Remote Sensing of Regenerating Vegetation

LBA-ECO

October, 2006

Plan for today's meeting

1. Brief look at what's been done
2. Resolve definitional issues
3. Identify gaps in research (geographical coverage, approaches, questions that remain unanswered)
4. Construct a plan of future work

Synthesis Products

a) Comprehensive review paper
   - Modeled on D. Lu's RS of Biomass paper
b) Methodologically consistent multi-site estimates of extent and persistence of regenerating vegetation
   - Modeled on D. Zarin et al. biomass accumulation paper

Regenerating vegetation

- geographical extent
- rate of change
  - rate of agriculture abandonment
  - persistence

There are several studies that provide these types of estimates, BUT can we do it in a across sites in a methodologically consistent way?

Remote sensing of regenerating vegetation: Sample of studies

- Mausel et al. 1993
- Li et al 1994
- Moran et al. 1994
- Skole et al. 1994
- Foody and Curran, 1994
- Sant'Anna et al. 1995
- Alves and Skole, 1996
- Steininger, 1996
- Bohlman et al. 1998
- Kimes et al. 1999a
- Kimes et al. 1999b
- Steininger, 2000
- Nelson et al. 2000
- Salas PhD chapter 2000
- Lucas et al. 2000
- Lucas et al. 2002a
- Lucas et al. 2002b
- Roberts et al. 2002
- Alves et al. 2003
- Vieira et al. 2003
- Batistella et al. 2003
- Foody et al. 2003 (transferability of refl. biomass models)
- Lu et al. 2003
- Lu et al. 2004
- Perz and Skole, 2004
- Steininger 2004
- Hirsch et al. 2004
- Arroyo-Mora et al. 2005
- Freitas et al. 2005
- Ferraz et al. 2005
- Morton et al. 2006
- Broadbent et al. 2006 (selective logging recovery)
- Carreiras et al. 2006

Sample of studies

- Provide explicit **definition** of regenerating vegetation: 52% (17 of 33)
  - Common Definition: Secondary vegetation are those areas that have been abandoned and that have become re-vegetated after all or a significant portion of the original forest has been removed.
- Three basic types of studies:
  - Single date information extraction (19)
  - Time series of land cover transitions (7)
  - Regional mapping (3)

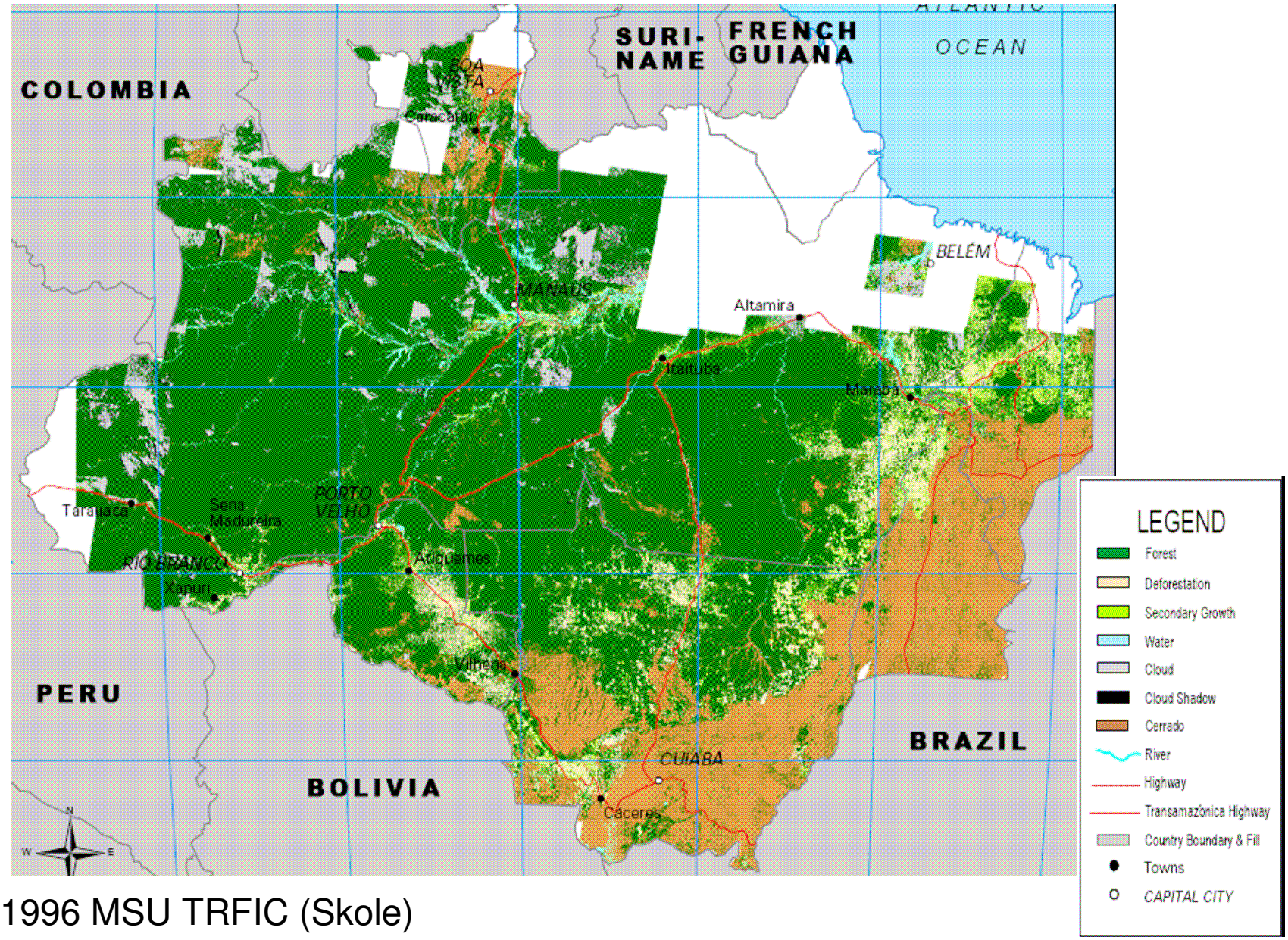
Sample of studies: Information extracted

- **Single Date Characterization** of regenerating vegetation:
  - Continuous Structure, such as biomass (7 of 19)
  - Discrete Stage, usually three stages (9 of 19)
  - Age (4 of 19)
  - Species or Regeneration Pathway (2 of 19)
- **Time series** of images
  - Land cover transitions (6 of 7)
  - Persistence of regenerating vegetation (2 of 7)
  - Patterns (e.g. proximity to highways) (4 of 7)

Sample of Studies: Extent and Persistence

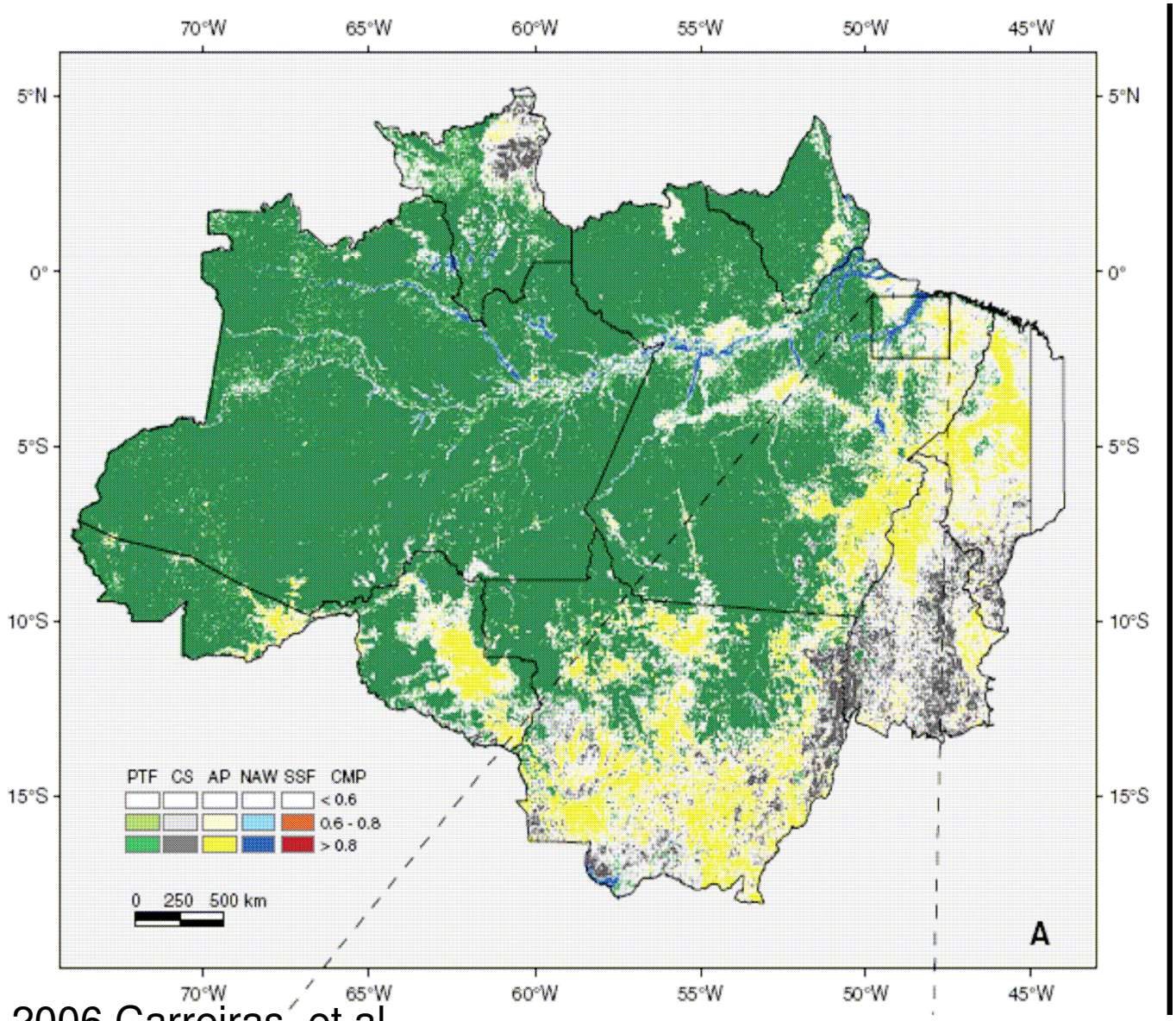
- Basin wide estimates (~150,000 km^2?)
  - Lucas et al., (2000): 35.8% of cleared lands prior to 1992
    - Combines AVHRR analysis with INPE estimates of cleared lands
  - Fearnside (1996): 47%
- Regional variability
  - The amount of cleared land in second growth varies considerably
  - Moran et al. (1994): Western Altimira, 46% (1985), 82% (1991)
  - Skole et al. (1994): Rondonia, 30%
  - Roberts et al., (2002): Rondonia, 22%
  - Ballester et al. (2003): Jiparana Basin, ~ 11%
- Persistence
  - Rarely quantified, but probably varies regionally
  - Skole et al., (1994): Second growth rarely persists 7 years in Rondonia.

Extent of regenerating vegetation

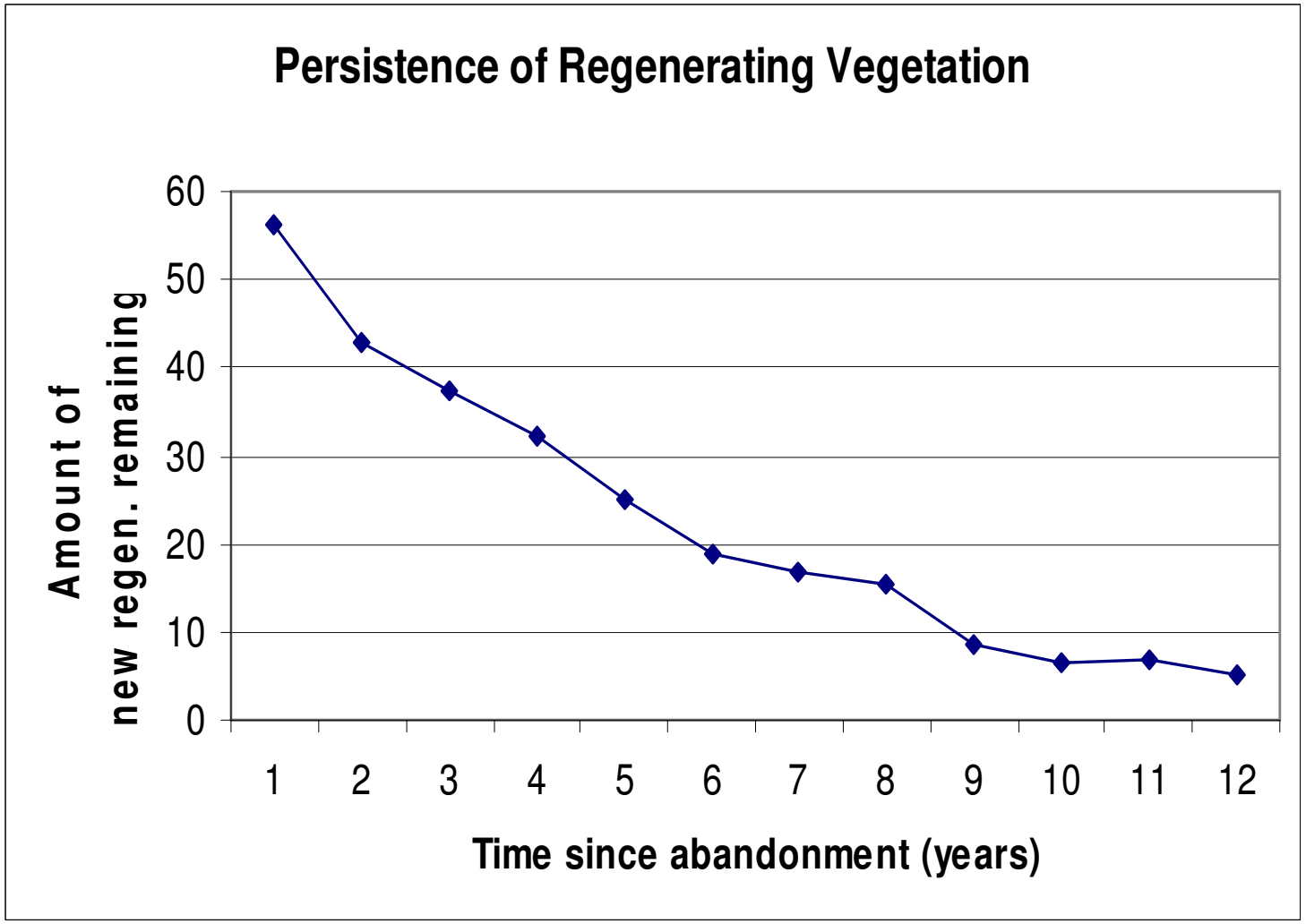


1996 MSU TRFIC (Skole)

Extent of regenerating vegetation



From 2006 Carreiras, et al.



From W.A.Salas, PhD Thesis. Averaged from three sites in Amazonia.

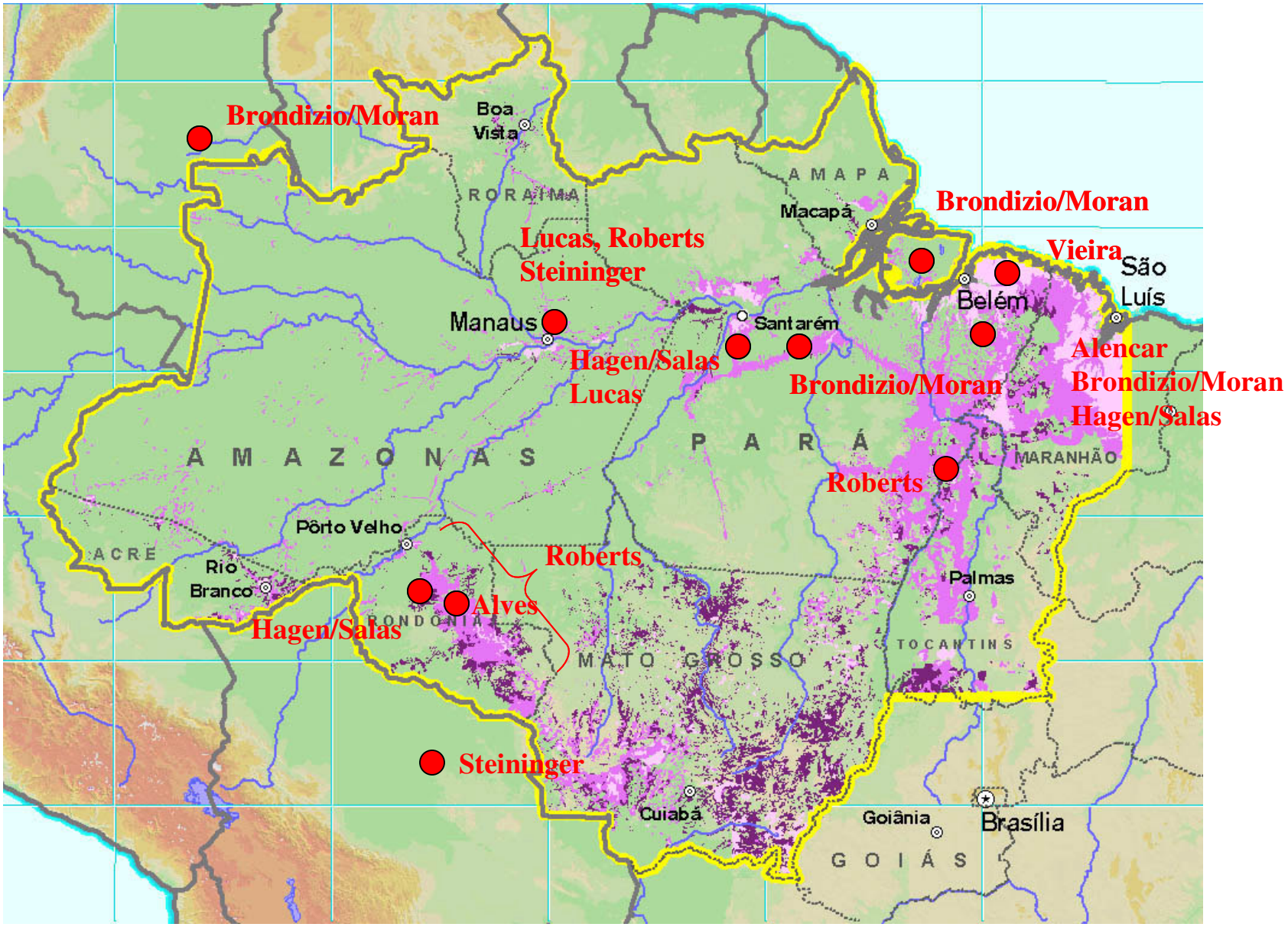
Preliminary survey results

Respondent #	1	2	3	4	5	6	7	Total
Survey Category								
RS Pre-Processing								
Atmospheric Correction			✓	✓	✓	✓	✓	**5 of 7**
Radiometric Normalization			✓	✓		✓	✓	**4 of 7**
RS Areal Measures								
SG Extent	✓	✓		✓	✓	✓	✓	**6 of 7**
Ratio SG/Cleared Lands	✓	✓		✓	✓	✓	✓	**6 of 7**
RS Biophysical Properties								
LAI					✓			**1 of 7**
APAR								**0 of 7**
F_c (fractional cover)			✓	✓		✓	✓	**4 of 7**
Biomass			✓	✓	✓		✓	**4 of 7**
Height			✓	✓		✓		**3 of 7**
Other							**Age**	**N/A**
RS Temporal Measures								
SG Age	✓	✓	✓	✓	✓	✓	✓	**All**
SG Successional State	✓	✓	✓	✓	✓			**5 of 7**
SG Persistence		✓		✓		✓		**3 of 7**
Field Surveys/Interviews								
Time since initial disturbance	✓	✓	✓	✓	✓	✓	✓	**All**
Cropping/pasture history	✓	✓	✓	✓	✓			**5 of 7**
Frequency of disturbance			✓	✓	✓	✓		**4 of 7**
Burn History	✓		✓	✓	✓	✓		**5 of 7**
SG Field Data								
Age	✓	✓	✓	✓	✓		✓	**6 of 7**
Stand Size	✓	✓	✓	✓	✓			**5 of 7**
Stand Shape	✓		✓	✓	✓			**4 of 7**
DBH	✓	✓	✓	✓	✓		✓	**6 of 7**
Tree Height	✓	✓	✓	✓	✓		✓	**6 of 7**
Tree Density			✓	✓	✓		✓	**4 of 7**
Species composition	✓	✓	✓	✓	✓		✓	**6 of 7**
Biogeochemical measures			✓					**1 of 7**

Respondent Key:

#1. Ane Alencar & Ima Vieira	IPAM
#2. Diogenes Alves	Instituto Nacional De Pesquisas Espaciais
#3. Eduardo Brondizio	Indiana University
#4. S. Hagen & W. Salas	University of New Hampshire, Applied Geosolutions, LLC
#5. Richard Lucas	University of Wales, Aberystwth
#6. Dar Roberts	UC Santa Barbara
#7. Marc Steininger	Conservation International

Study Locations



What is missing?

- Site level estimates of **persistence** (fluxes):
  - regenerating vegetation
  - pasture/agriculture
- Since gaps in annual time series of Landsat are common, estimation of **regeneration stage** is useful. Can we find a method that is **transferable** in space & time?
- Updated map of regenerating forest **extent** (pool).

Proposal

1. Consolidate image data from participating groups (3-10 geographic locations; time series)
   a) Geo-registered
   b) Radiometrically calibrated
   c) Atmospherically corrected (?)
2. Classify imagery
   a) Apply consistent methodology (mixture modeling or maximum likelihood)
   b) Include successional stages (?)
3. Identify persistence (rates of change) in stands of regenerating vegetation

Points of Discussion

- Definition of regenerating vegetation
- Successional stages
- Persistence (Time series of Landsat)
- Pasture/Regenerating confusion
- Regenerating/Mature confusion
- Common methodology
  - Mixture modeling vs. maximum likelihood
- Scaling up to Basin/Legal Amazon
  - Landsat (Asner) vs. MODIS (Carreira)

Definition of Regenerating Vegetation

- Swidden agriculture?
- Dirty pasture?
- Structurally complex regenerating forest?

Successional stages

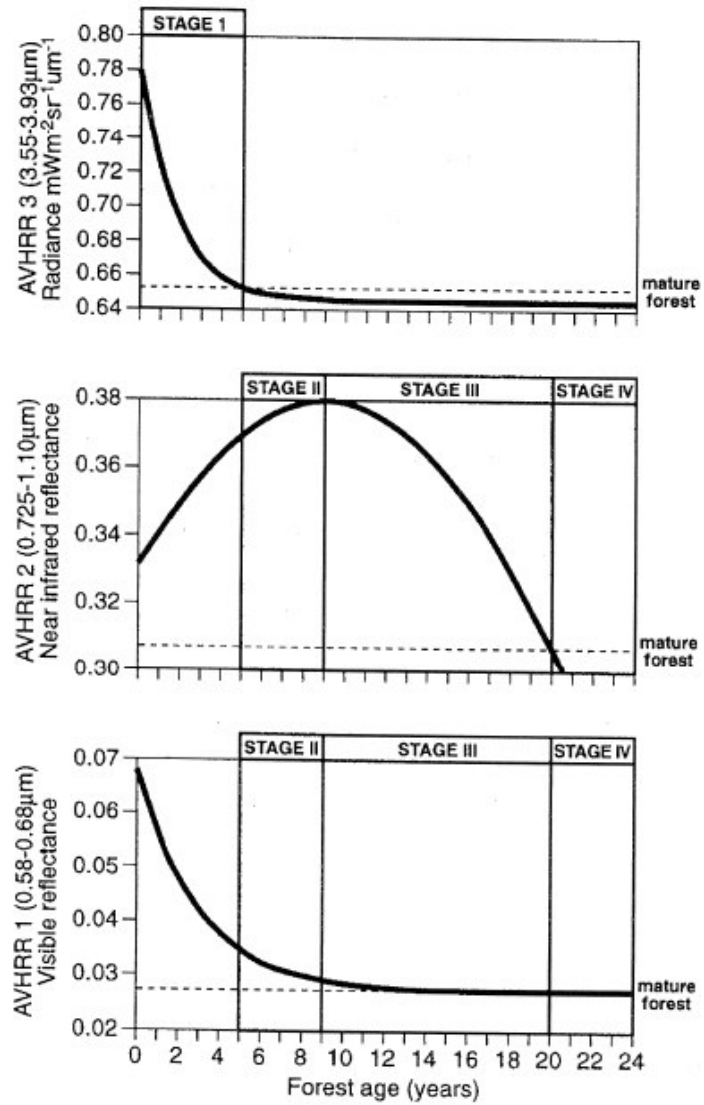
- Two, three, or four stages?
- Spectral or structural information?

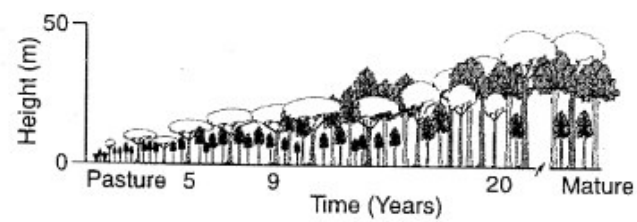
Successional Stages

Conceptual diagram relating biomass recovery (Bormann and Likens 1979) to forest structural stages (Oliver 1981) following disturbance.

Successional Stages

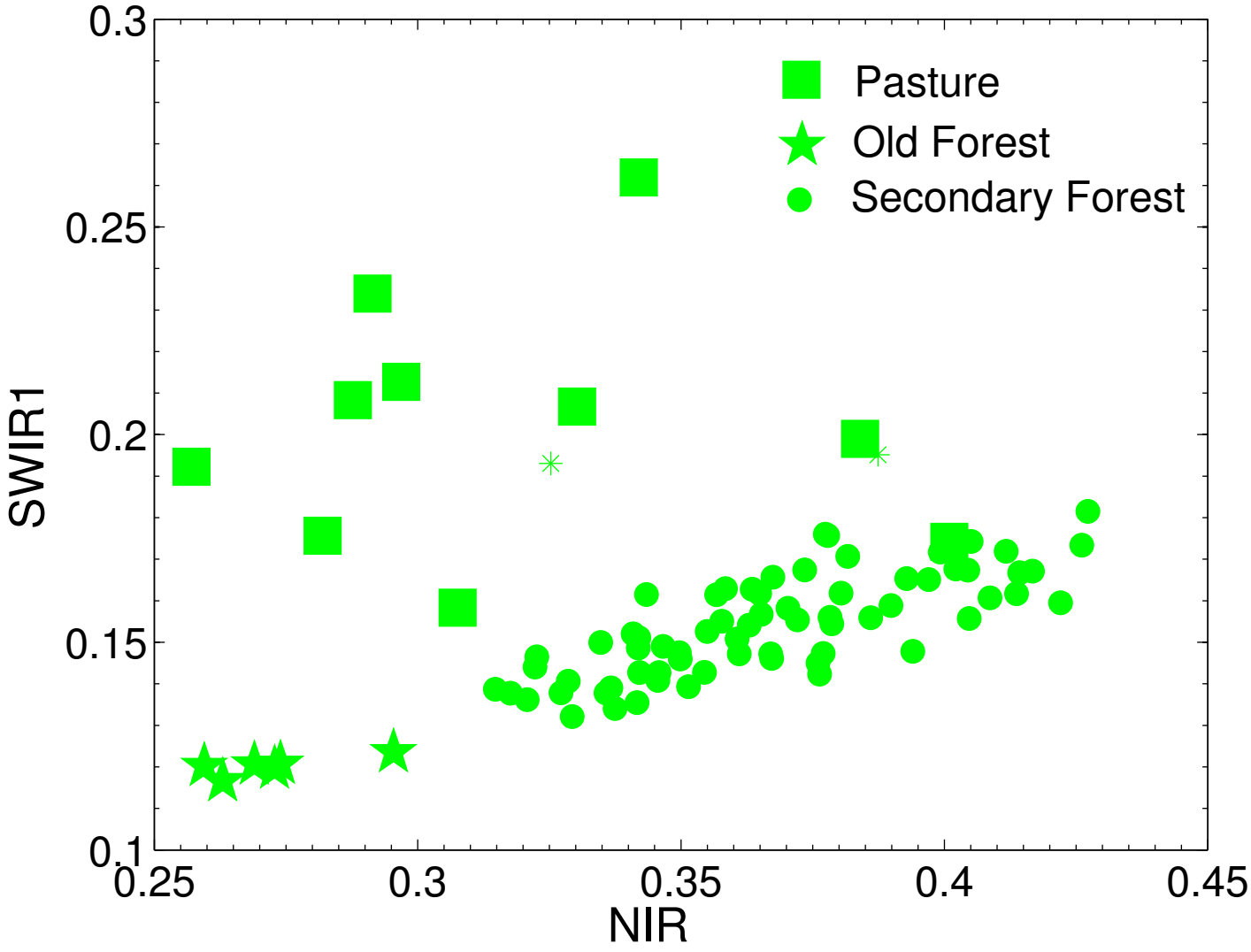
	Visible Reflectance	NIR Reflectance	MIR Reflectance
Pasture/crop areas*	High	Variable, < SS1	High (dry soils)
SS1	Moderate	High	Moderate
SS2	Moderate, higher green/red ratio	Moderate	Low-Moderate
SS3	Low, with higher green/red than SS1, SS2	Low	Low
Mature Forest	Low	Lowest	Lowest

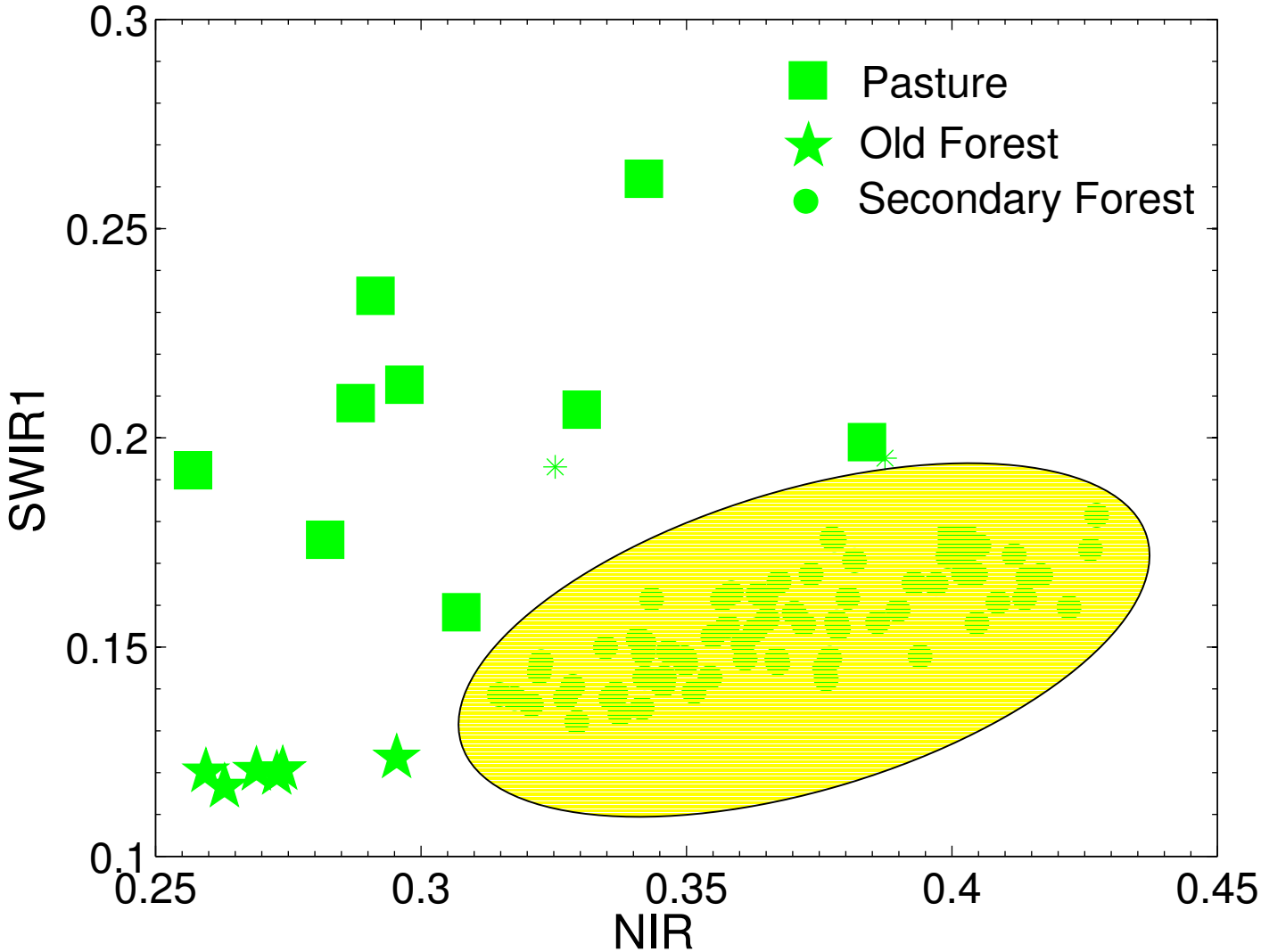




Model transferability

- If we are to have a cross-site study, we need:
  - consistency in definitions and methods
  - methods that are less sensitive to atm. correction, seasonality, etc.


Pasture
Old Forest
Secondary Forest
SWIR1
NIR
0.3
0.25
0.2
0.15
0.1
0.25
0.3
0.35
0.4
0.45


Pasture
Old Forest
Secondary Forest
SWIR1
NIR
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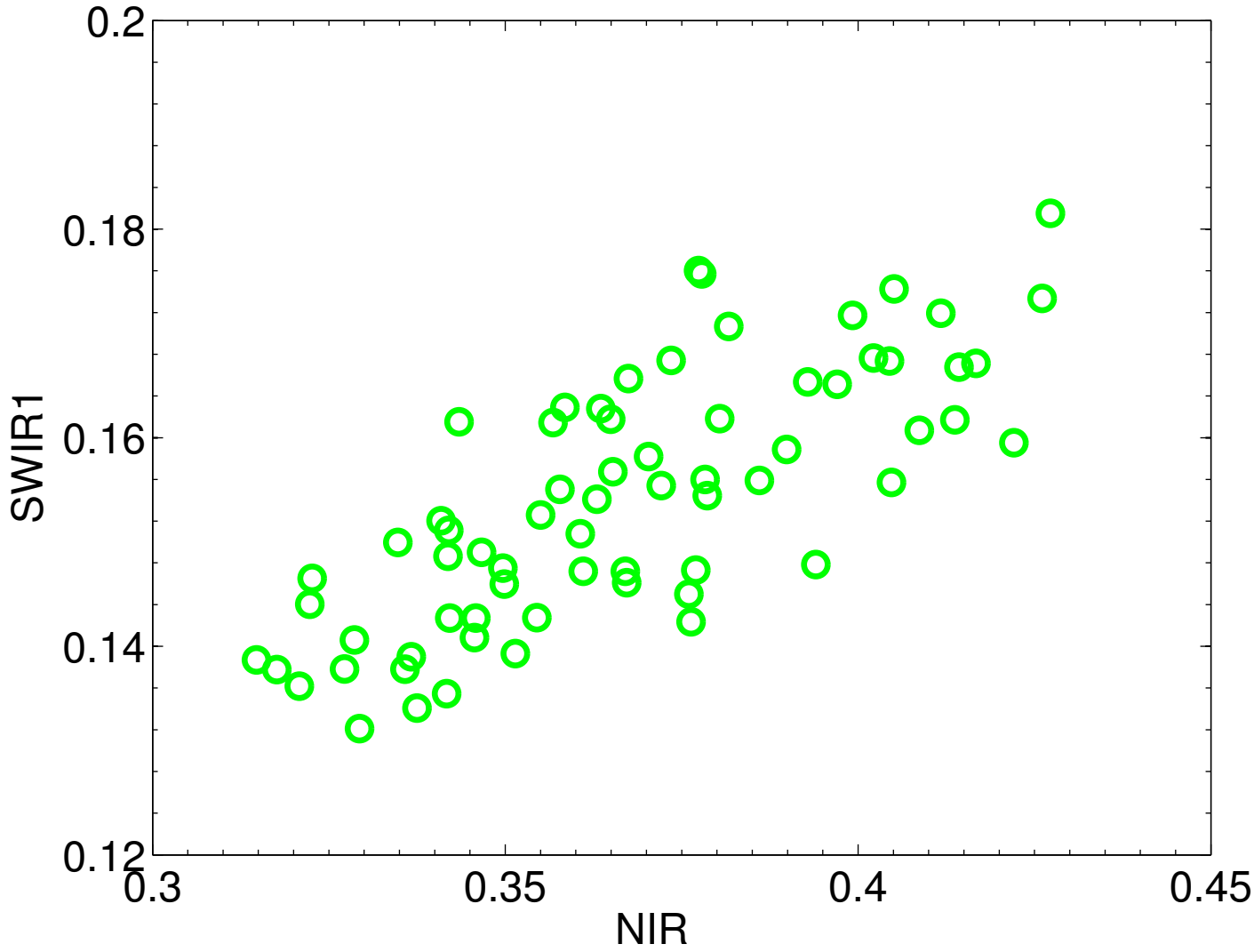
0.2
0.18
0.16
0.14
0.12
SWIR1
0.3
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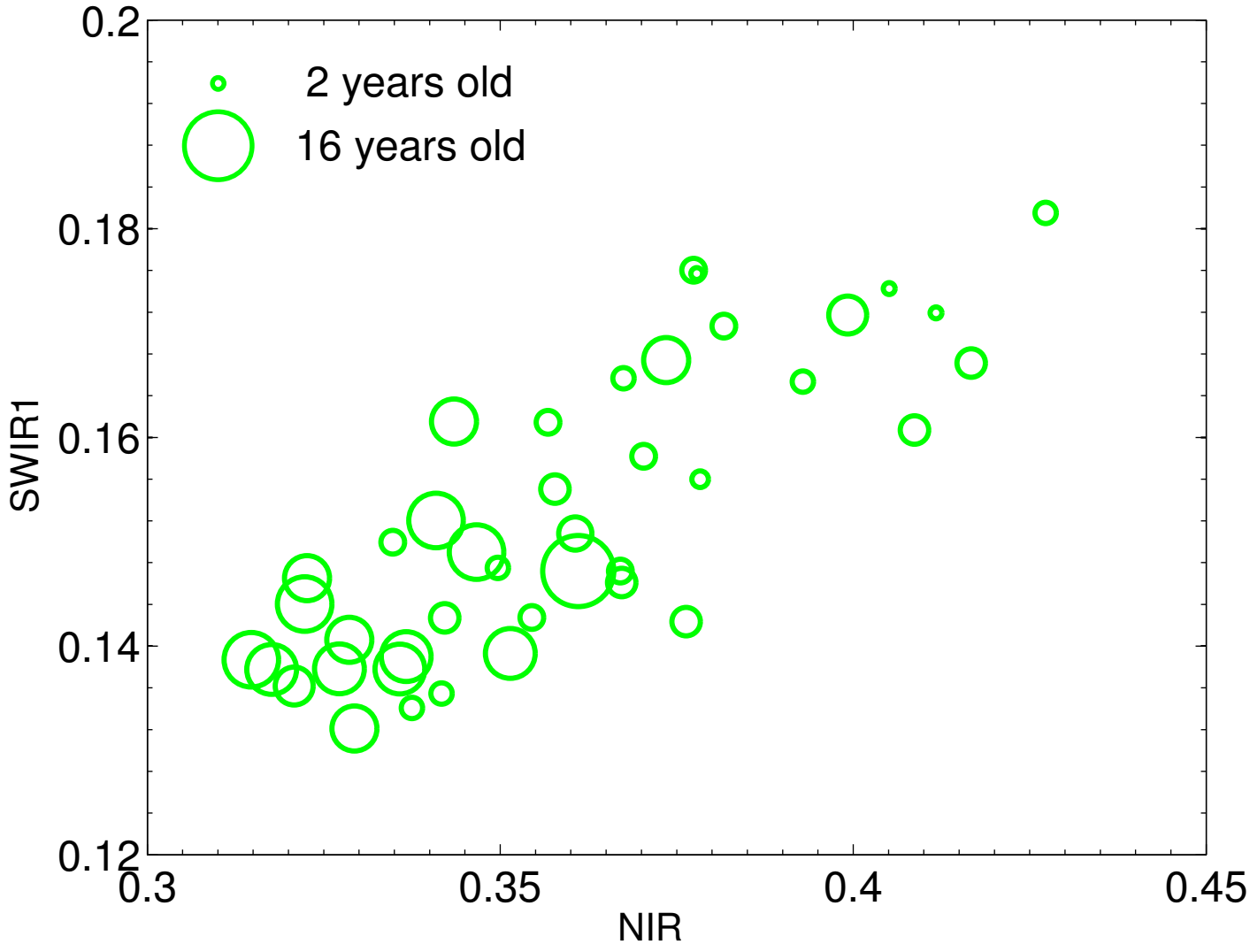
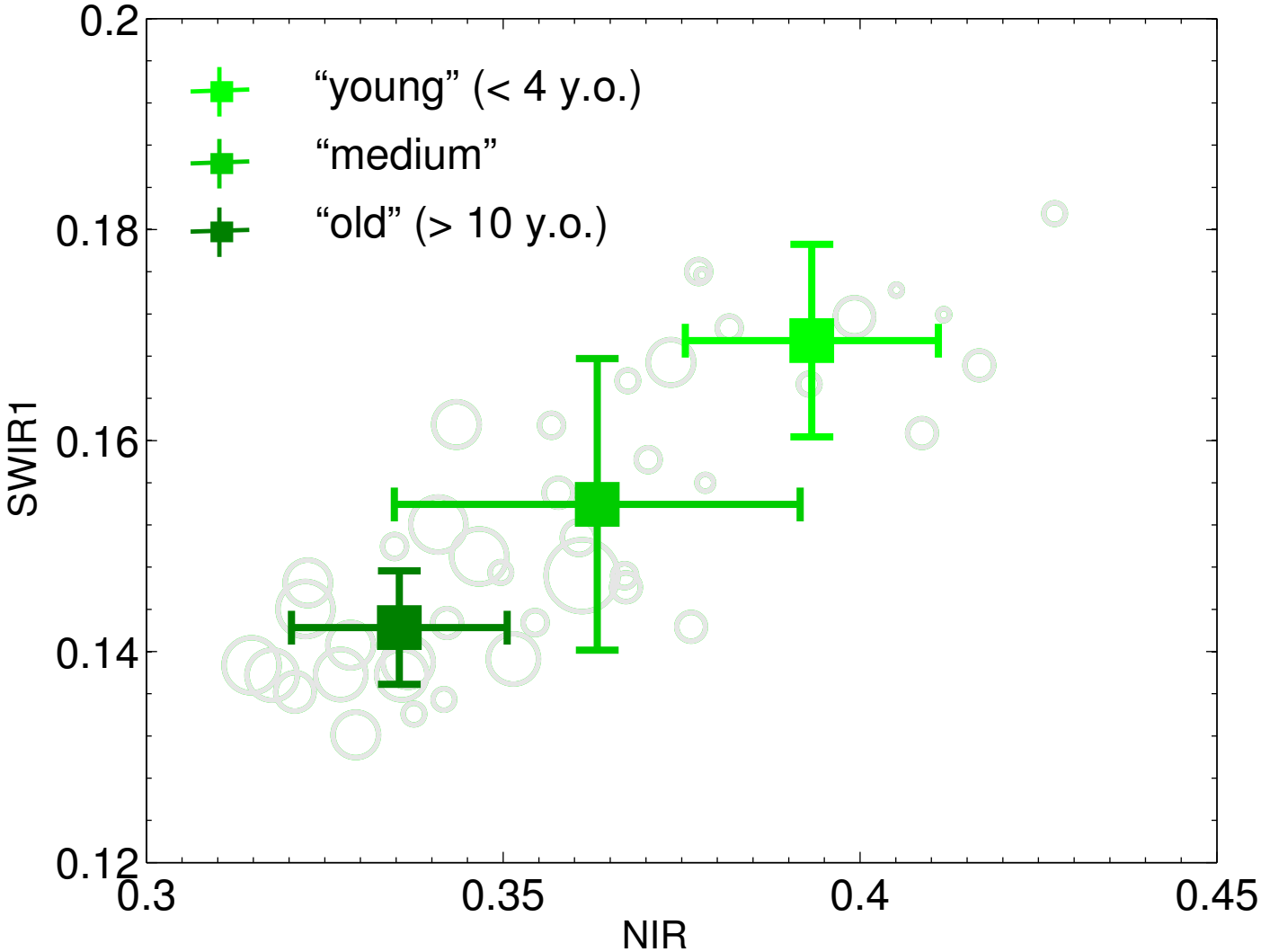
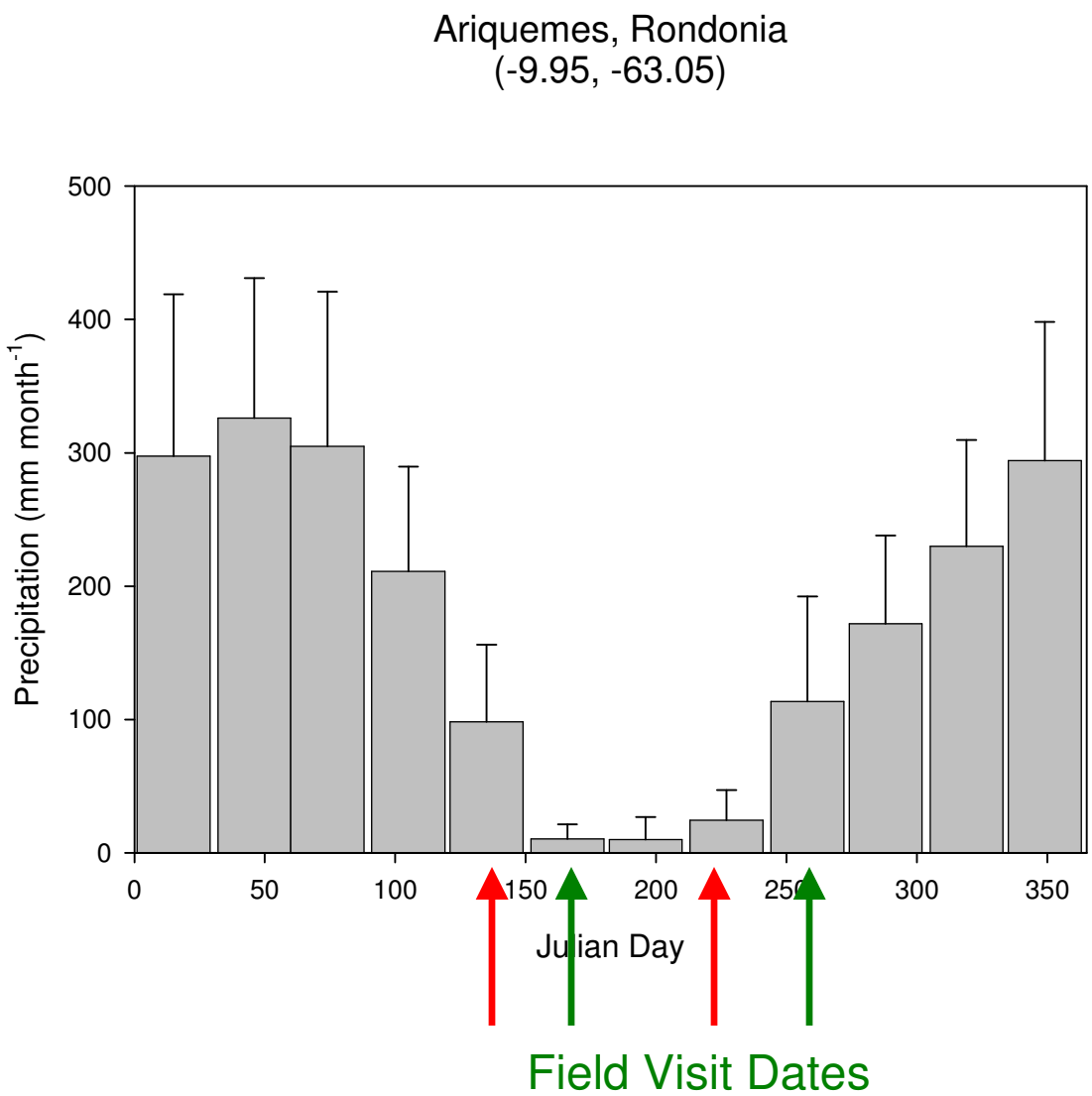
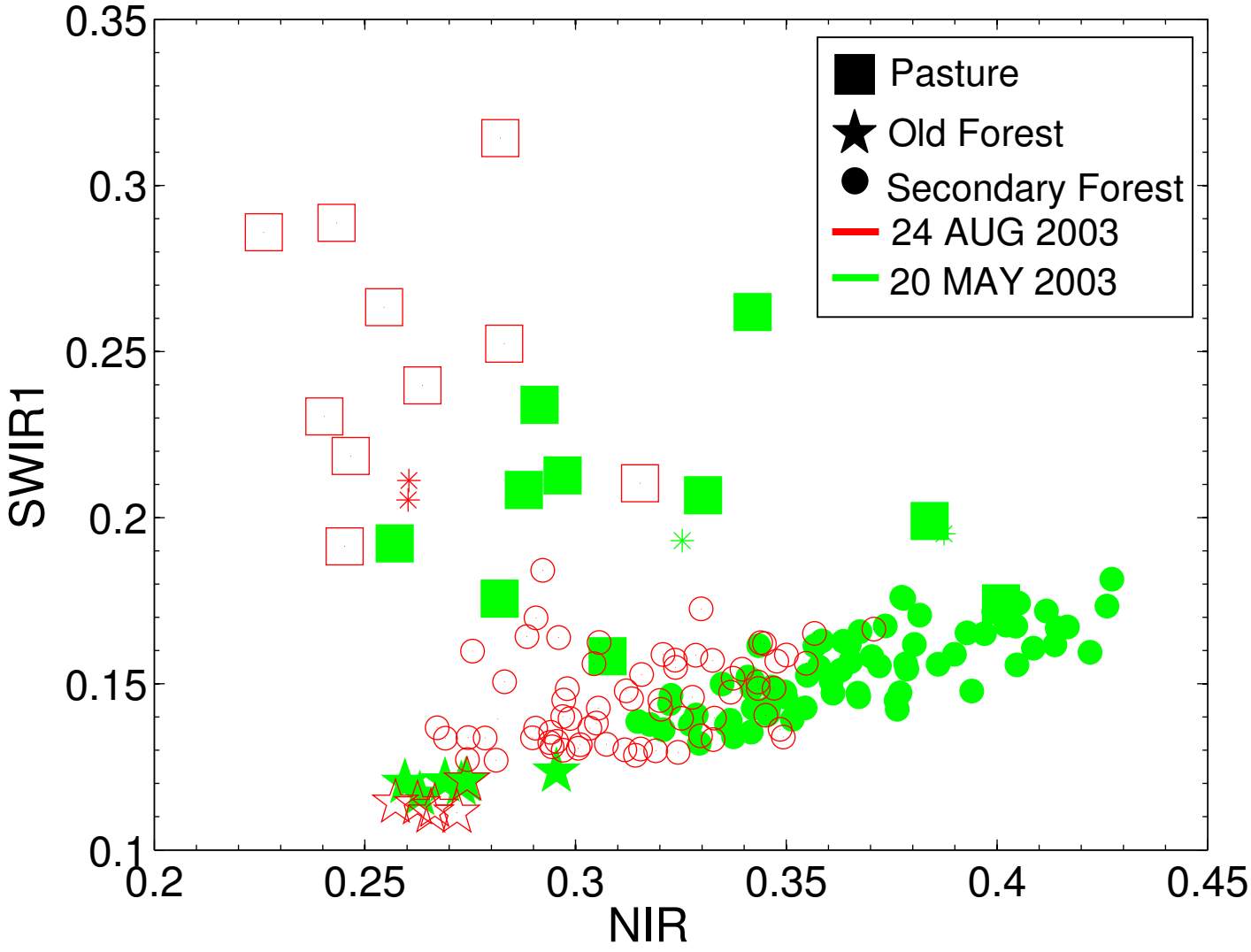
0.4
0.45
NIR


2 years old
16 years old
0.2
0.18
0.16
0.14
0.12
SWIR1
0.3
0.35
0.4
0.45
NIR


0.2
0.18
0.16
0.14
0.12
SWIR1
0.3
0.35
0.4
0.45
NIR
“young” (< 4 y.o.)
“medium”
“old” (> 10 y.o.)


Ariquemes, Rondonia
(-9.95, -63.05)
Precipitation (mm month-1)
500
400
300
200
100
0
0
50
100
150
200
250
300
350
Julian Day
Field Visit Dates


Pasture
Old Forest
Secondary Forest
24 AUG 2003
20 MAY 2003
SWIR1
NIR
0.35
0.3
0.25
0.2
0.15
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0.2
0.25
0.3
0.35
0.4
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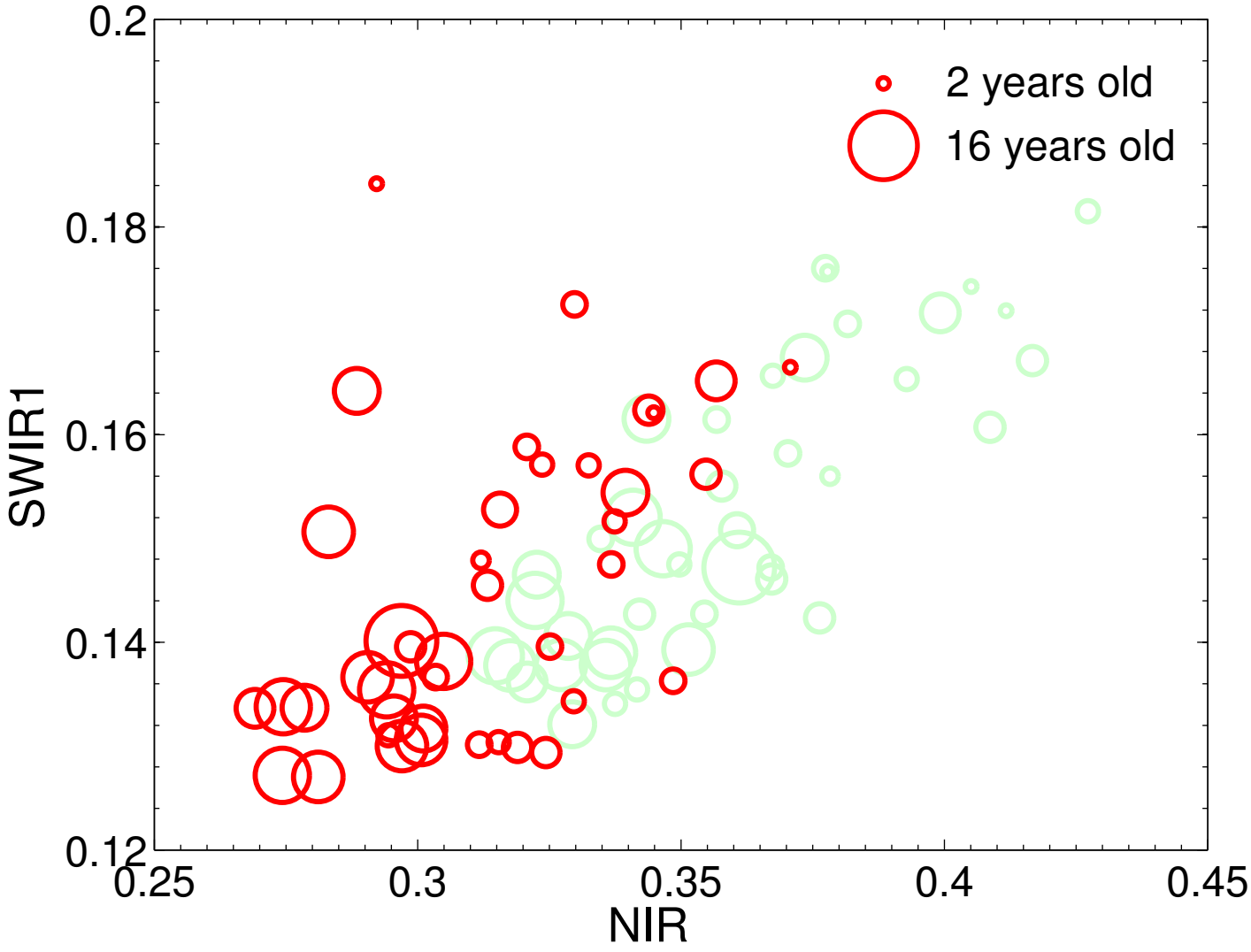
2 years old
16 years old
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NIR
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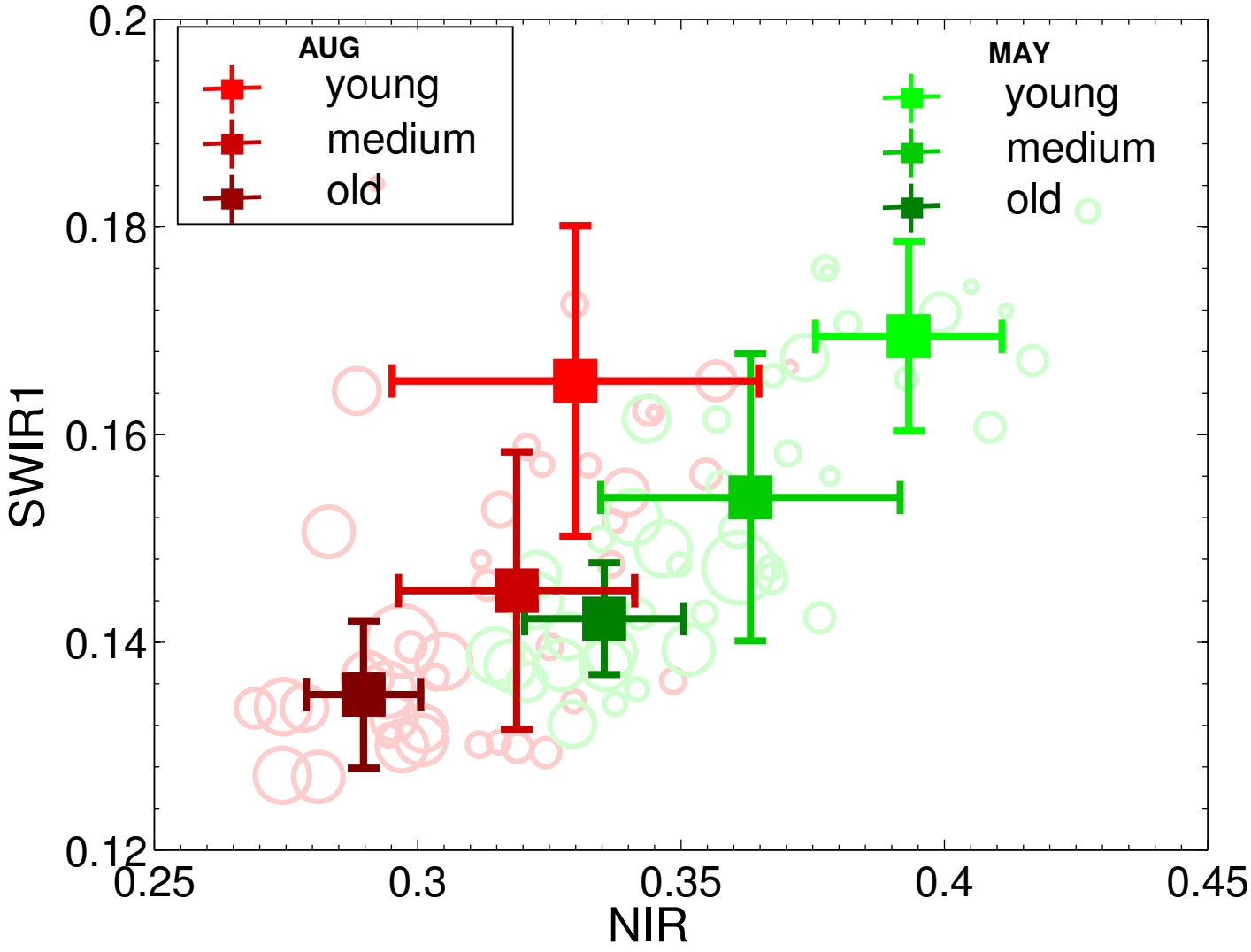
AUG
young
medium
old
MAY
young
medium
old
SWIR1
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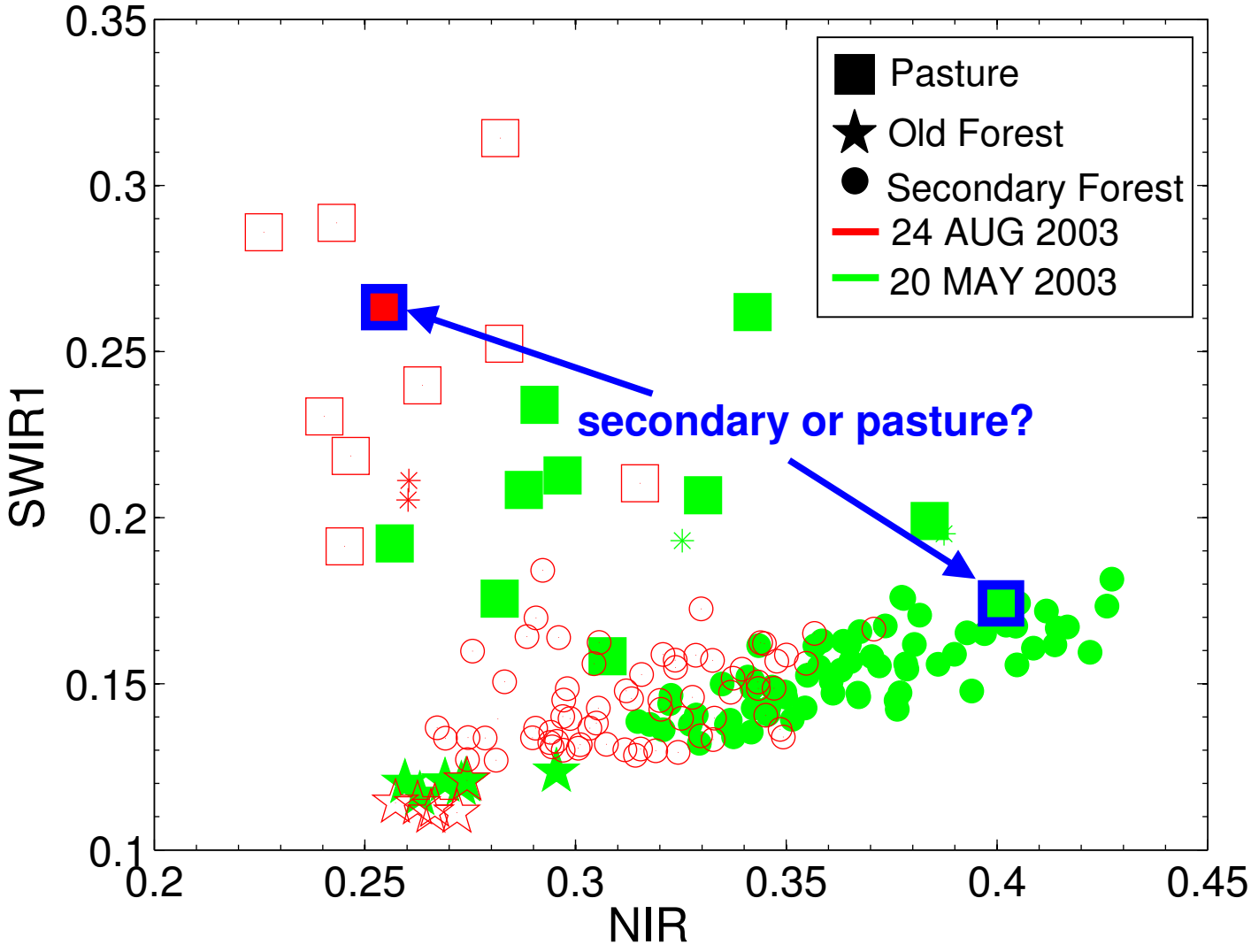
Pasture
Old Forest
Secondary Forest
24 AUG 2003
20 MAY 2003
secondary or pasture?
SWIR1
NIR
0.35
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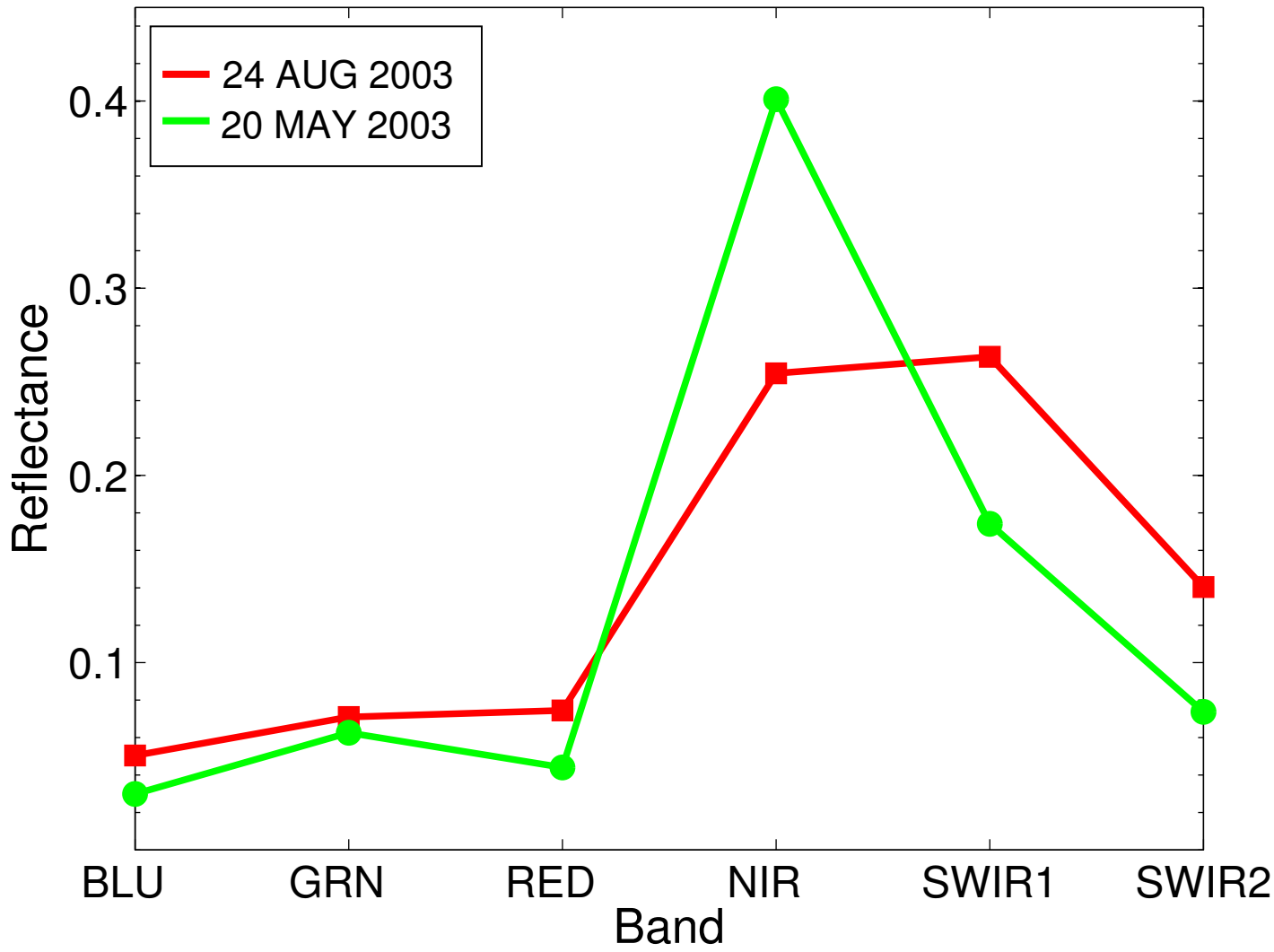
24 AUG 2003
20 MAY 2003
0.4
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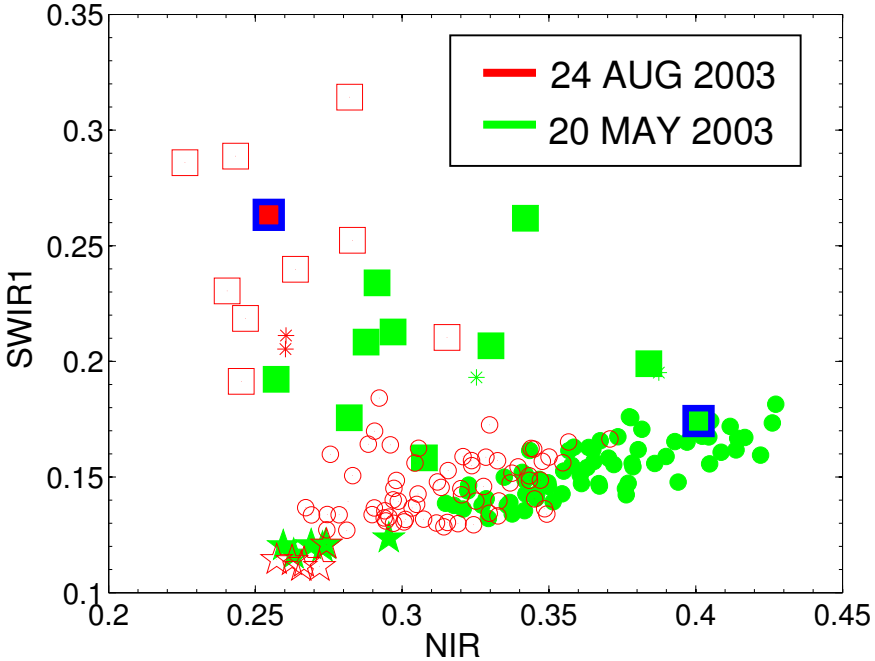
Reflectance
BLU
GRN
RED
NIR
SWIR1
SWIR2
Band


24 AUG 2003
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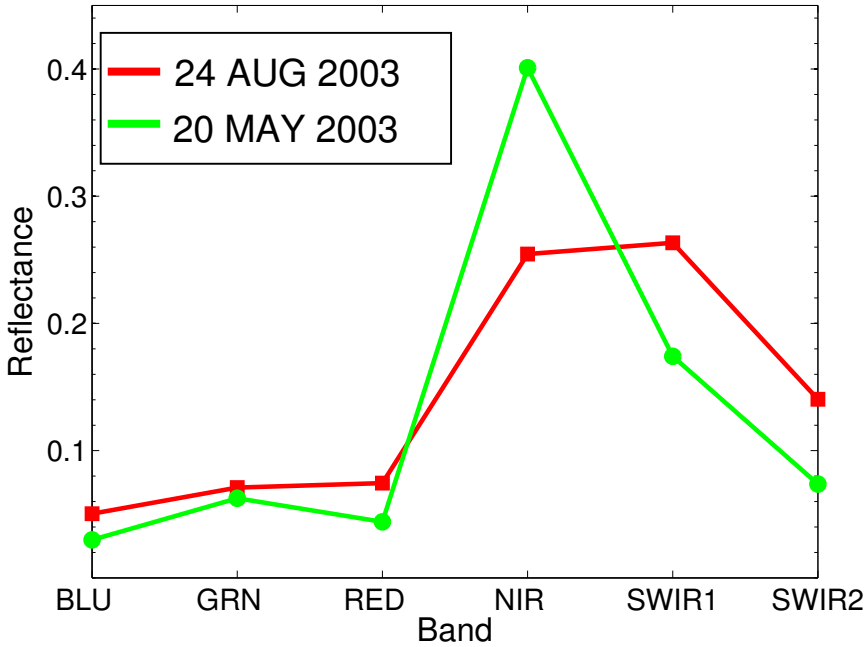
MAY


24 AUG 2003
20 MAY 2003
Reflectance
Band
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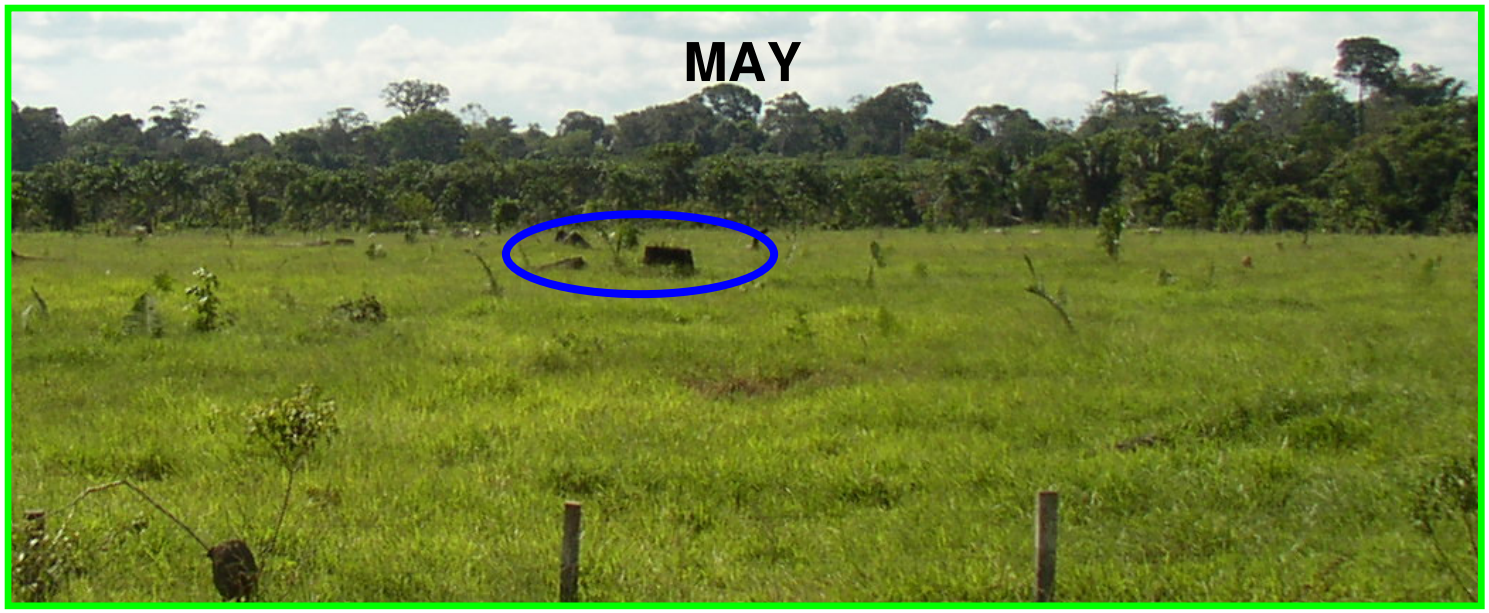
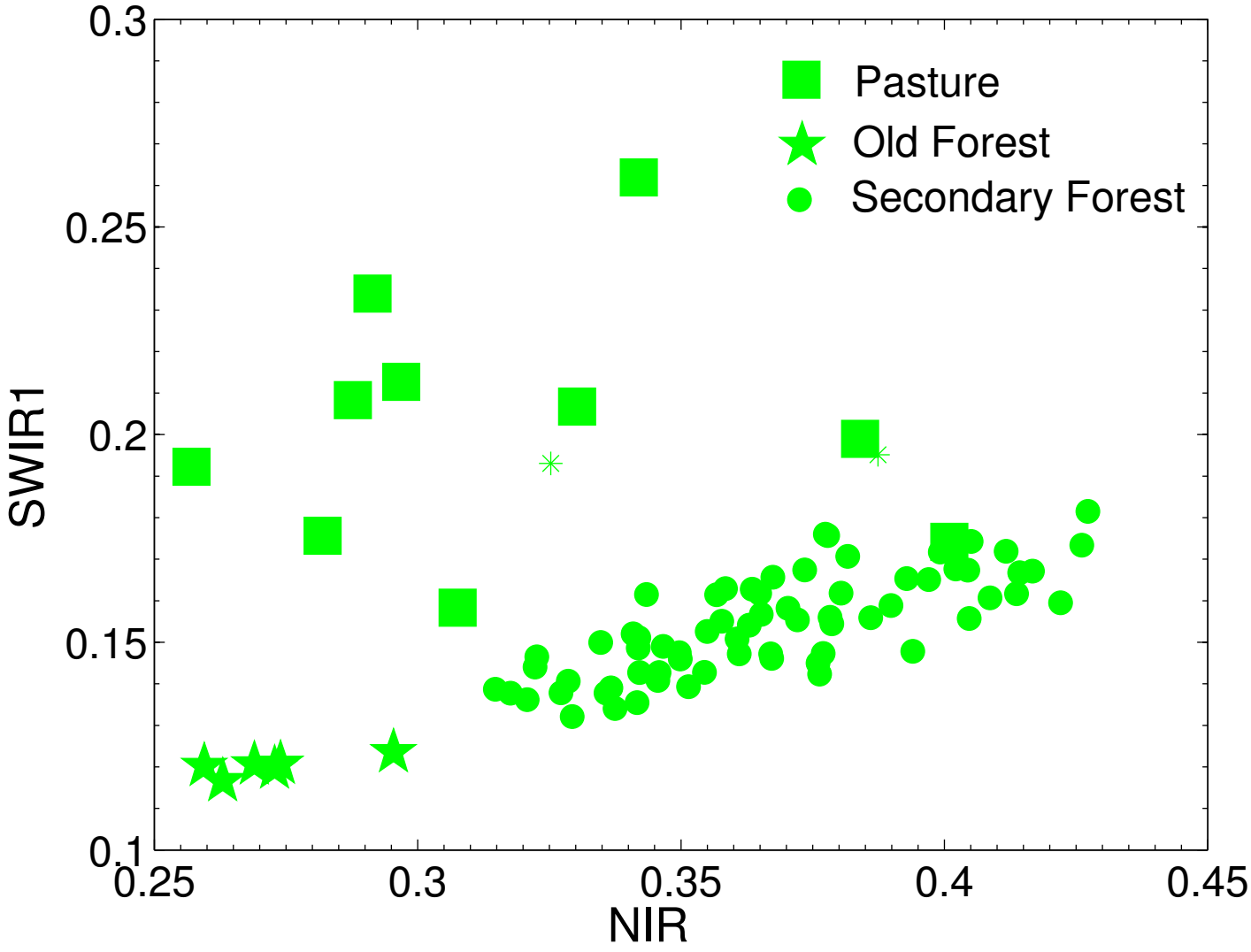
BLU
GRN
RED
NIR
SWIR1
SWIR2

AUGUST


MAY

AUGUST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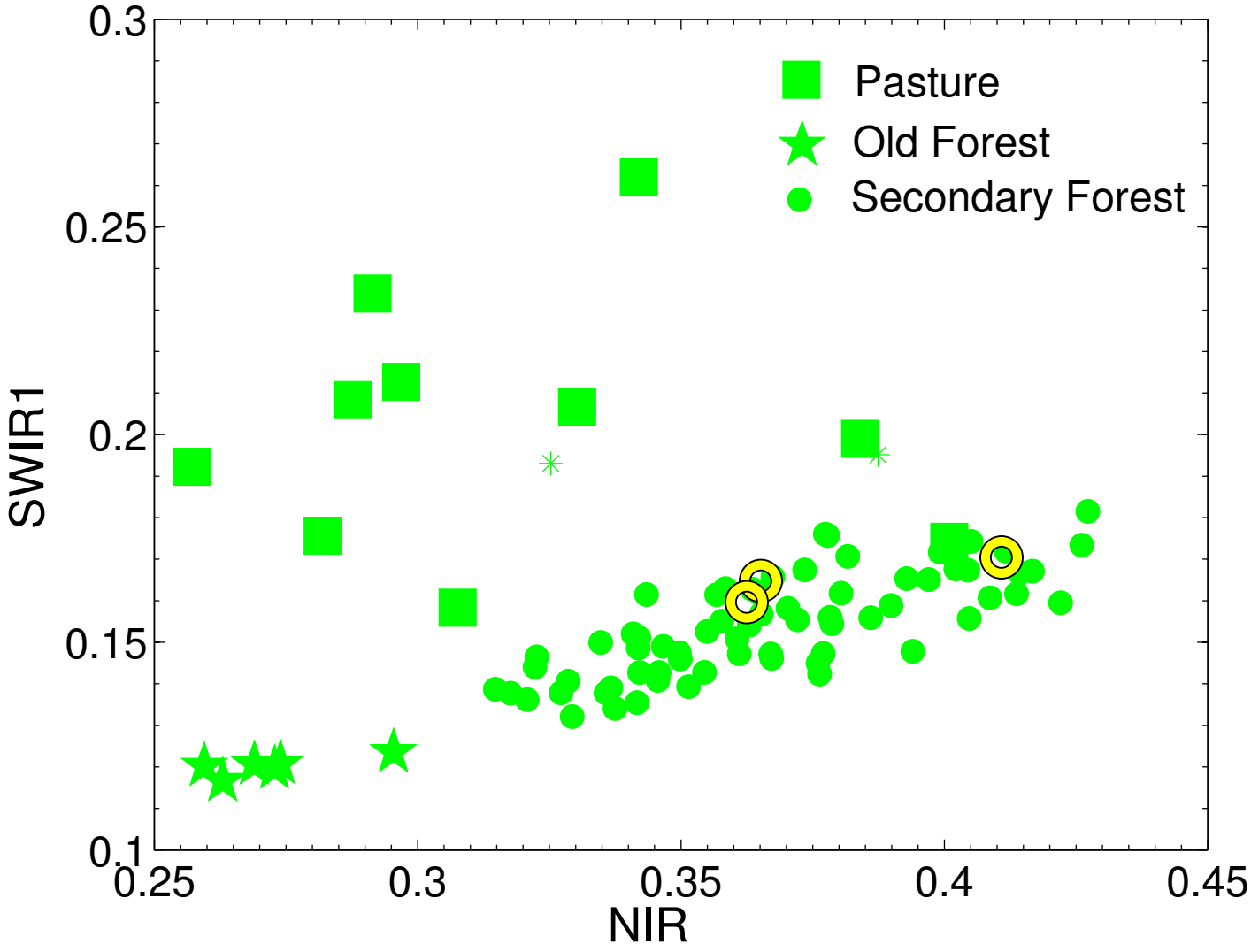
Pasture
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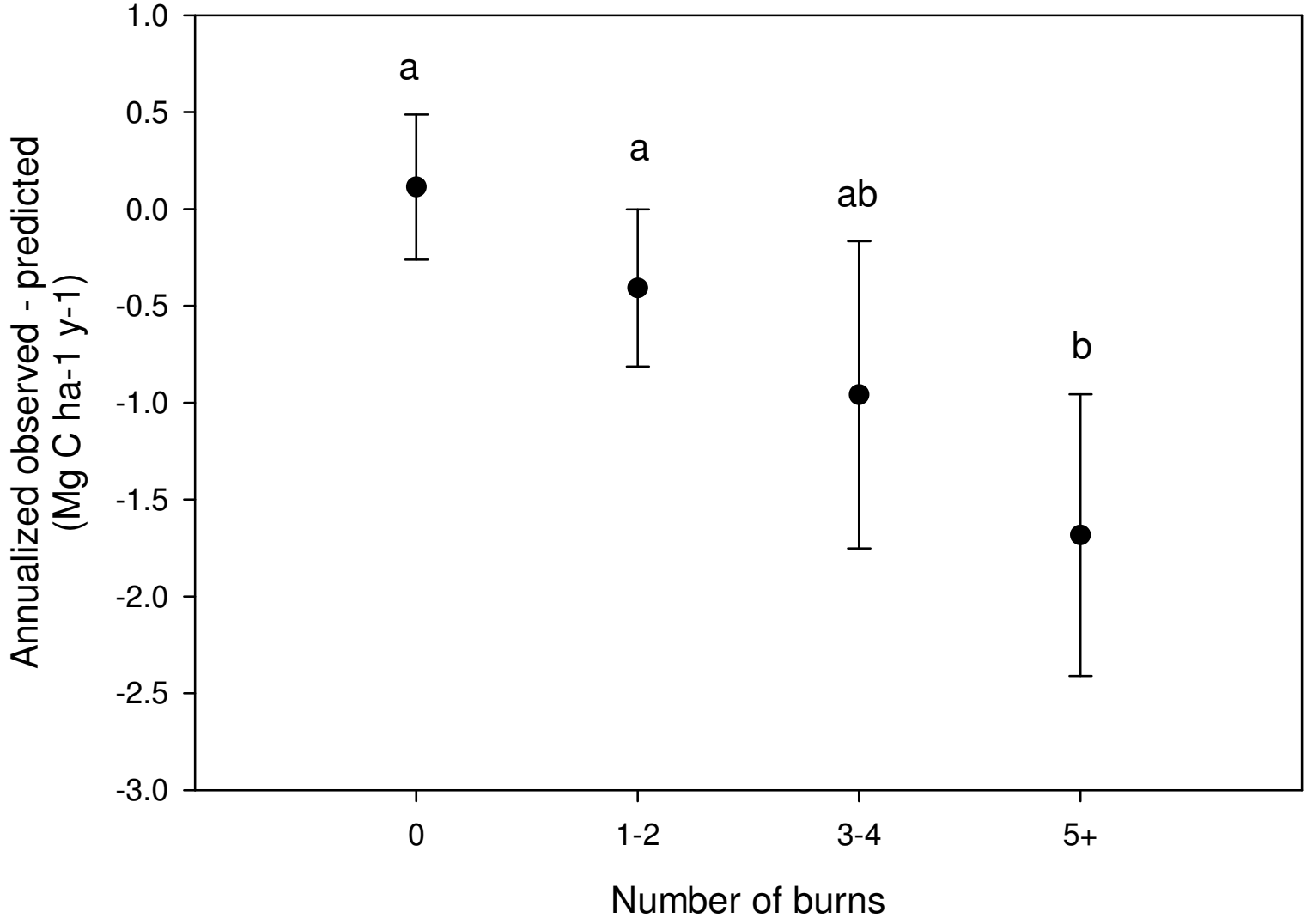
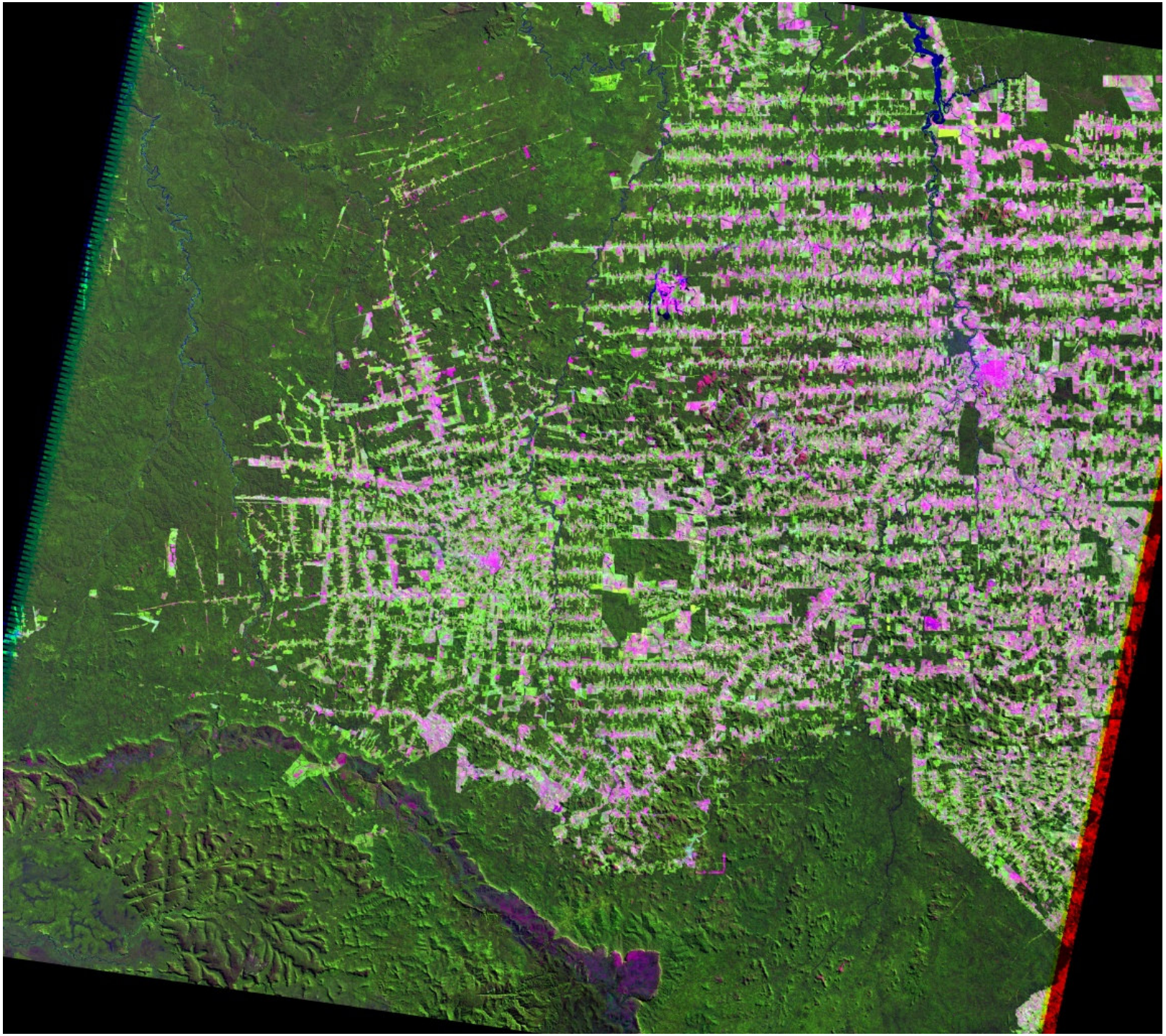
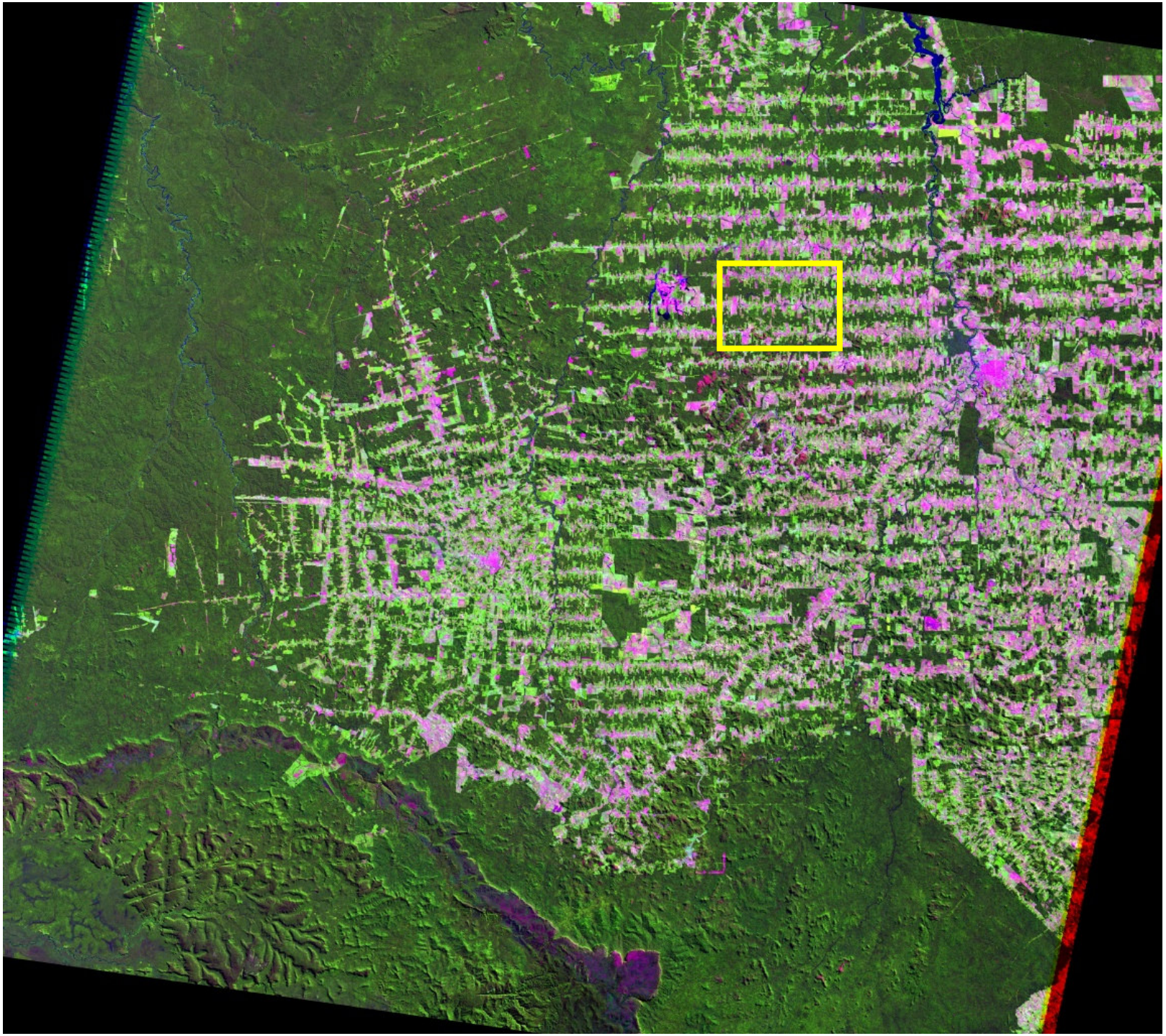
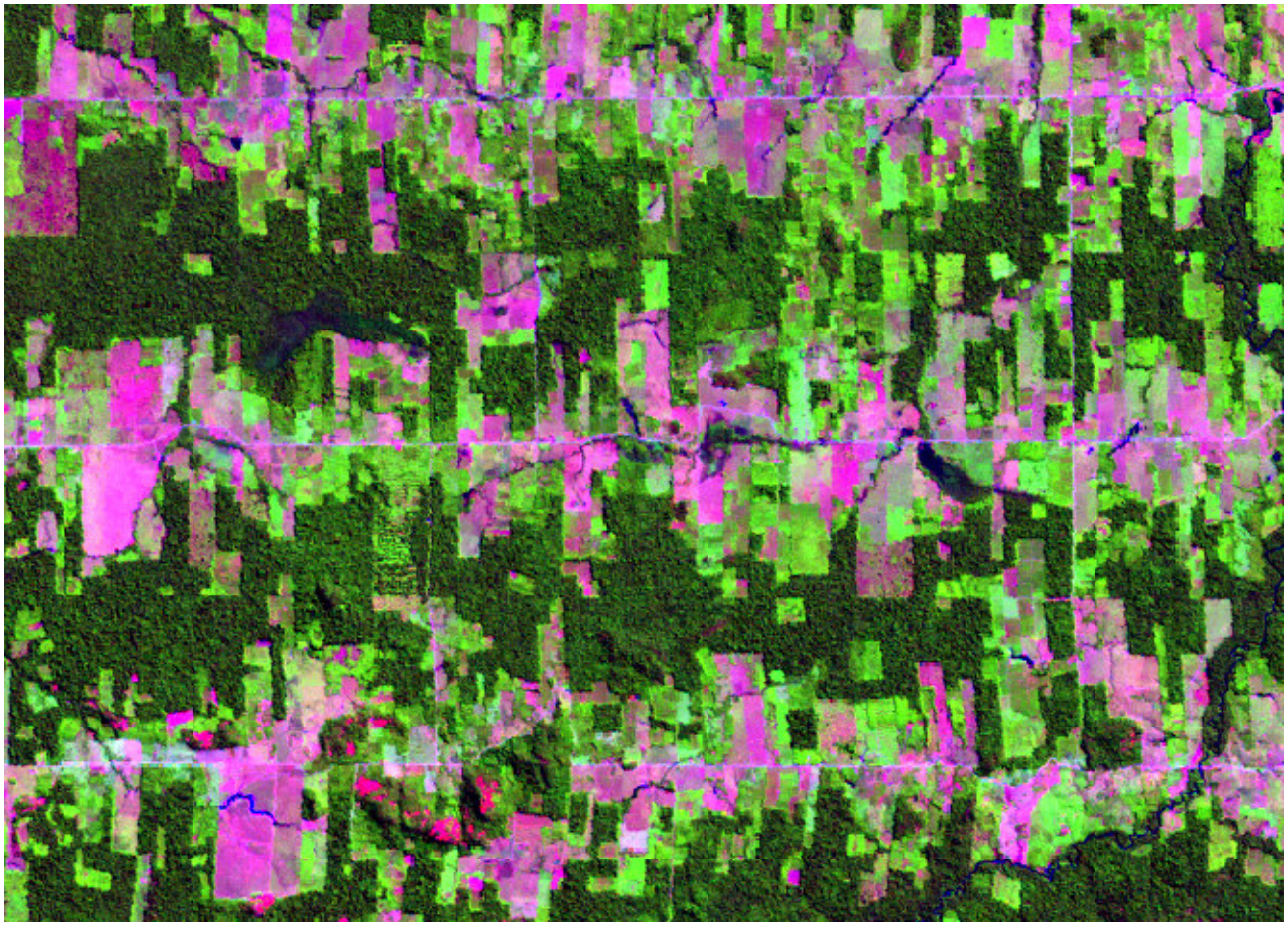


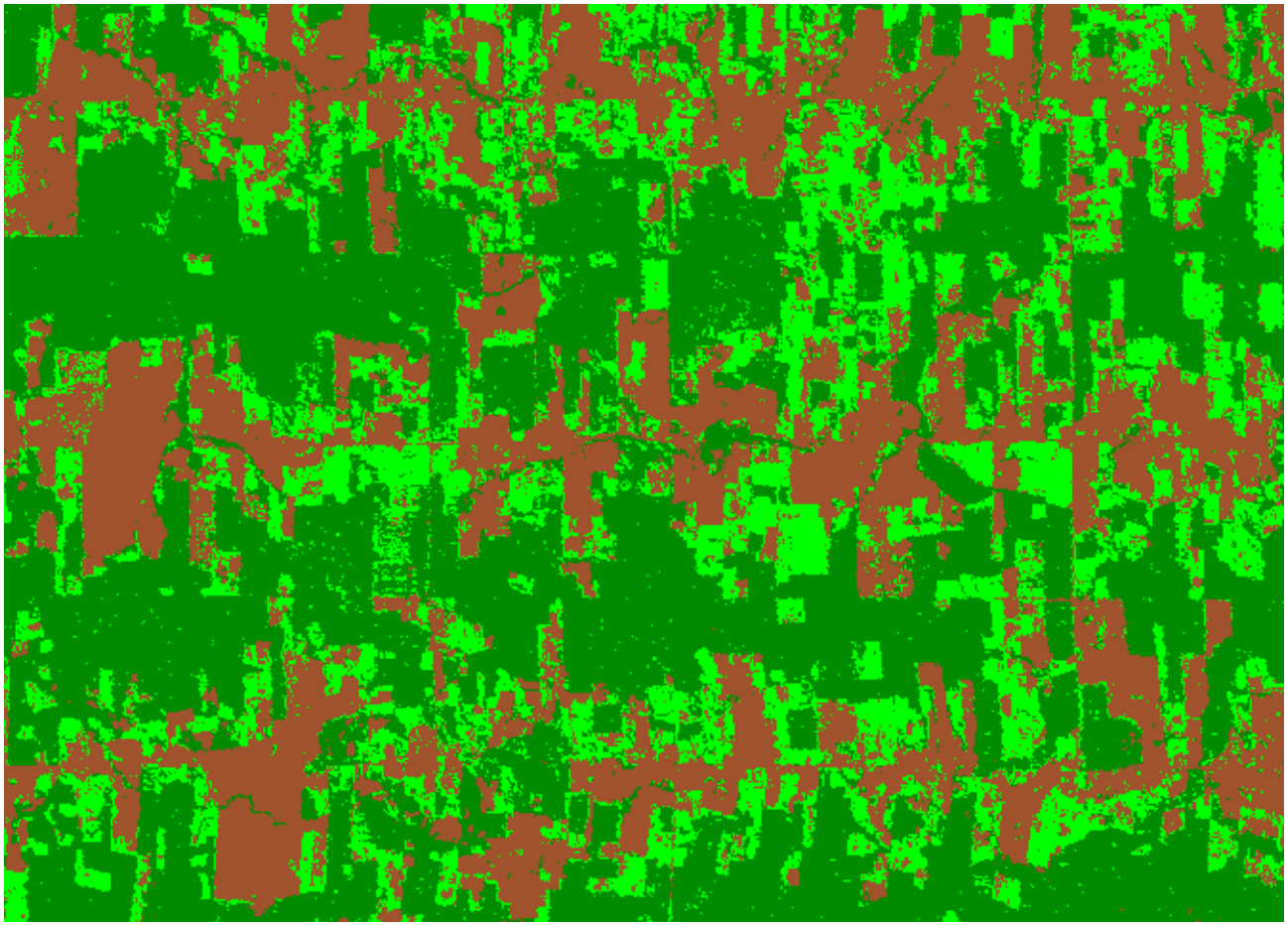
In sites that have burned repeatedly, the observed rates of secondary forest regrowth fall below expectations based on a previously validated empirical model that predicts growth from climate and soil properties. From Zarin et al. Front. Ecol.& Environ. 2005. 3:365-369



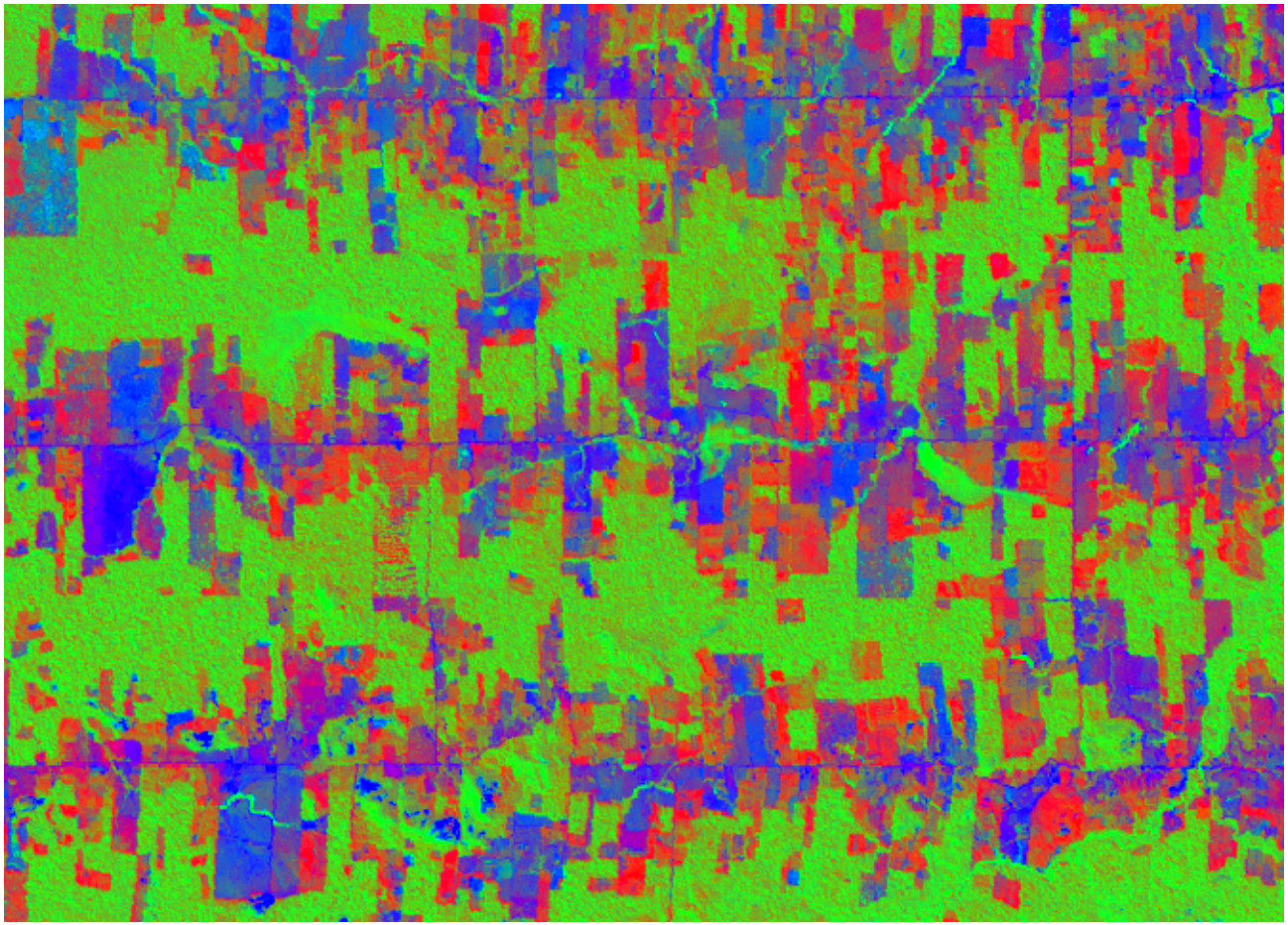




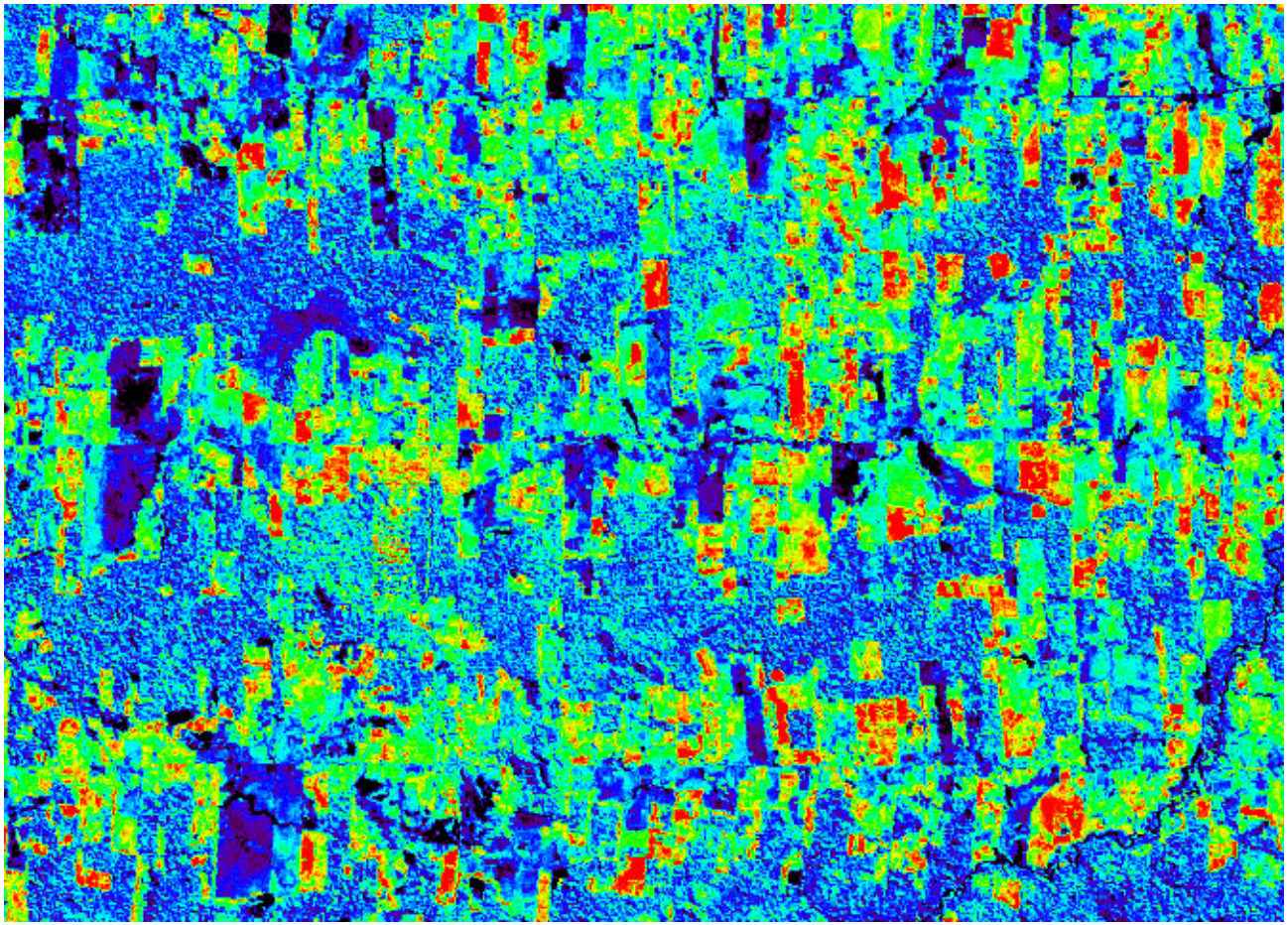
R-SWIR1 **G-NIR** **B-RED**



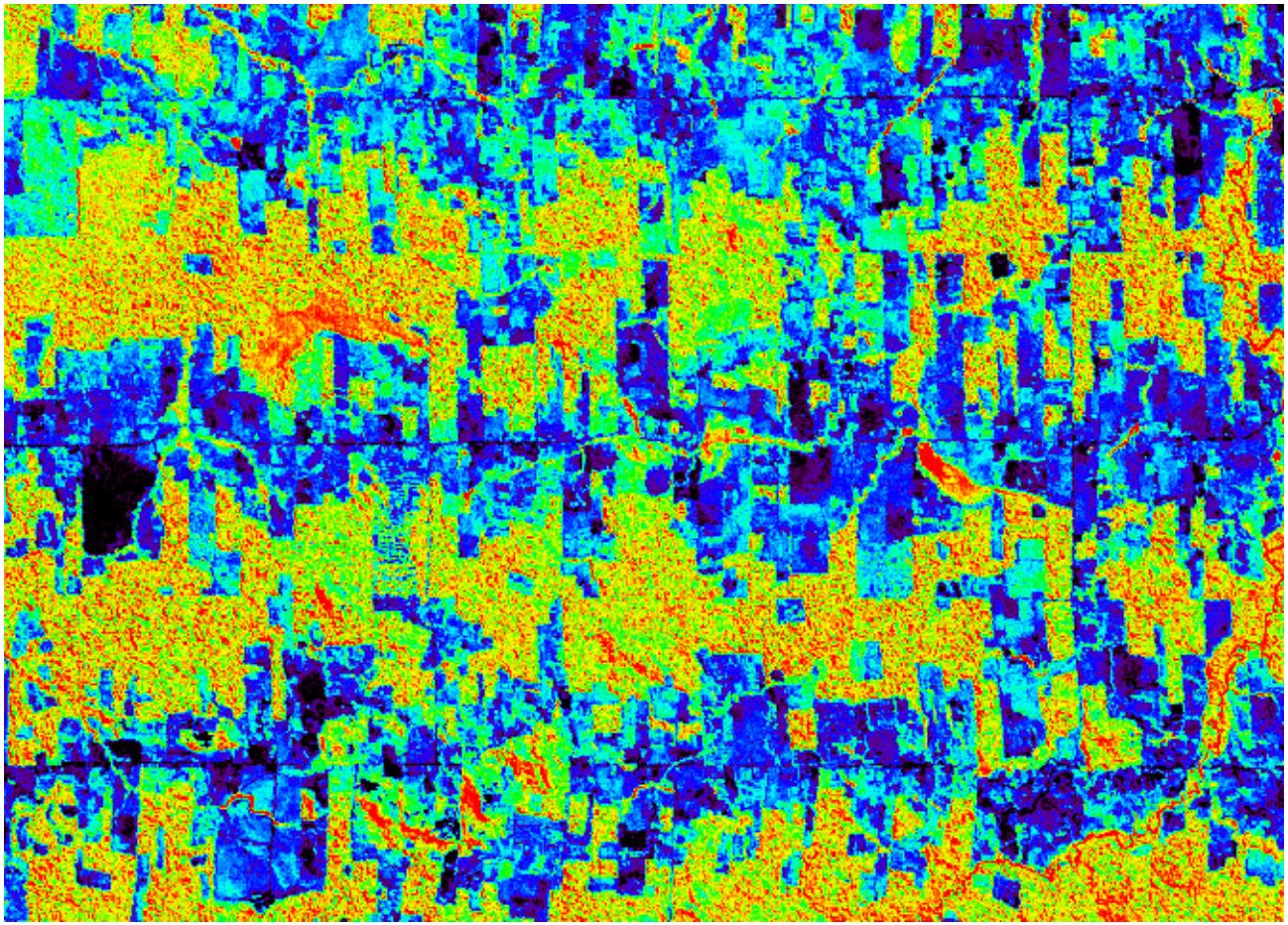
Land cover classification



R-Green Veg. **G-Shade** **B-Soil**



Fraction of Green Vegetation



Fraction of Shade

Resources and Limitations

- Resources
  - processed Landsat scenes from >10 locations
  - ground truth data (class validation, structure)
  - knowledge base

- Limitations
  - limited time
  - limited funds