spectrum, using aircraft and satellites.



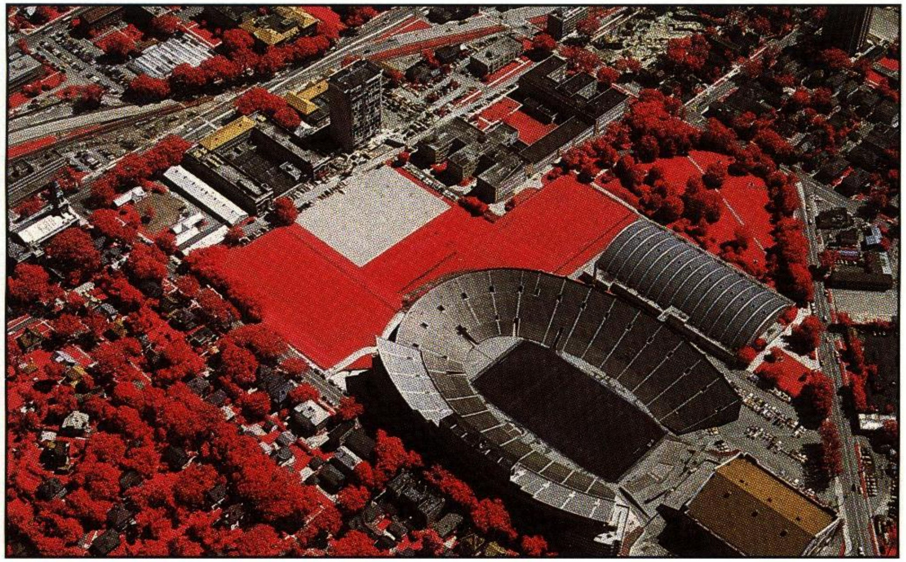
Environmental Factors for Ticks Populations

- Temperature: -10 to 35^{o}C.
- Relative humidity: no lower than 80%.
- Vegetation: forest cover and decaying vegetation help maintain relative humidity.
- Soil moisture helps tick avoid desiccation.

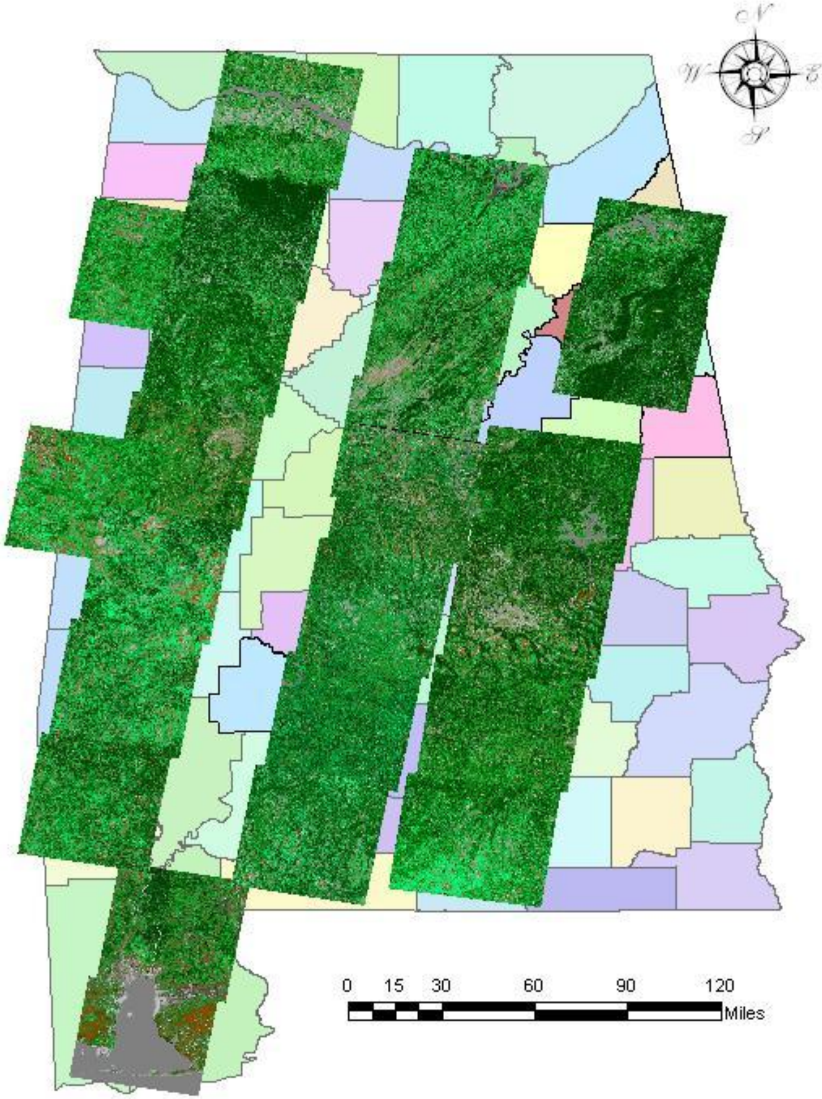
Normalized Difference Vegetation Index

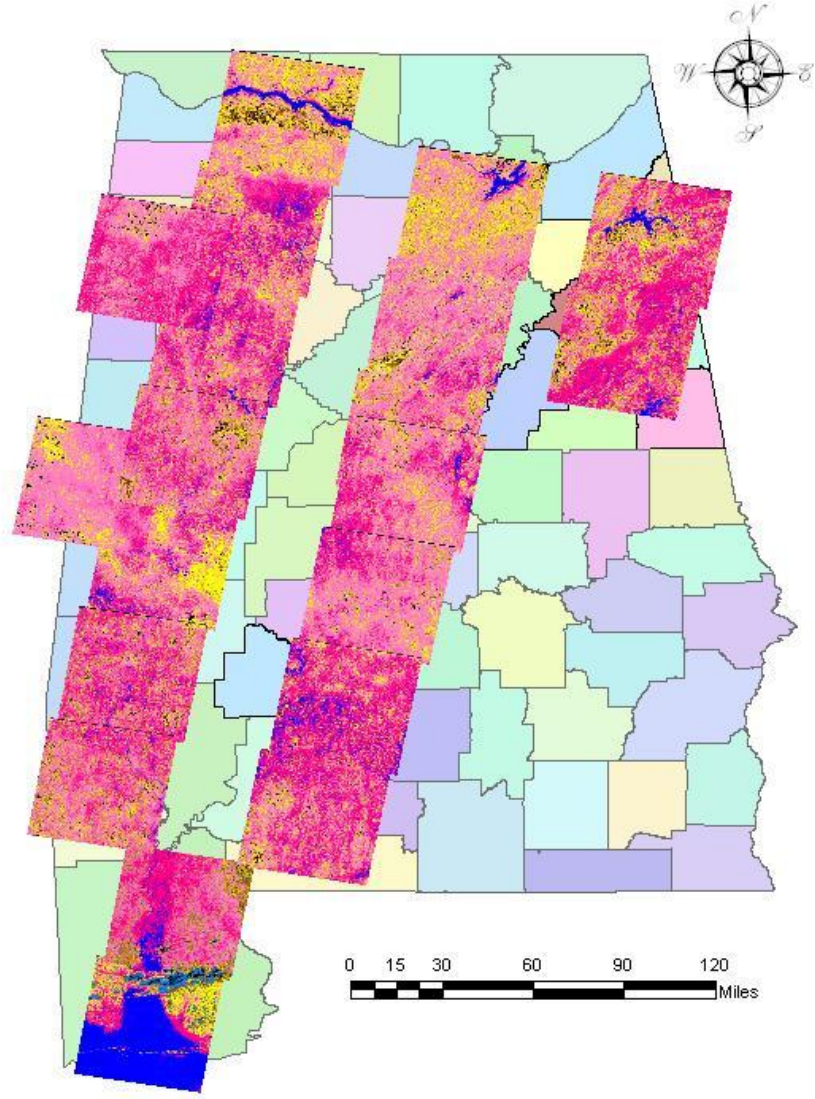
- Creates a ratio between -1 and 1 using the visible and NIR bands
- Helps separate areas with vegetation and those without.
- Can track vegetation vigor.

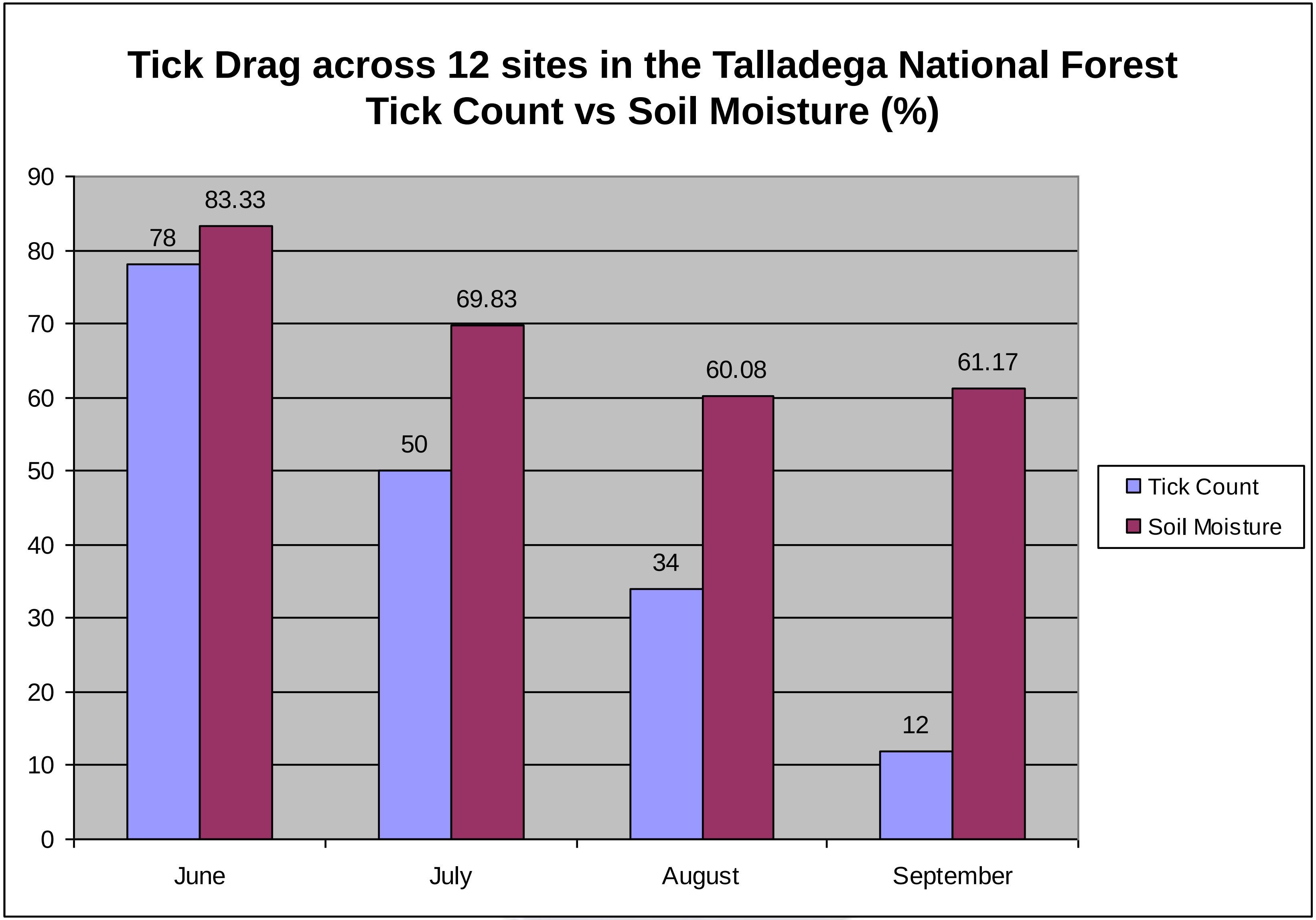
$$\mathrm{NDVI} = \frac{(\mathrm{NIR} - \mathrm{RED})}{(\mathrm{NIR} + \mathrm{RED})}$$



ASTER NDVI and SM





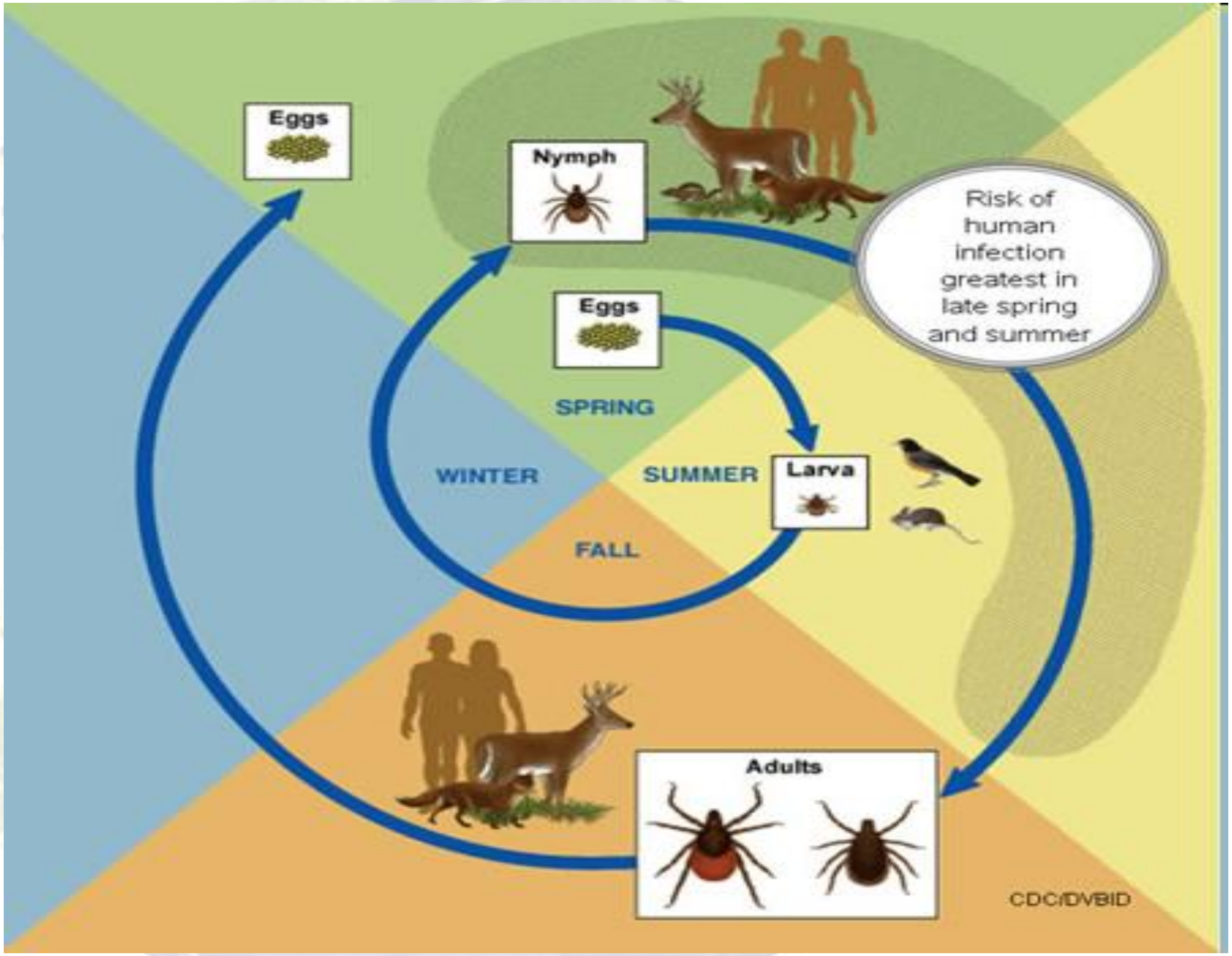

Tick Drag across 12 sites in the Talladega National Forest
Tick Count vs Soil Moisture (%)
90
80
70
60
50
40
30
20
10
0
78
83.33
50
69.83
34
60.08
12
61.17
June
July
August
September
Tick Count
Soil Moisture

Tick Life Cycle

Stages:

Egg
↓
Larva
↓
Nymph
↓
Adult

(2 years)



Limitations

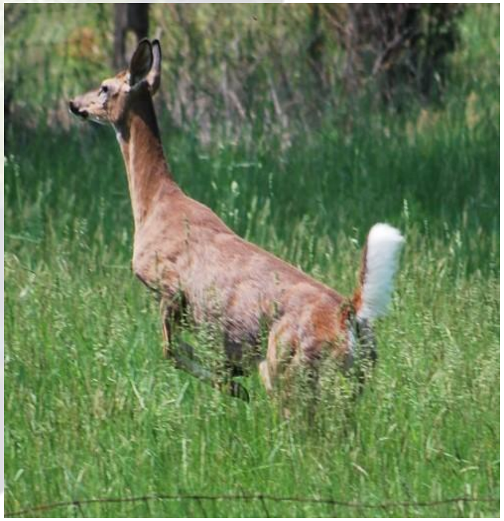
- Small sample size.
- CDC case data does not indicate time of year or location of contraction.
- Vegetation by itself may not be a good indicator of tick presence.
- Need to consider the ecology of the vector and hosts.

Tick Hosts

- Small mammals
  - For larval and nymphal stages

- White-tailed deer
  - For adult stage

- Over 30 types of animals and many species of birds may be hosts



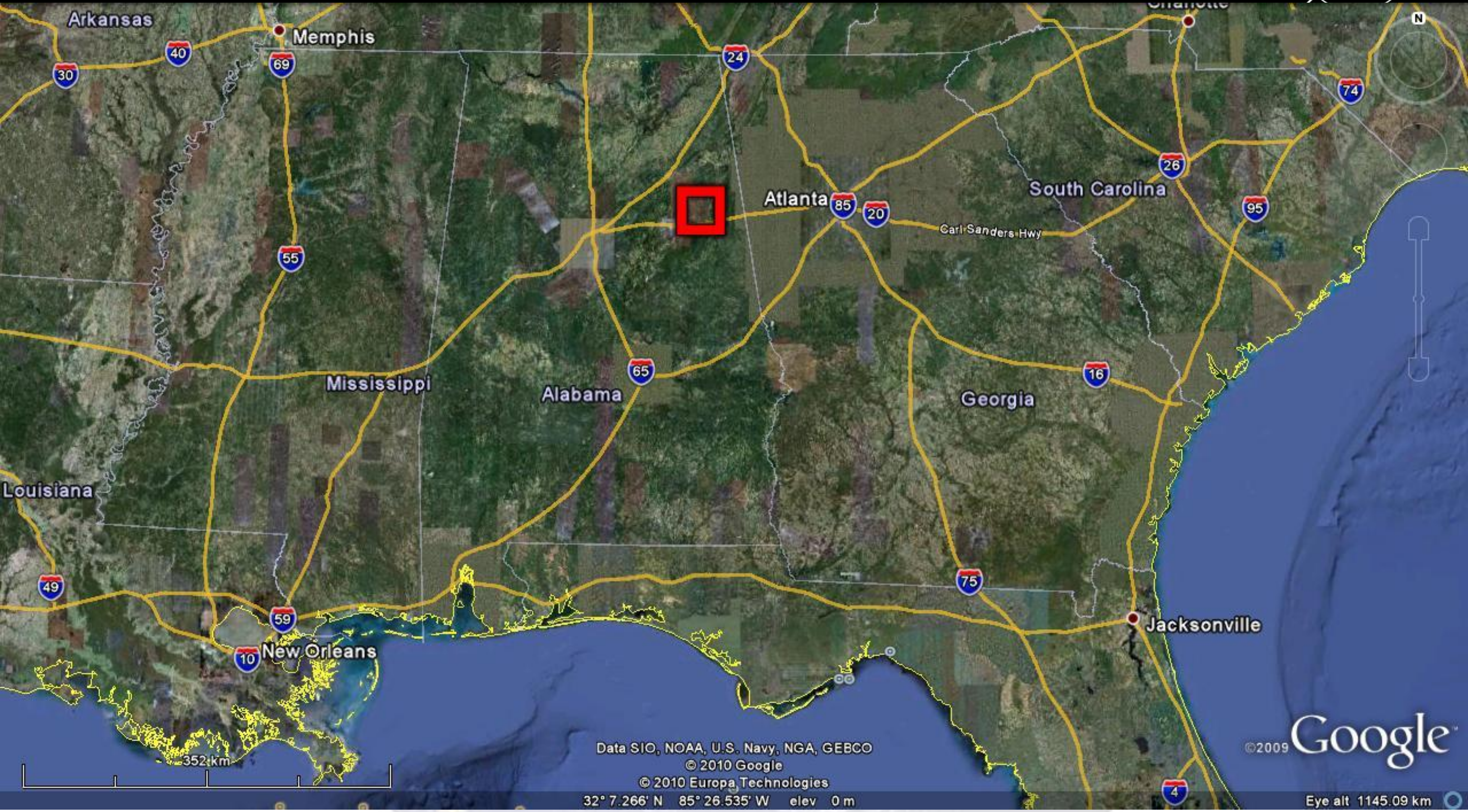
Ecological factors

- What the are the preferred environments of the hosts?

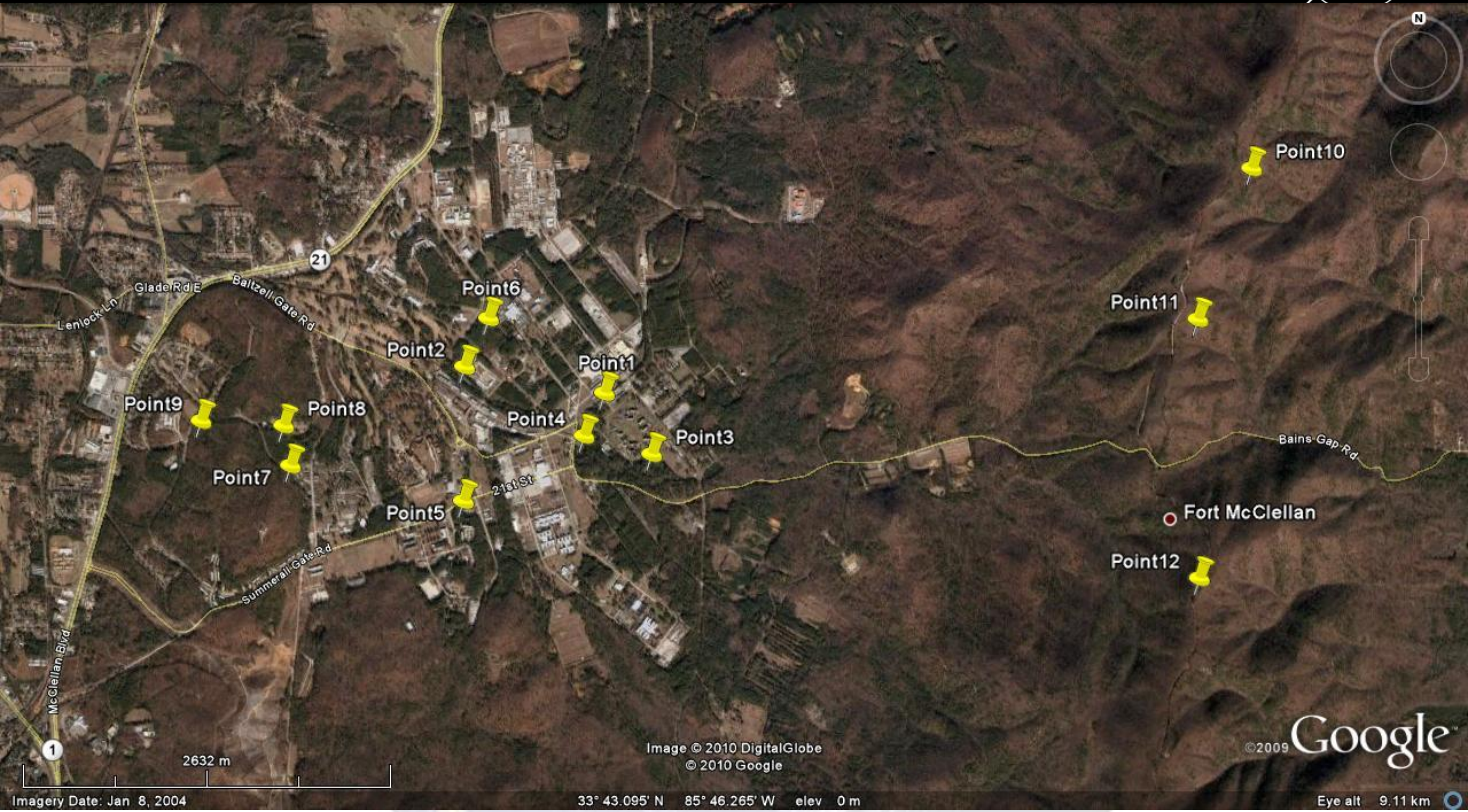
- How can we measure environmental factors through remote sensing?

- How can we explain tick distribution?

Fort McClellan

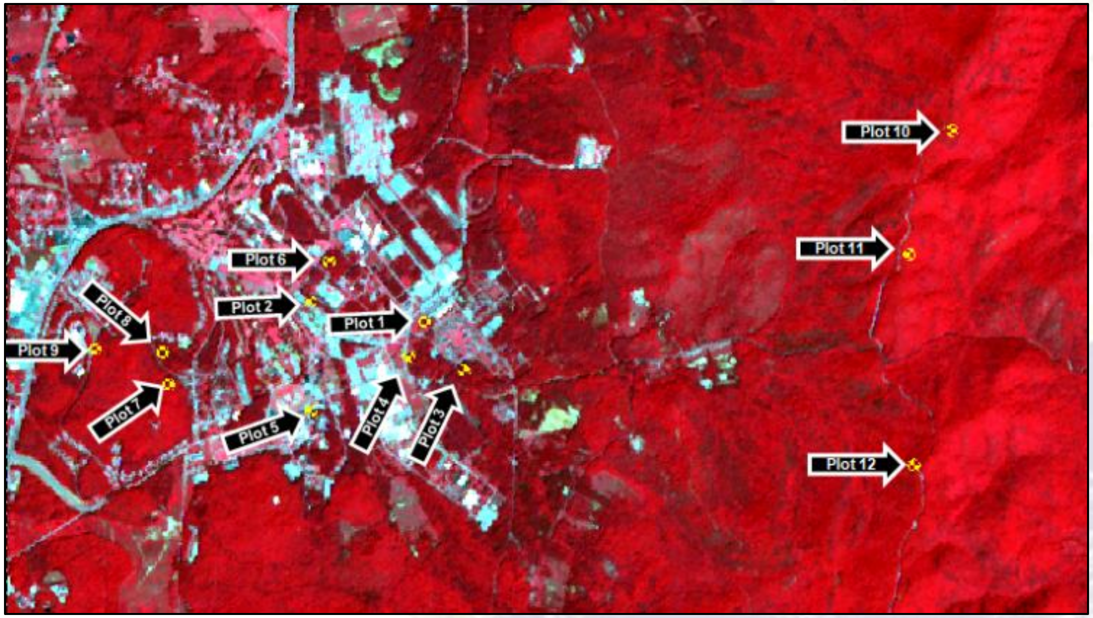


Fort McClellan



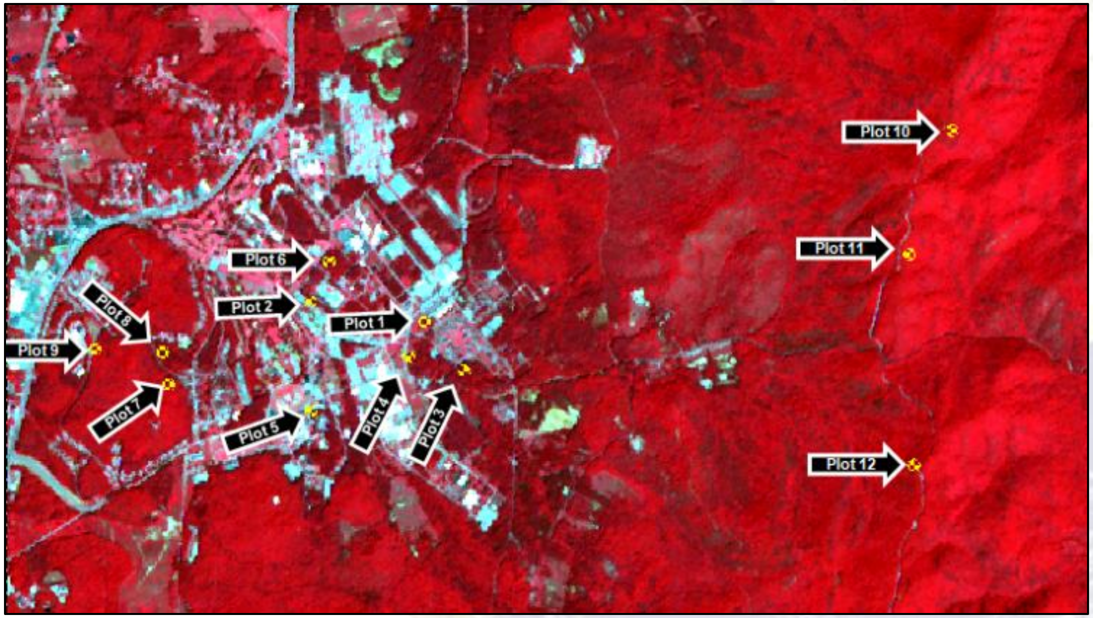
Methodology

ASTER image

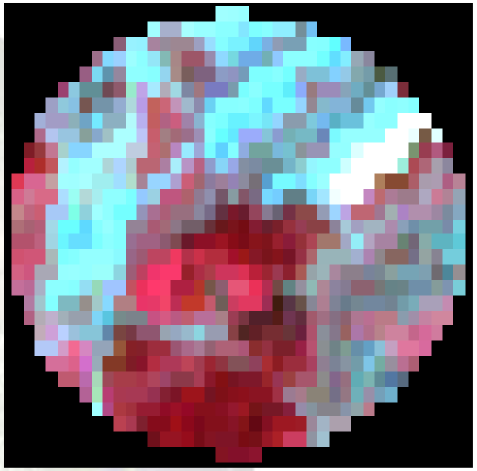


Methodology

Overall ASTER image

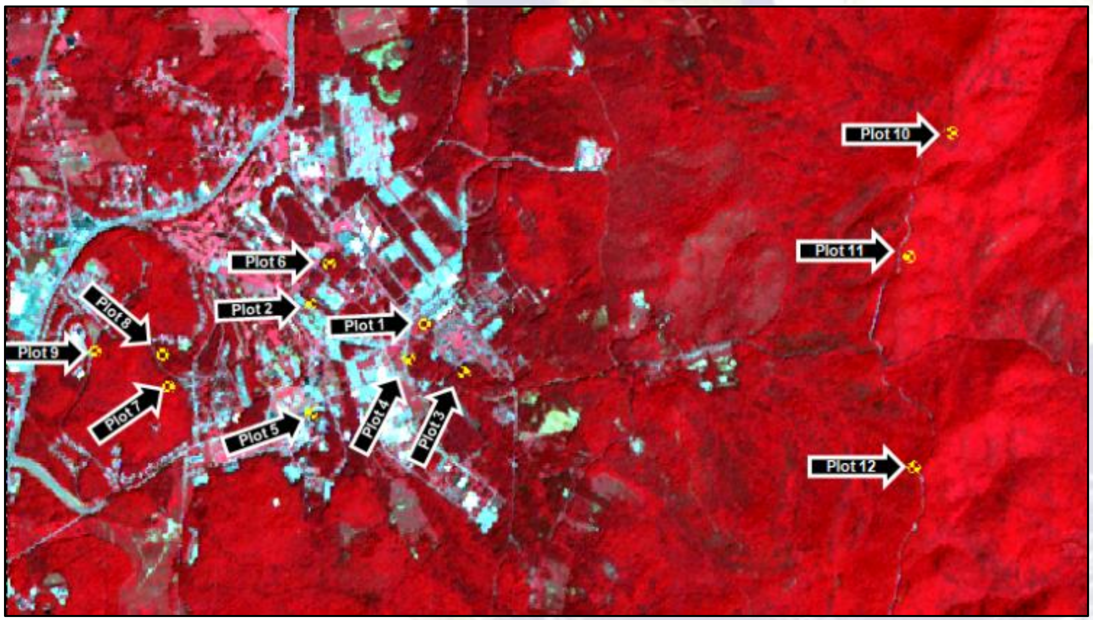


Plot 1 (ASTER)

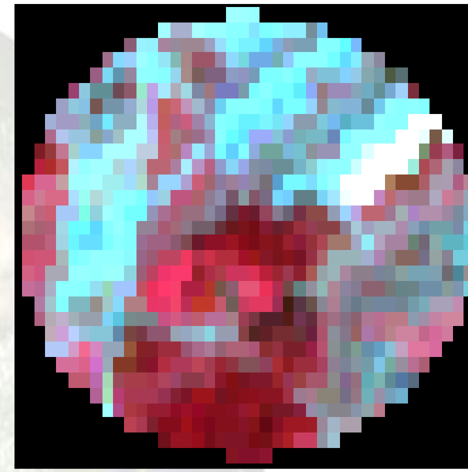


Methodology

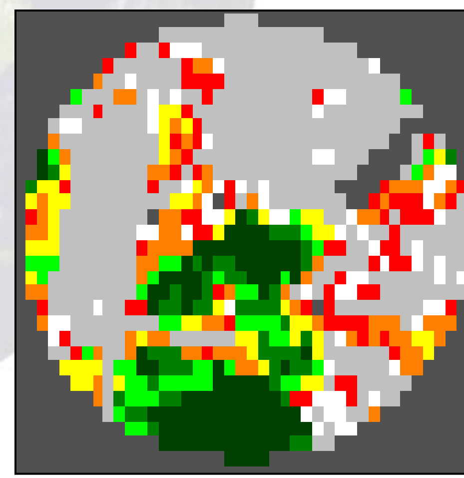
Overall ASTER image



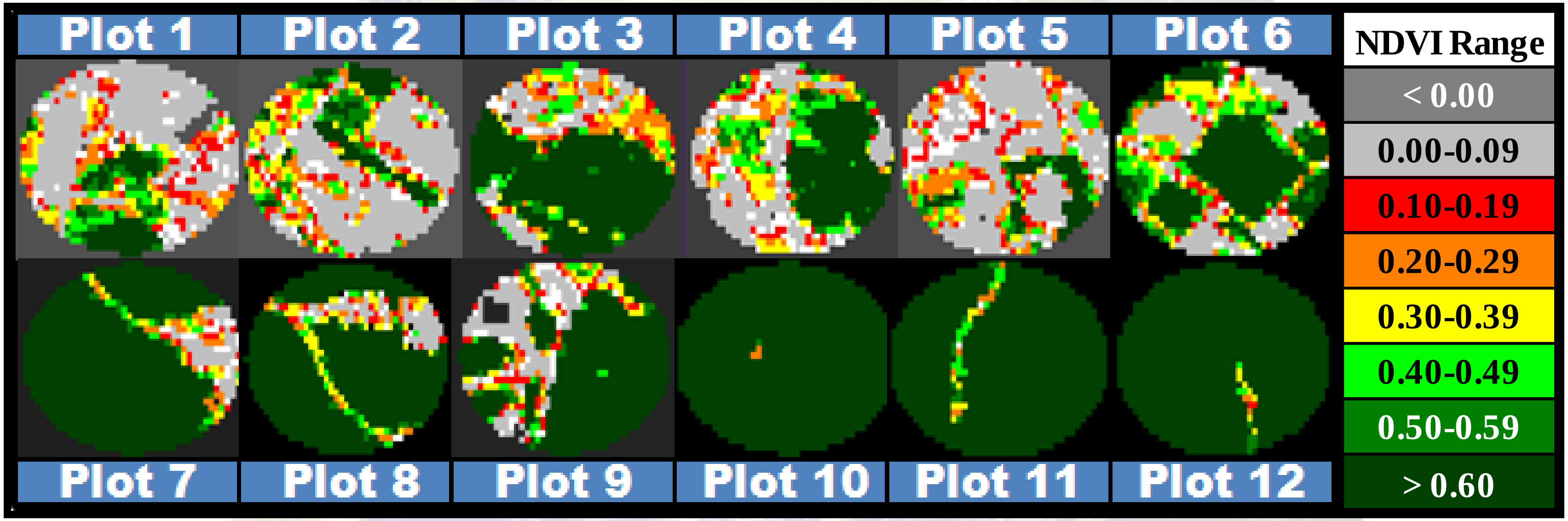
Plot 1 (ASTER)



Plot 1 (NDVI)



Results – % NDVI class: plot detail



Results – Table 1

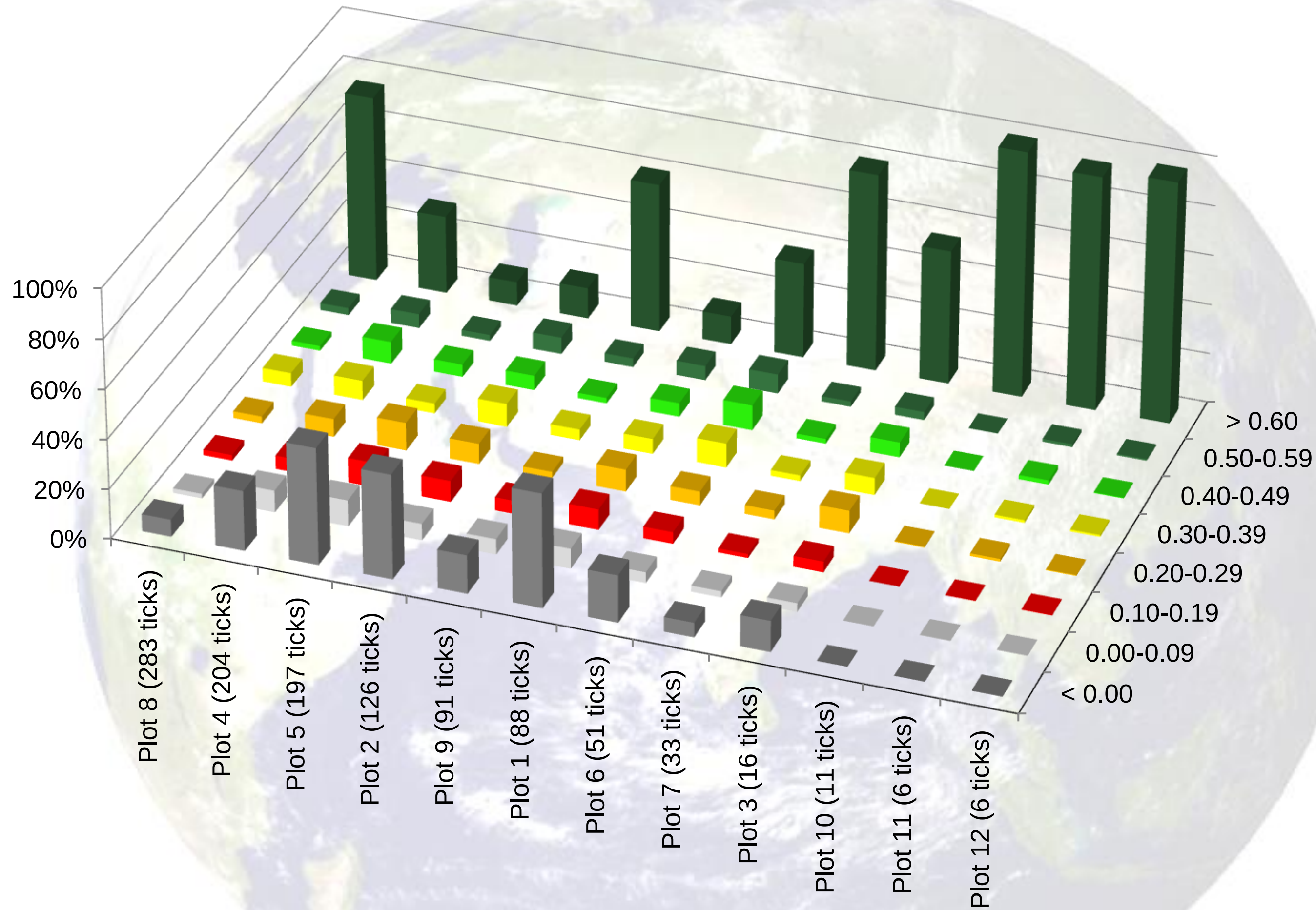
Overall tick density by plot and species

Plot	*Amblyomma americanum N=1095*			*Dermacentor variabilis N=17*			Total
	ALSF	ALSM	LSN	DOG M	DOG F	DOG N	
1	8	7	67	2	3	1	88
2	4	11	108	1	0	2	126
3	1	2	13	0	0	0	16
4	11	17	175	1	0	0	204
5	6	15	172	2	1	1	197
6	8	5	37	1	0	0	51
7	5	3	25	0	0	0	33
8	6	6	271	0	0	0	283
9	8	9	74	0	0	0	91
10	0	2	9	0	0	0	11
11	2	1	2	0	1	0	6
12	0	0	5	0	1	0	6
Total	**59**	**78**	**958**	**7**	**6**	**4**	**1112**

General Conclusions

1) **Difference by species** - ***Abylomma Americanum*** **made up 98.5% of all ticks counted**
2) **Difference by stage of development** - **Nymphal ticks represented 86.5% of the total ticks sampled**
3) **Difference by plot** – **Tick counts ranged by plot from 283 (25% of total) to 6 (>%1 of total)**

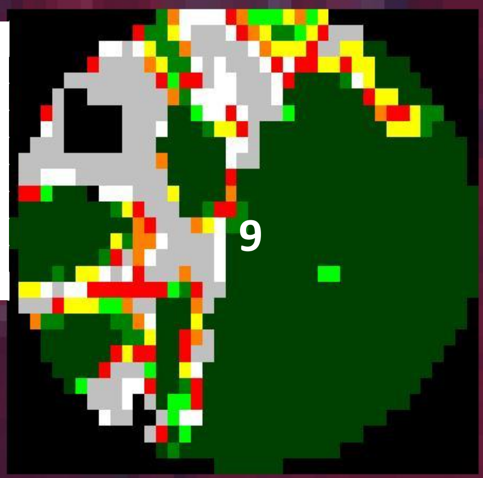
Results – % NDVI class analysis

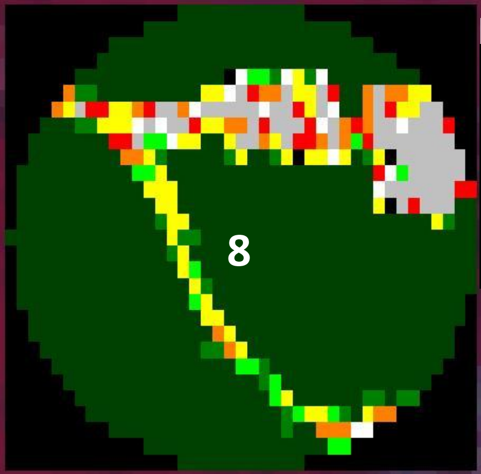


NDVI class proportion by plot sorted by tick count

Results – Integrated image variables

Plot9	Percent
< 0.00	15%
0.00-0.09	6%
0.10-0.19	5%
0.20-0.29	2%
0.30-0.39	4%
0.40-0.49	2%
0.50-0.59	4%
> 0.60	60%
sum=	100%





Plot8	Percent
< 0.00	7%
0.00-0.09	2%
0.10-0.19	2%
0.20-0.29	3%
0.30-0.39	6%
0.40-0.49	2%
0.50-0.59	3%
> 0.60	76%
sum=	100%

	Plot 9			Plot 8	
General	Mean plot digital number	170.3	*General*	Mean plot digital number	155.4
	% NDVI by class	above		% NDVI by class	above
Edge	Patch area (meters^2)	91382.3	*Edge*	Patch area (meters^2)	63711.5
	Distance to nearest edge from centroid (m)	1.6		Distance to nearest edge from centroid (m)	46.2
	Edge length (m)	854.9		Edge length (m)	1217.2
	Edge length/Patch area ratio	0.00002		Edge length/Patch area ratio	0.01910

Results – Image variables by tick count

Plot	Edge length (m)	Patch area (m^2)	Distance to nearest edge (m)	Edge length/ Patch area ratio	Tick density
1	523.52	5747.2	17.19	9.11%	88
2	669.51	7460.5	15	8.97%	126
3	2217.65	107075.1	46.15	2.07%	16
4	1372.8	59244.7	8.97	2.32%	204
5	432.44	3863.8	15	11.19%	197
6	1241	43837.1	58.29	2.83%	51
7	1346.49	156,744	58.59	0.86%	33
8	1217.2	63711.5	46.24	1.91%	283
9	854.86	91382.3	1.61	0.94%	91
10	153.55	199610.57	55.65	0.08%	11
11	1185.9	188249.8	77.27	0.63%	6
12	655.55	198277.6	33.81	0.33%	6

atio 0.00002 Edge length/Patch

Conclusions

- Tick density inversely associated with plots where > 90% of all area is over NDVI of 0.60.
- Satellite remote sensing can identify environmental factors associated with likely tick habitats.

- What is the next step?
  - Statistical analysis to be performed.
  - RT-PCR
  - Initial findings: forest fragmentation, the theory of island biogeography, and meta population dynamics to be explored.
  - Risk Perception survey created and awaiting IRB approval

Transition to Partner

Partners:

Alabama Department of Health
Birmingham Lyme
Camp Coleman

Benefits to Partner

- Identified high risk areas
  - Map of high risk areas
- Camp Coleman
  - 5 presentations on prevention and treatment
  - Reached approx 40-50 campers each session

Project Transition Plan

- Best practices document
  - Document can be used as a guide for continued outreach at Camp Coleman or as a basis for new effort by Birmingham Lyme and the Alabama Department of Health

Outreach


CAMP COLEMAN
Bus/Equestrian
Center
Entrance
FIRE/RESCUE
ACCREDITED

MSFC/UAB Team Members Summer 2009-Fall 2010

- Joshua Harden, B.S.
- Joe Olson
- Connor Whitley
- Michael Behring, M.S.
- Taylor Poston, M.P.H.
- Damien Willis, M.S.
- Jonathan Adams, M.S.
- Rusty Nall, B.S.
- Stephen L. Firsing III, M.P.A., M.A.
- Emily G. Capilouto
- Robyn Hyden, B.A.
- Kathryn Jackson
- Kyle Levy, M.S.
- Marilyn McAllister, M.S.

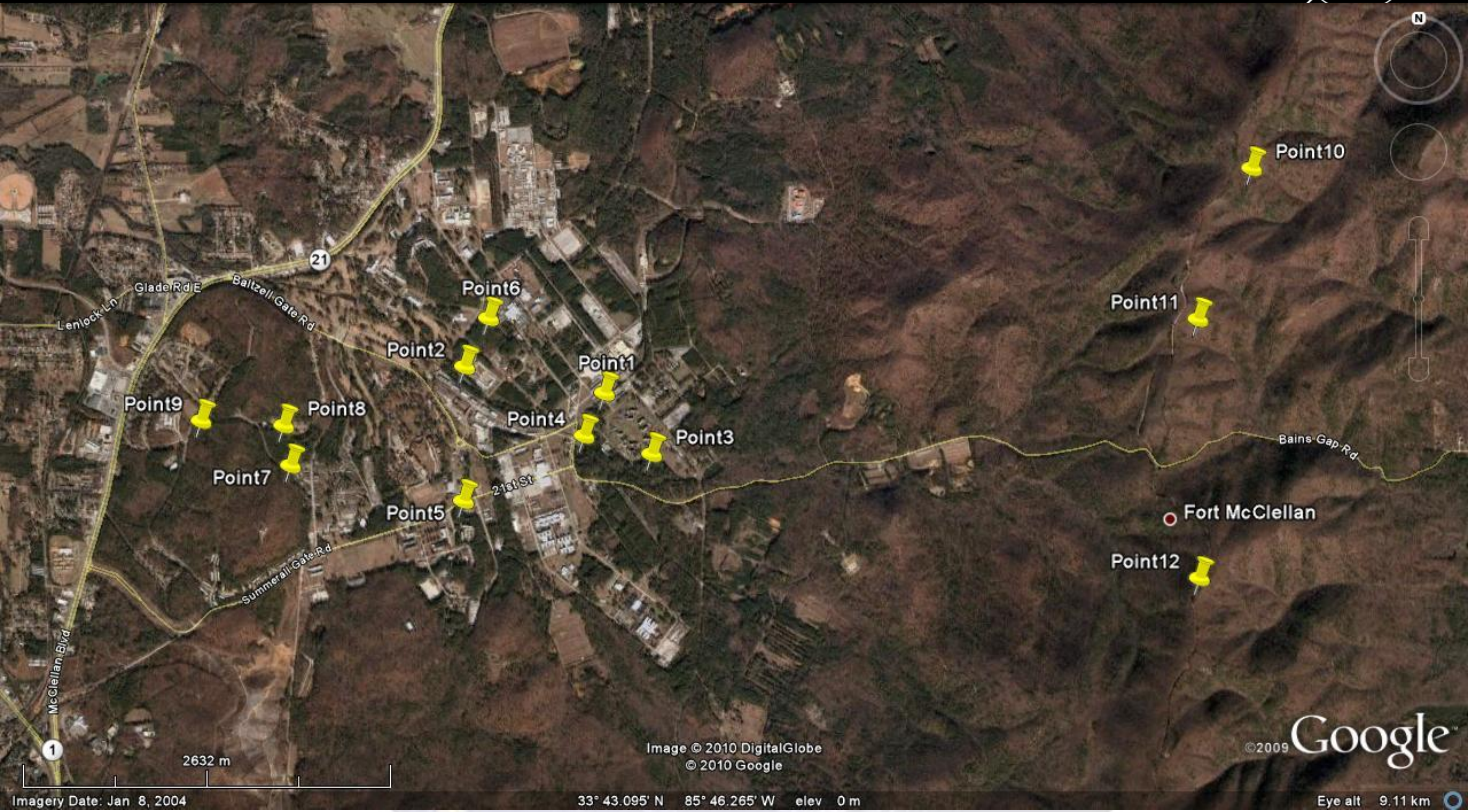
Foreign Nationals

- Steve Padgett-Vasquez, M.S. (Honduras)
- Jin Huang, B.S. (China)
- Nathan Renneboog, B.S. (Belgium)
- Sarah Hemmings, M.S. (Canada)
- Meghan Tipre, B.D.S. (India)
- Zhang Yan, M.P.H. (China)
- Kathryn Roa, M.D. (Philippines)
- Shveta Setia, B.D.S. (India)
- Lili Xie, M.D. (China)

Adivsors

- Dr. Jeffrey C. Luvall- NASA MSFC Advisor
- Dr. Sarah H. Parcak- LGHO Director
- Dr. Donna Burnett- Science Advisor

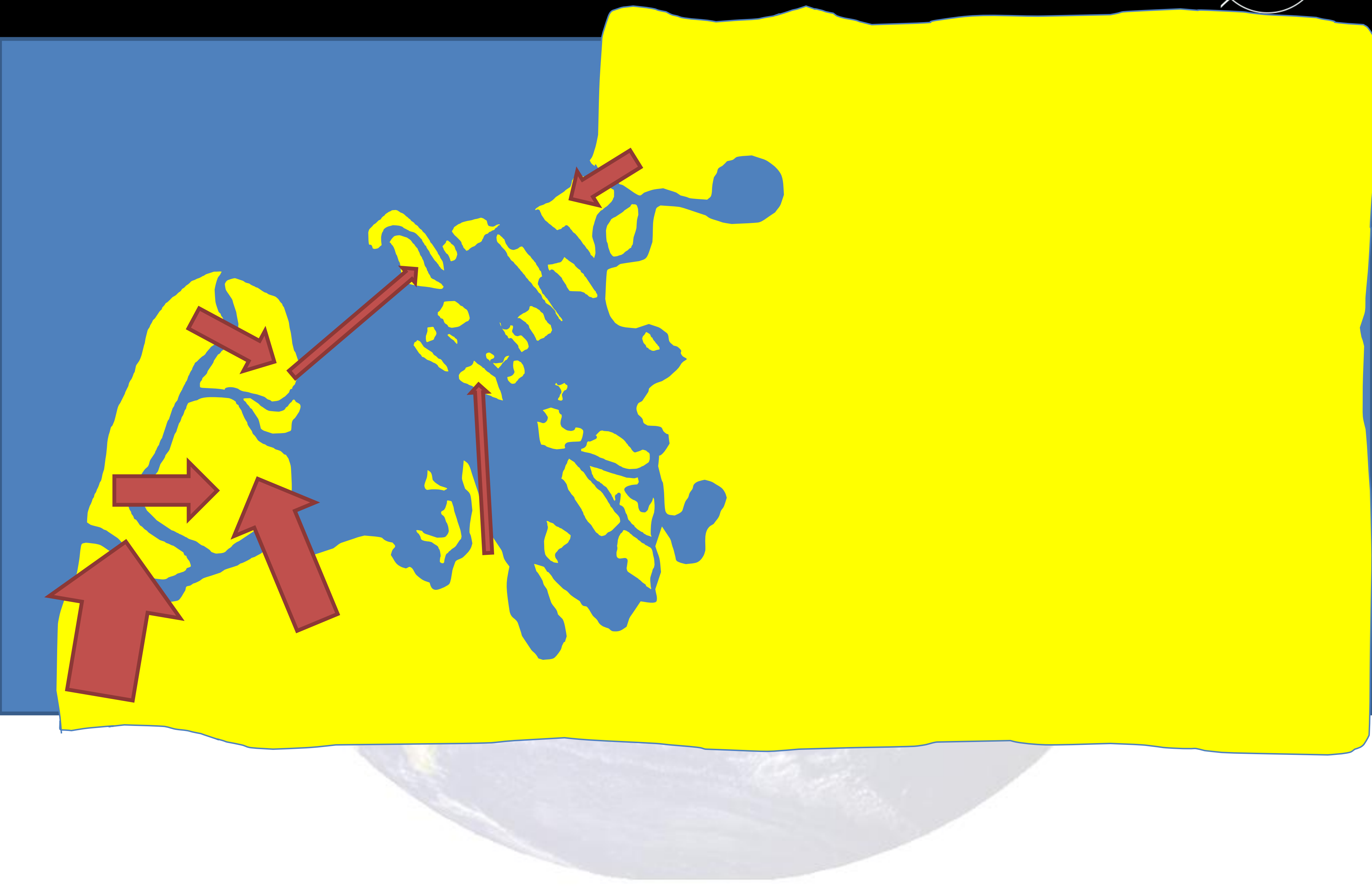
Fort McClellan



Fort McClellan

Island Biogeography

Island Biogeography



Results - 500 m diameter NDVI plots