Deforestation and Degradation in Southern Central African savannas

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Dennis Lettenmaier

http://www.inform.umd.edu/geog/LGRSS/Projects/degradation.html

Deforestation and Degradation in Central and Southern African Savannas

Outline of proposal

– Integrated land degradation and deforestation detection system.

–Southern African Development Community (SADC) region plus southern Zaire.

–Move beyond classification of land cover to monitor the processes involved.

–Socio-economic drivers of land cover change and biophysical factors employed to identify degradation processes.

Deforestation and Degradation in Central and Southern African Savannas

Outline of proposal (continued)

– Radar and optical methods to measure biomass.

–Visible, near infrared and thermal remote sensing to monitor primary production.

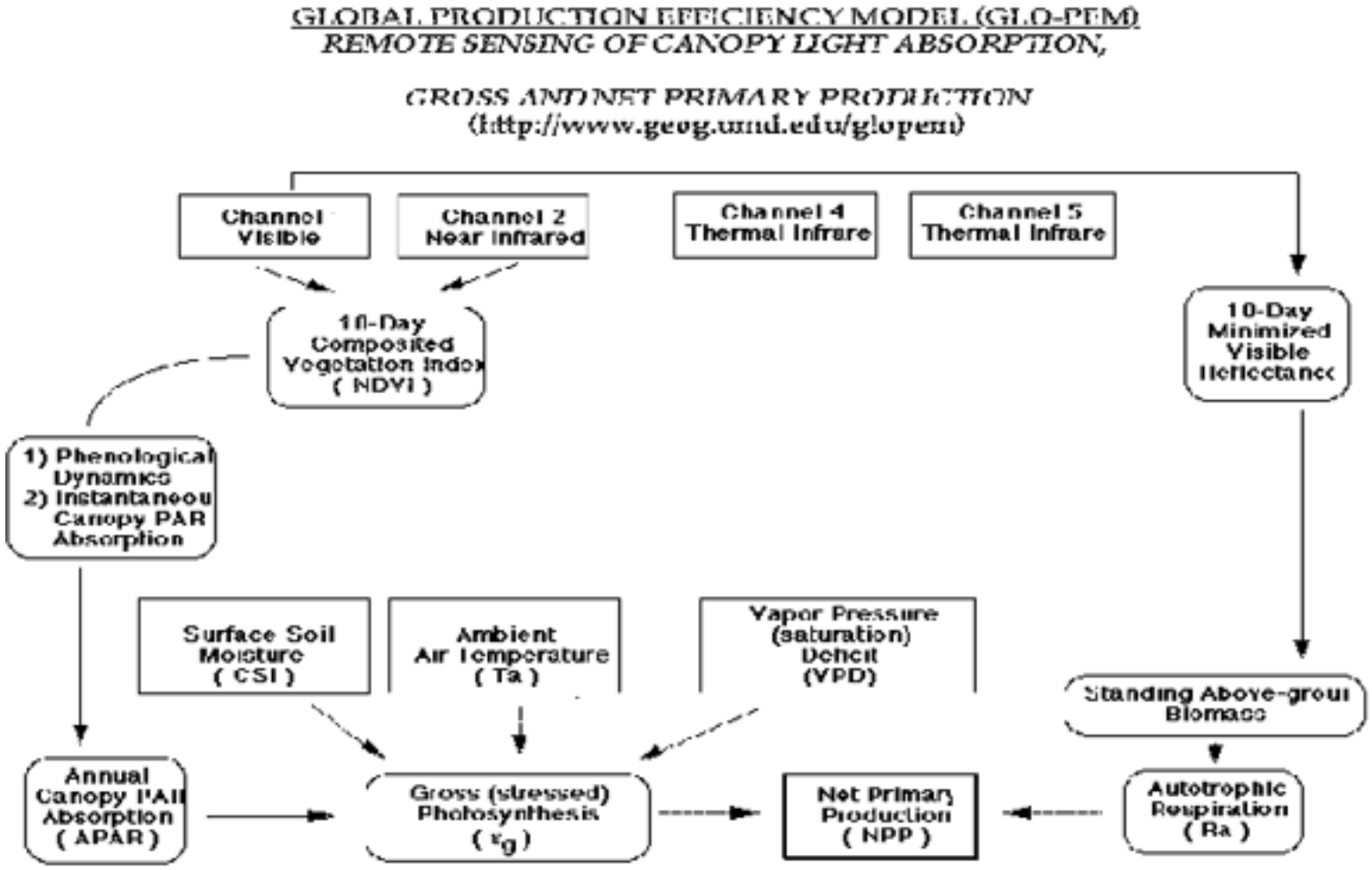
– Soil moisture and runoff modeled with surface water and energy balance models driven with remotely sensed data.

– Biophysical, socio-economic and cultural variables combined to create empirical models to identify leading indicators of environmental degradation.

–Prototype degradation early warning system (DEWS) for southern and central Africa and for similar areas worldwide.

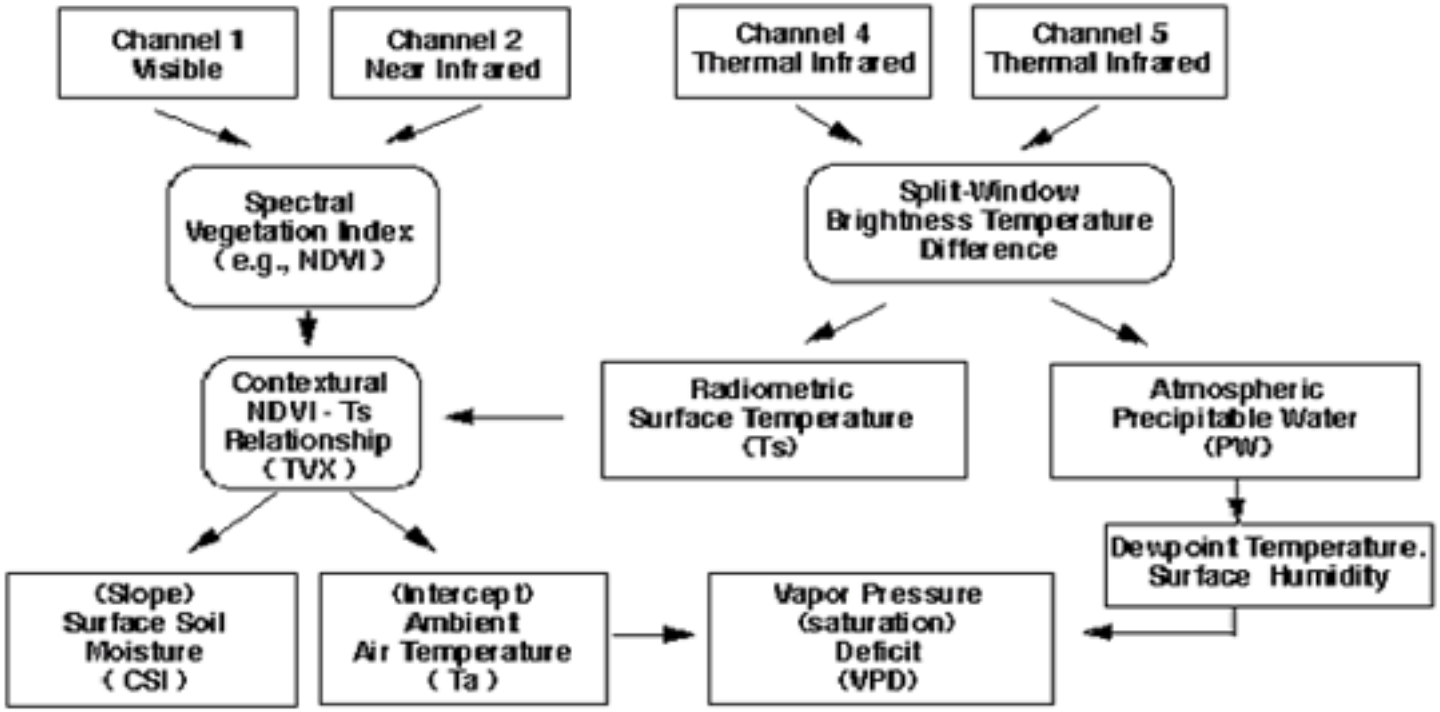
NPP monitoring using GLO-PEM model

Model Outline



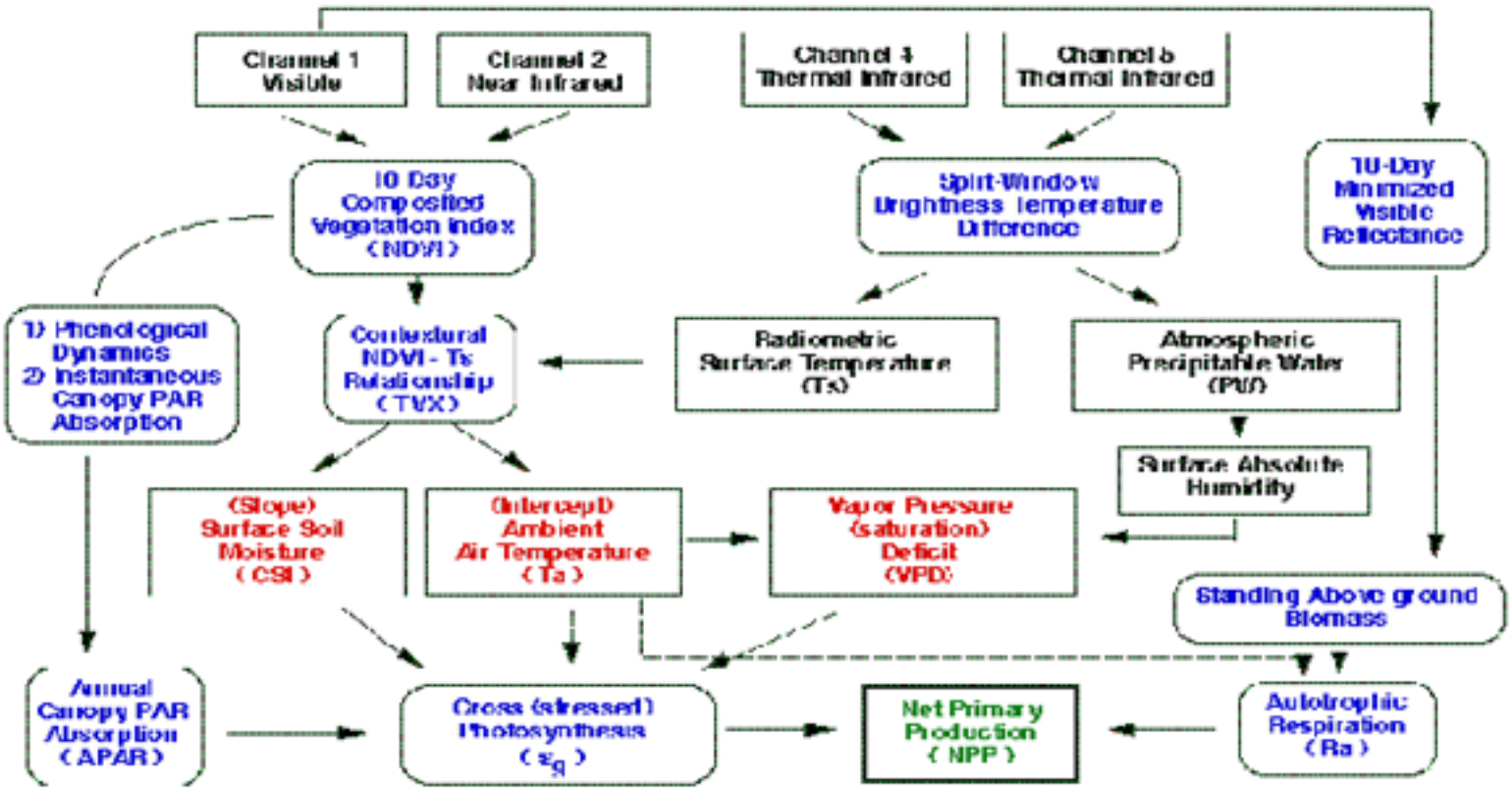
Model Outline

GLOBAL PRODUCTION EFFICIENCY MODEL (GLO-PEM)
REMOTE SENSING OF ENVIRONMENTAL VARIABLES..



Model Outline

GLOBAL PRODUCTION EFFICIENCY MODEL (GLO-PEM)
REMOTE SENSING OF CANOPY LIGHT ABSORPTION, SURFACE ENVIRONMENTAL VARIABLES, GROSS AND NET PRIMARY PRODUCTION
(http://www.geog.umd.edu/glopem)



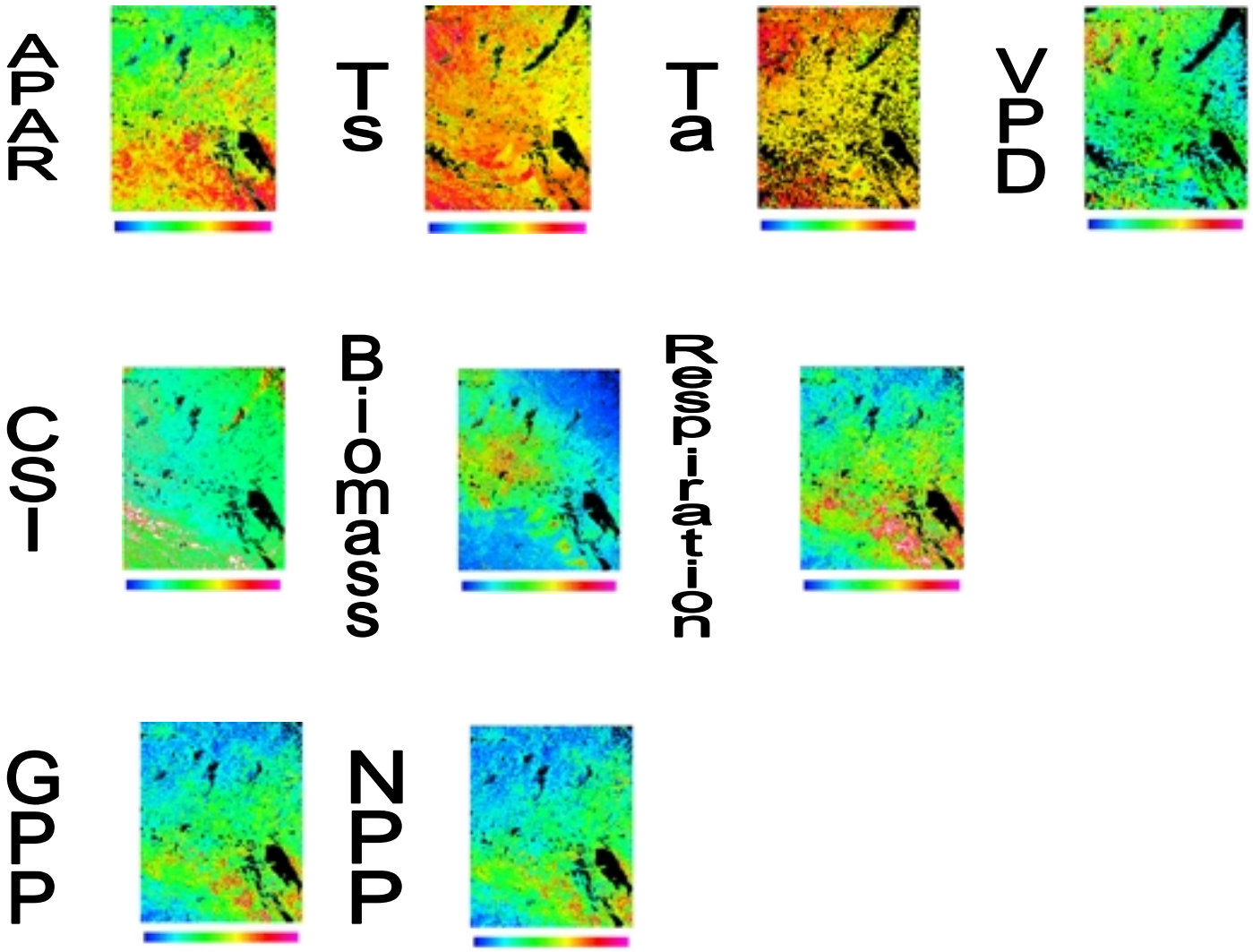
New developments

- Canopy respiration rates modeled exponentially using deviation from long-term air temperature (Ta)
- Ta inferred from TVX relationship, except where:
  - Slope is flat or positive: Ta = Ts-1stdev (or) Ts @ NDVI avg
  - $R^2 < 0.5$; small sample size or variance of Ts or NDVI low
  - Other conditions apply / thresholds are exceeded
    - (e.g., clouds, sparsely vegetated areas)
- Ts calculated with new LUT approach
  - Varies with emissivity (CERES), atmos water vapor
  - Coeffs specific to AVHRR instruments (NOAA-7 to 13)

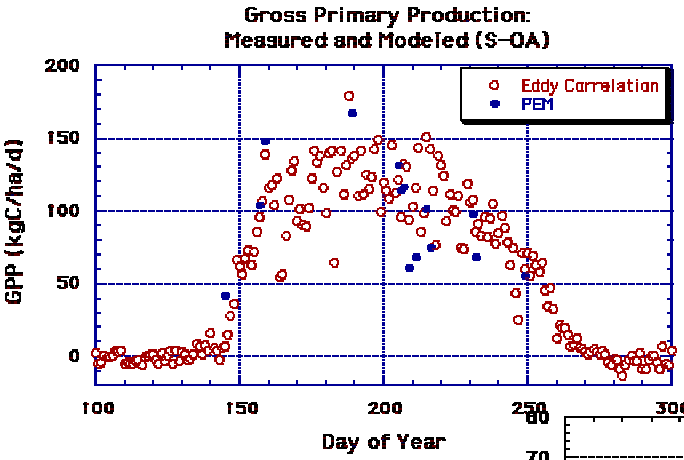
New developments

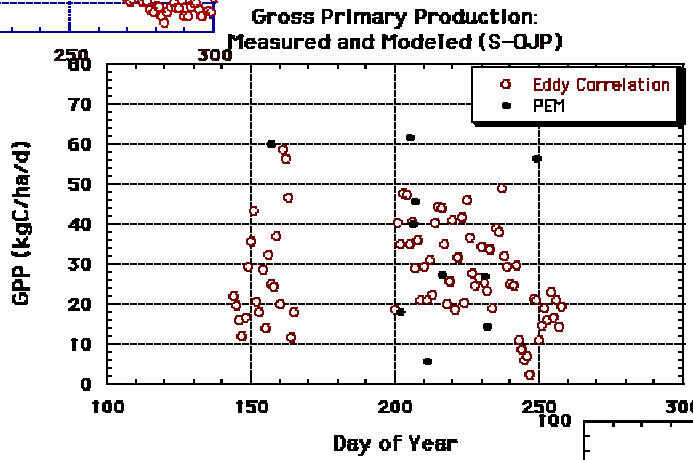
- Soil moisture stressor a continuous variable rather than a switch, ramps in below 30% (by volume).
- DAO atmospheric water vapor rather than DT4-T5 & LOWTRAN (avoids non-unique solution)
- Combined, these provide solutions for >80% land surface
- Methodology to compensate for AVHRR time drift devised.
  - SSiB simulations stratified by cover type, latitude
    - ISLSCP forcing variables
    - Diurnal Ta curves interpolated 3-hourly
  - LUT correction factors for overpass drift (~13:40 - 16:50 GMT)

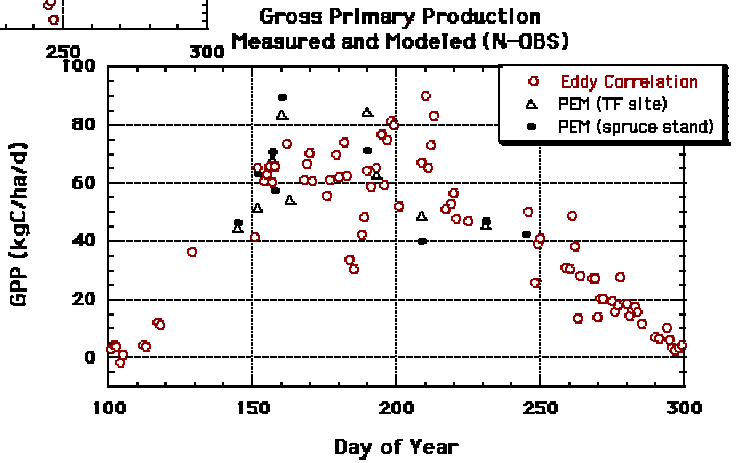
NPP monitoring using GLO-PEM model
Validation: BOREAS



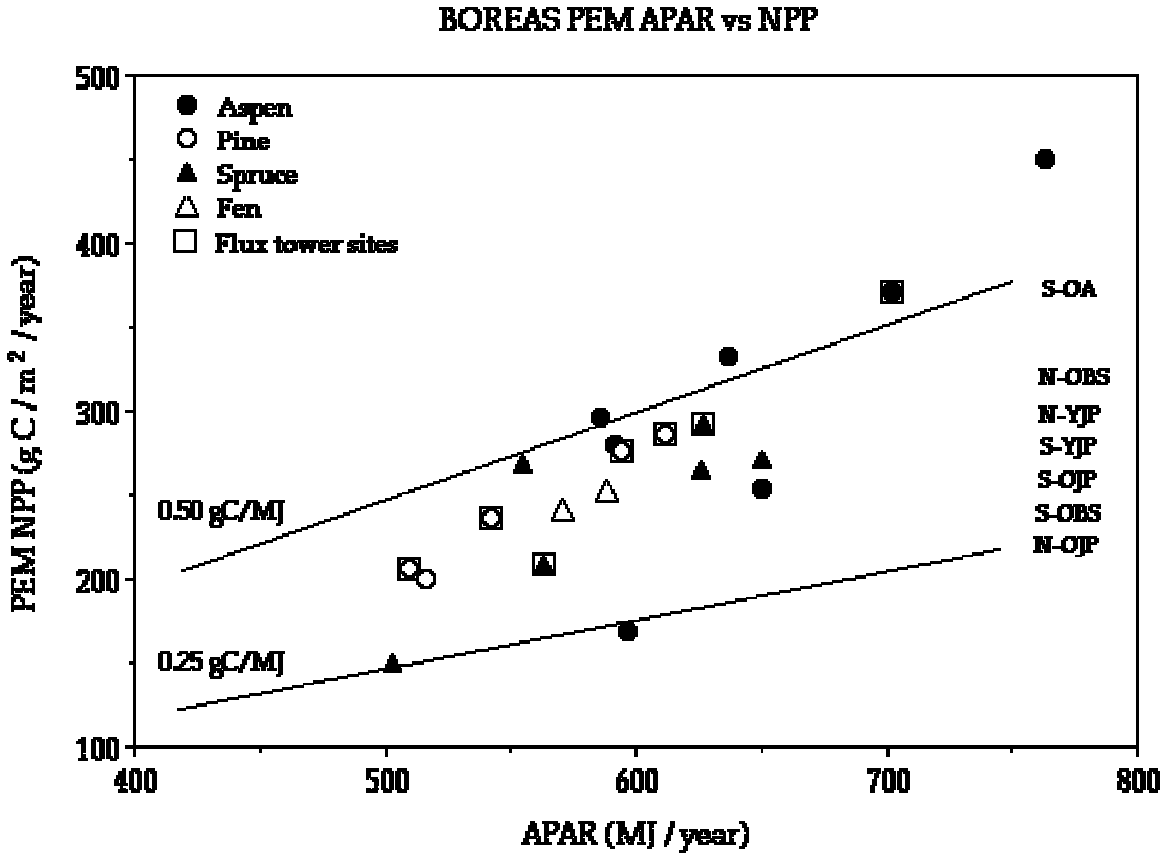
Validation of glo-pem npp model in boreas







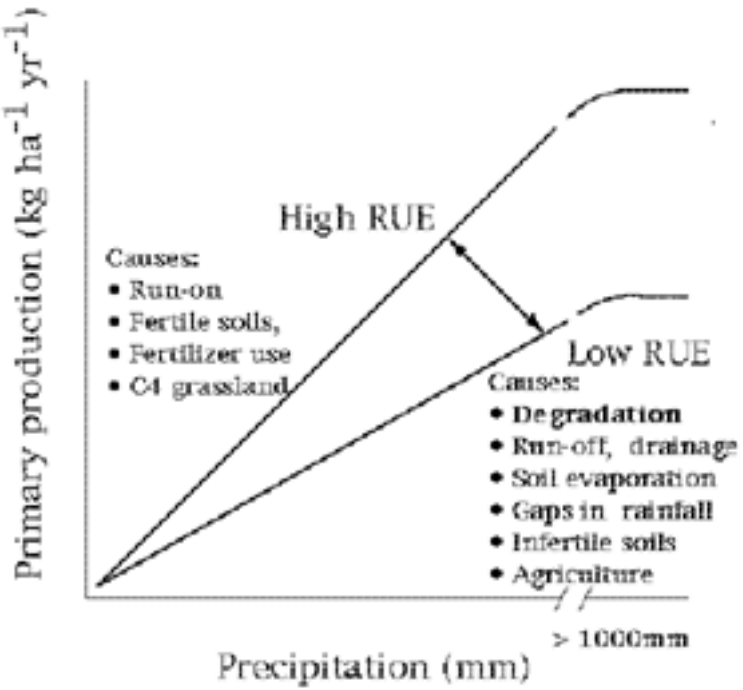
Glo-pem modeled
light use efficiency in boreas



PIK NPP Model Intercomparison

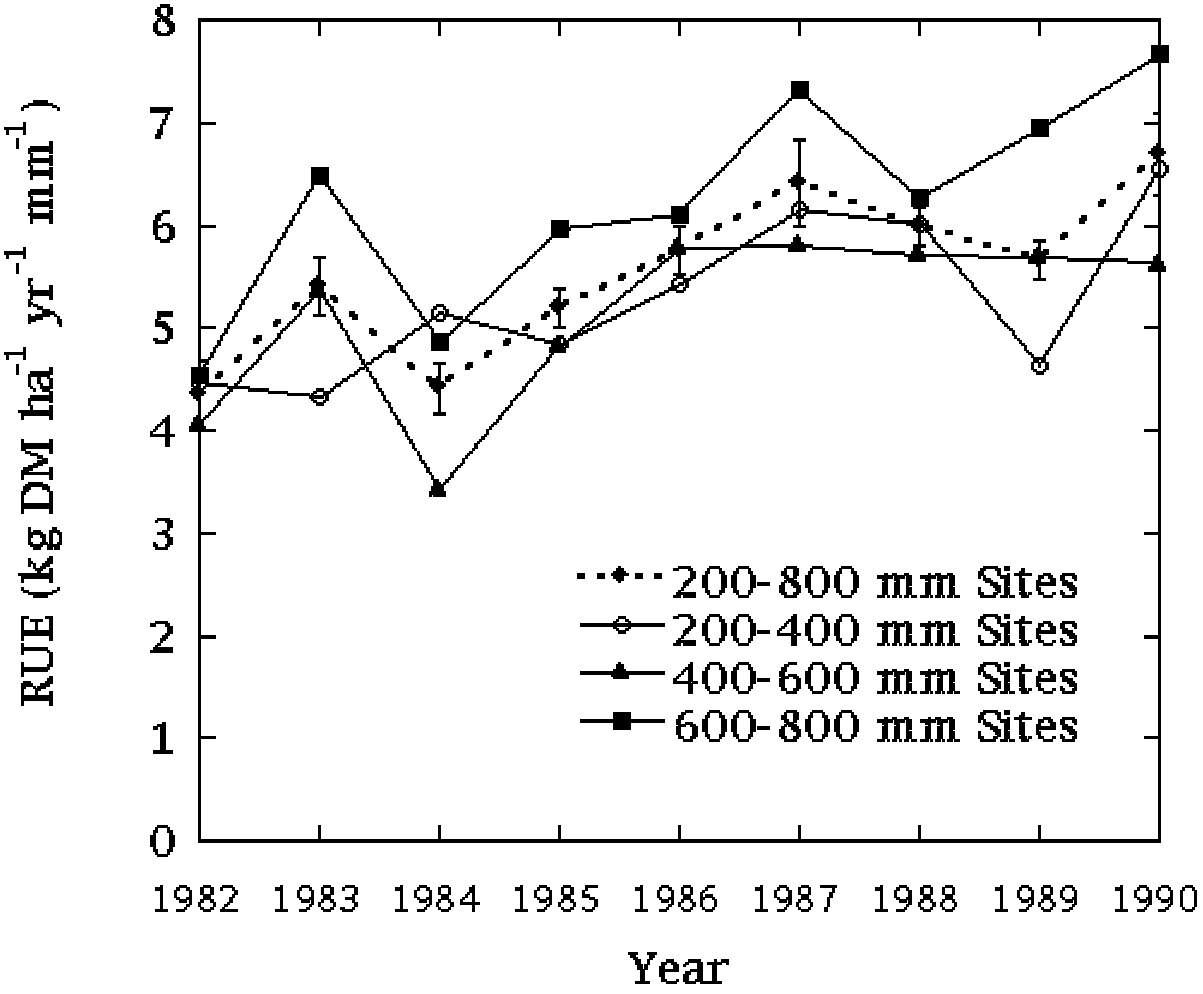
Rain Use Efficiency Theory

Outline of Theory



- **RUE = P_n / T = P_n / (T + E + I) + (D + R) + (ΔW + ΔWp)**
- **P_n = net primary production (NPP)**
- **P_r = precipitation** **All in volume water/time.**
- **T = transpiration**
- **E = soil evaporation**
- **I = evaporation from wet canopy**
- **D = drainage from the root zone**
- **R = run-off**
- **ΔW = change in water content of the soil**
- **ΔW_p = change in water content of the vegetation**

Sahelian multitemporal results



Significance of RUE as an objective index of degradation

Evidence from rain-use efficiencies does not indicate extensive Sahelian desertification

S. D. PRINCE, E. BROWN DE COLSTOUN and L. L. KRAVITZ

Abstract

Drawing a line in the desert sands

FOR decades the United Nations has campaigned to control desertification, the apparently inexorable advance of deserts, particularly the Sahara. But ecologists have never convinced that the process is happ- two recently published studies r scepticism.

images from an American satel- w that, in the past 15 years, the ahara has moved rapidly to and ng on rainfall. The movements as 300 kilometres in a few years ole period. "there is no progres- f the desert," says Dr Sharon Ni- lorida State Univer the land itself be not becoming des he greenness of t ith the amount of r here is no decline i th the plants use r d Dr Stephen Prin laryland concur in reports.

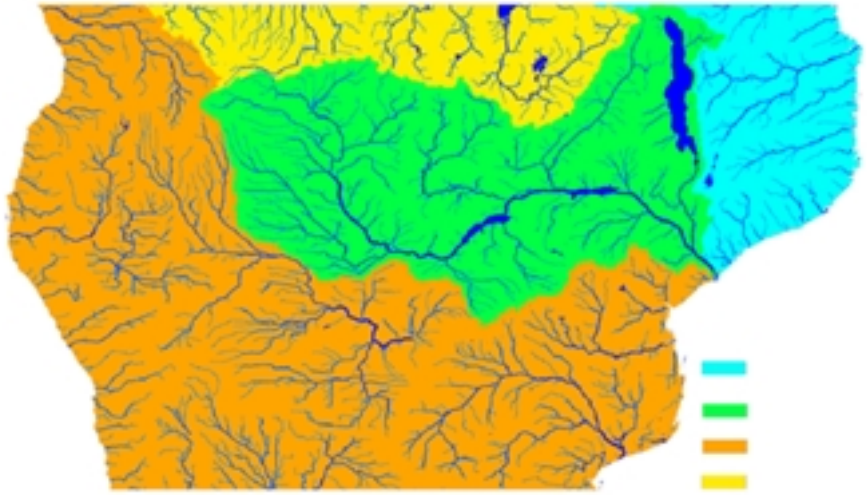
ECOLOGY

The Sahara Is Not Marching Southward

REMOTE SENSING

Study Shows No Long-Term Growth of Sahara Desert

Future Developments
Hydrological modeling to separate runoff and soil moisture components



River Catchments
Coastal Mozambique
Zambeze
Limpopo/Okavango
Zaire

- **RUE = P_n / T = P_n / (T + E + I) + (D + R) + (ΔW + ΔWp)**
- **P_n = net primary production (NPP)**
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- **D = drainage from the root zone**
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- **ΔW = change in water content of the soil**
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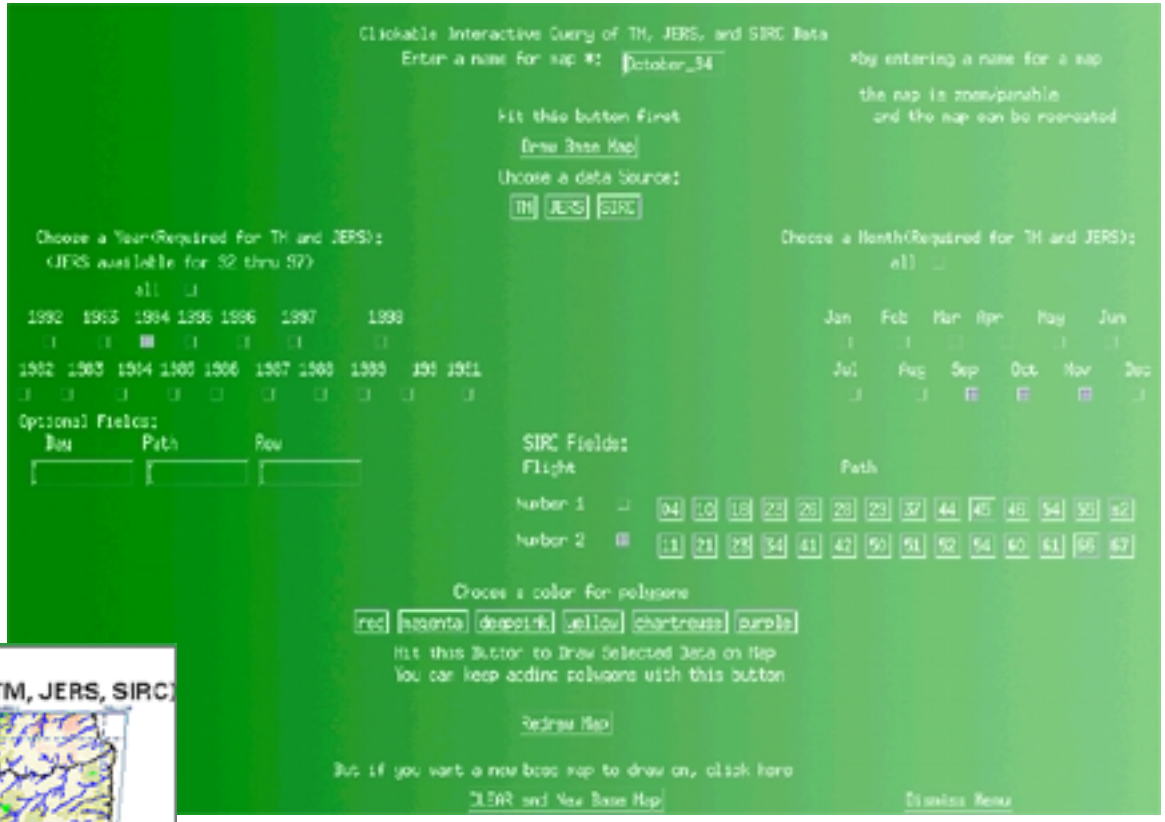
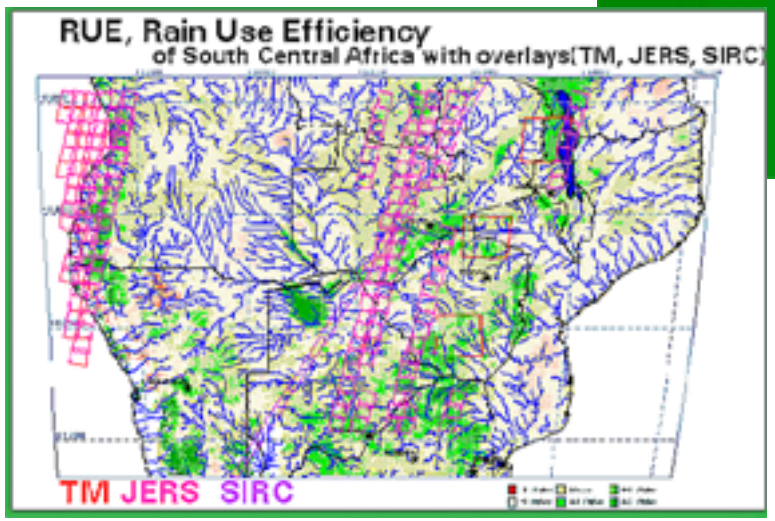
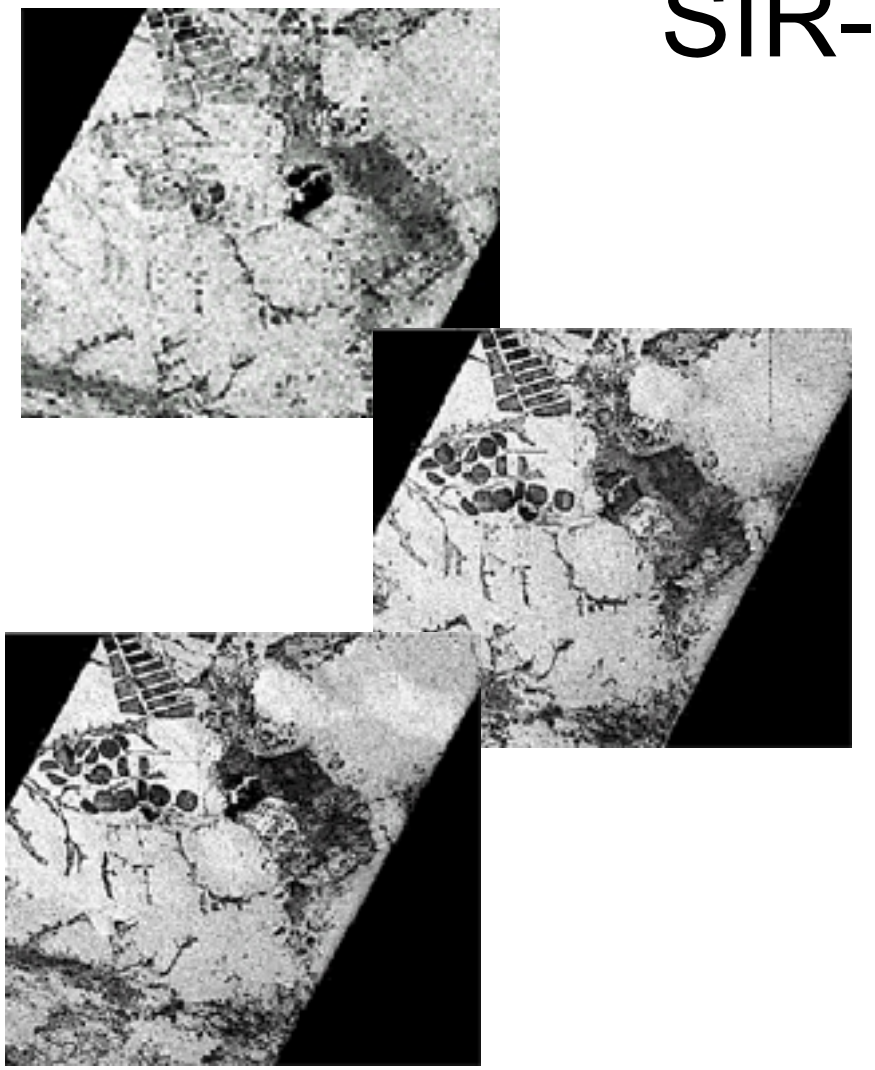
High Resolution Remote Sensing

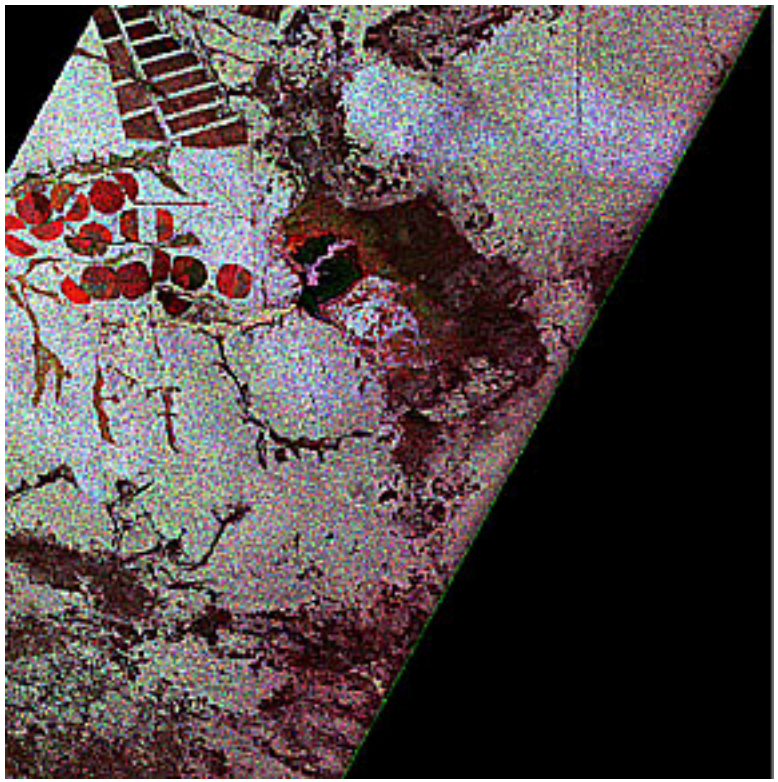
Database


Clickable Interactive Query of TM, JERS, and SIRC Data
Enter a name for map #:
October_94
Hit this button first
Draw Base Map
Choose a data Source:
TM
JERS
SIRC
Choose a Month(Required for TM and JERS):
all
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Optional Fields:
Row
Path
SIRC Fields:
Flight
Path
Number 1
Number 2
Choose a color for polygons
red
magenta
dodgerblk
yellow
chartreuse
purple
Hit this Button to Draw Selected Data on Map
You can keep adding polygons with this button
Redraw Map
But if you want a new base map to draw on, click here
CLEAR and New Base Map
Dismiss Menu

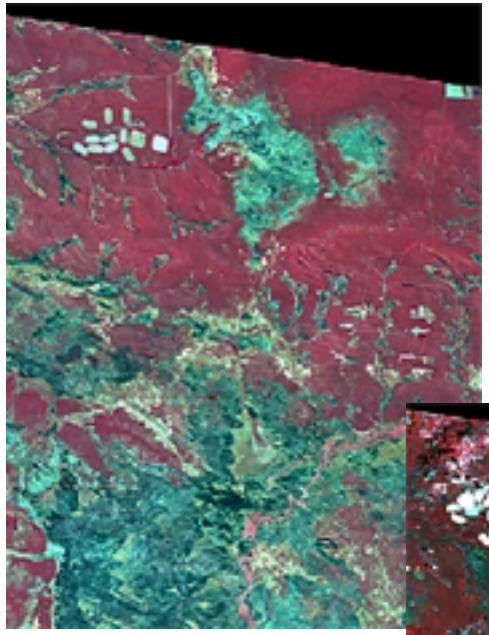

RUE, Rain Use Efficiency
of South Central Africa with overlays(TM, JERS, SIRC)
TM JERS SIRC

SIR-C

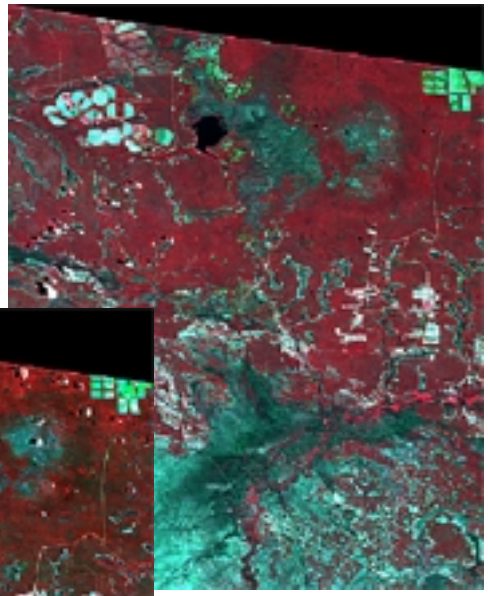




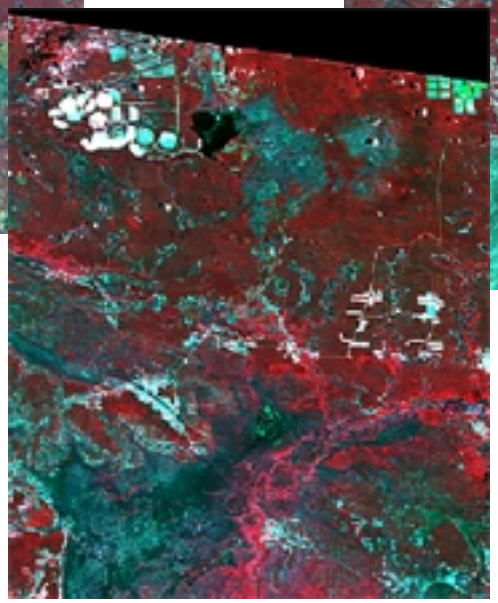
- 3 TM images & SIR-C 3-band image of Muncumpua, Zambia



1984

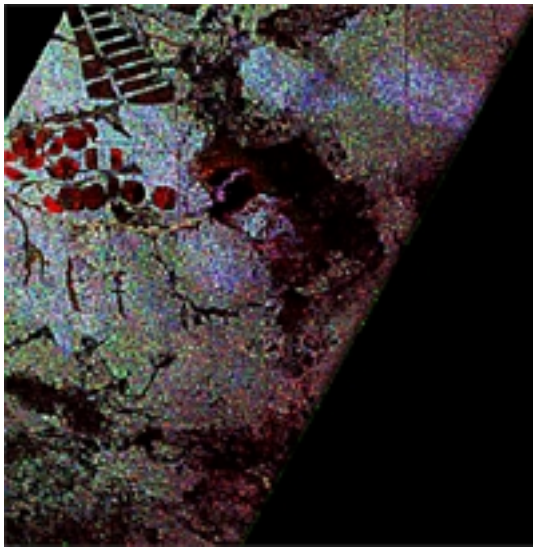


1994



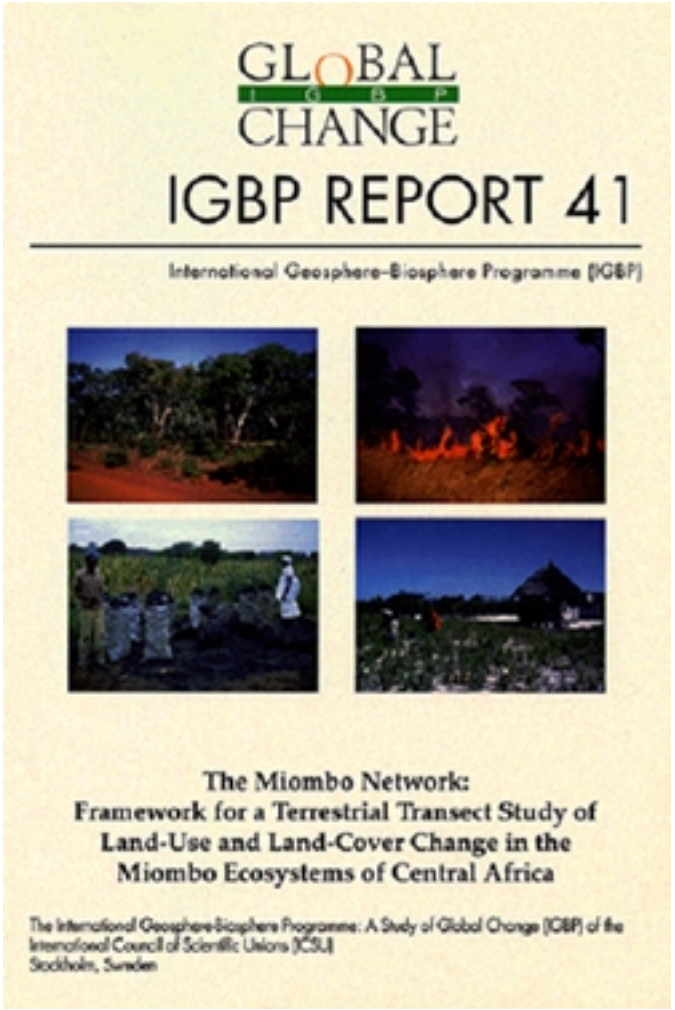
1986

SIR-C



Field Studies

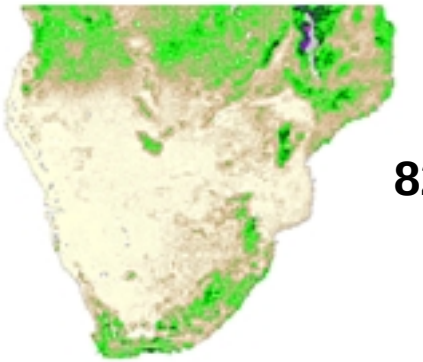
Miombo Network



Net Primary Production

Results: NPP

7 years NPP



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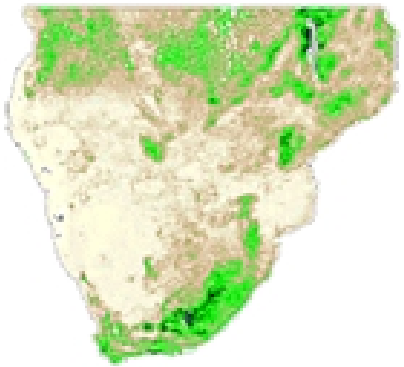

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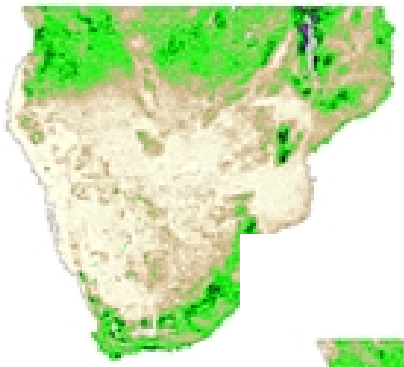
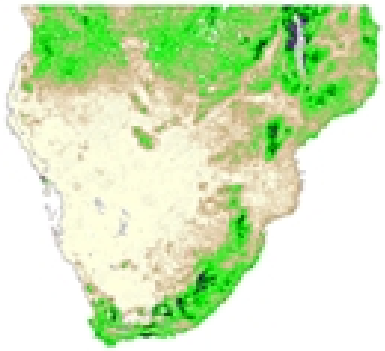


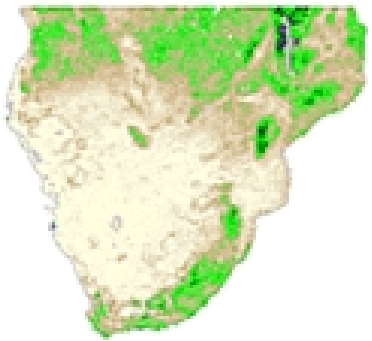
83-84

87-8_

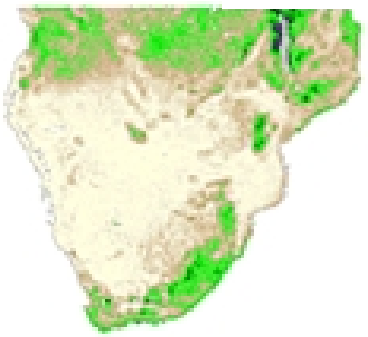
84-85



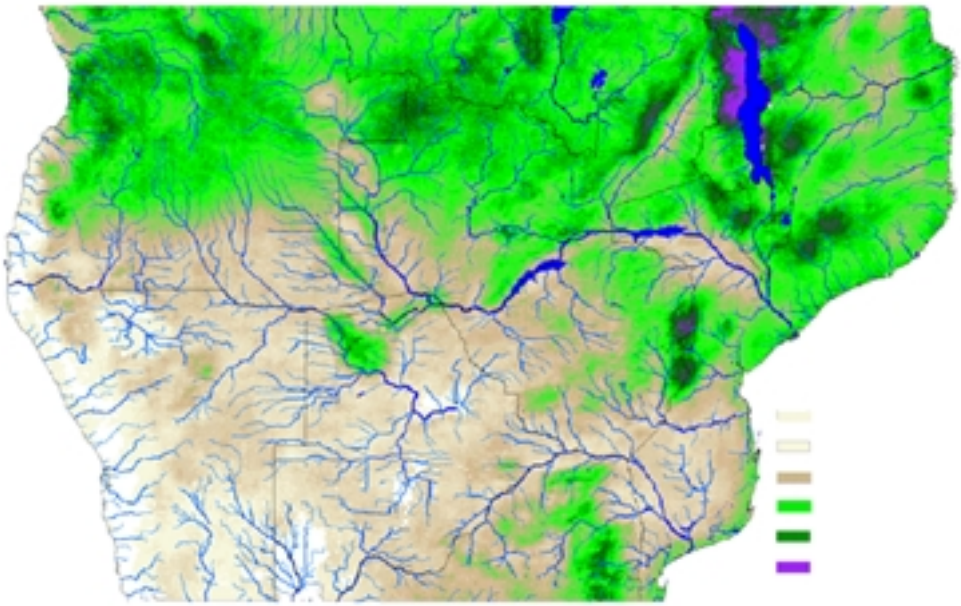
85-86



86-87



Mean NPP

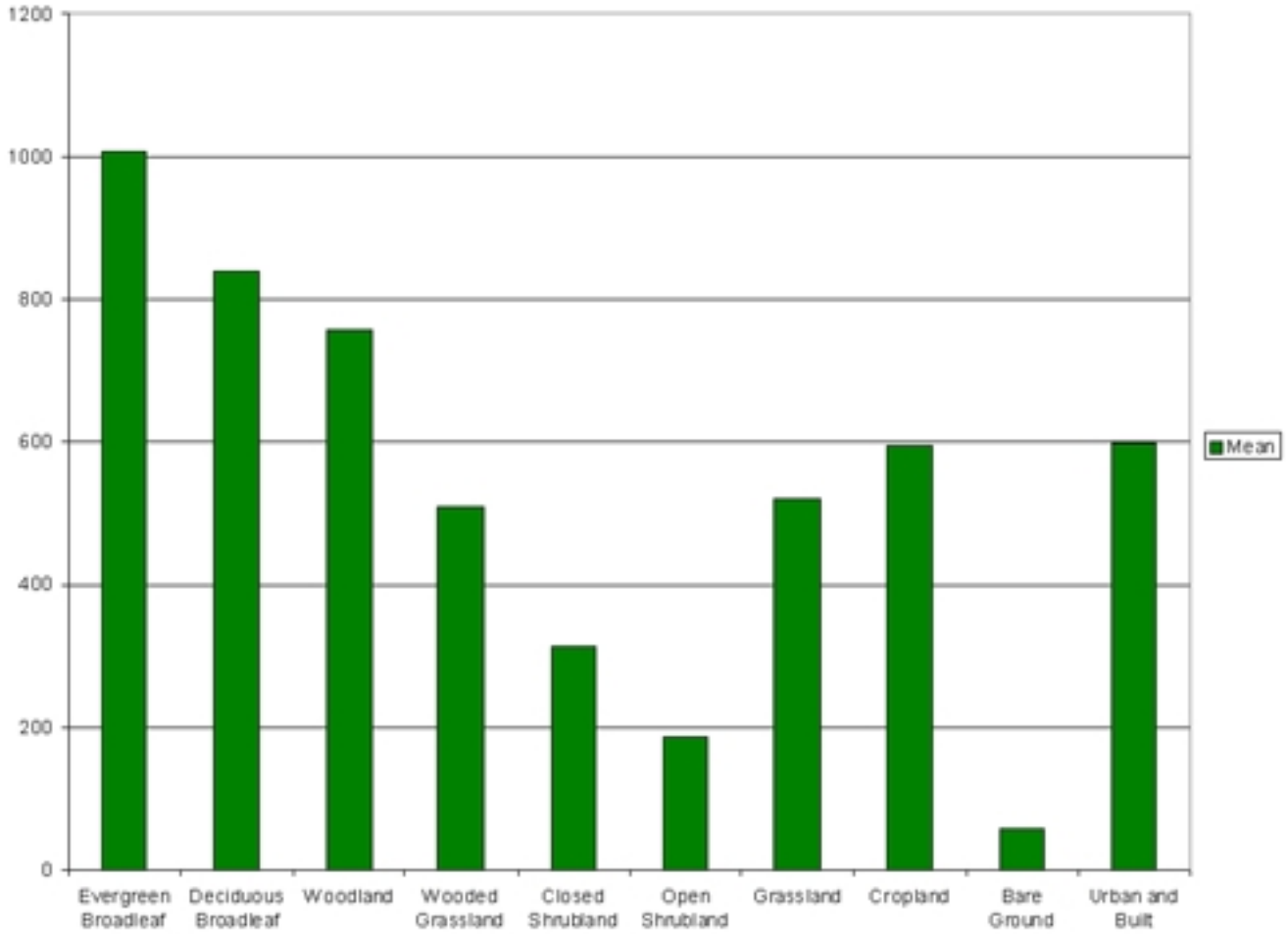


Mean NPP from 1982 to 1989

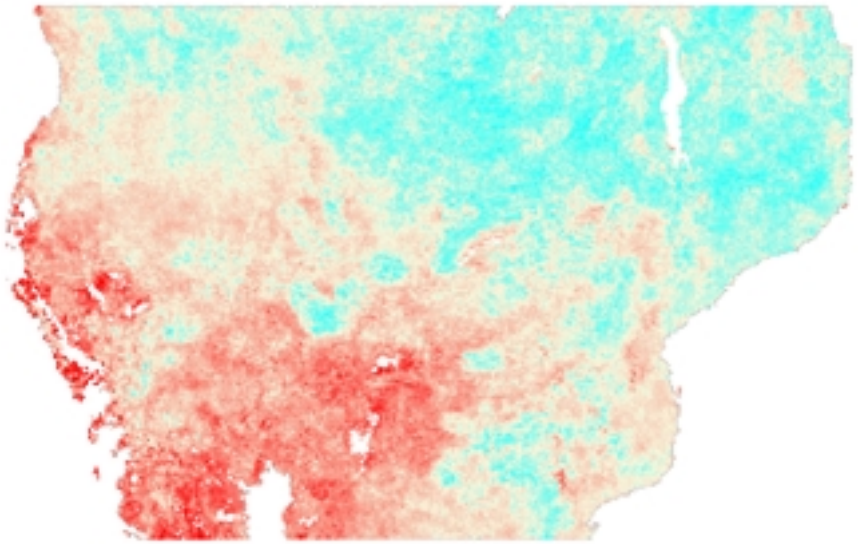
NPP g/m2/yr
7
118
452
780
1014
1500

Results: NPP

Mean npp by land cover class



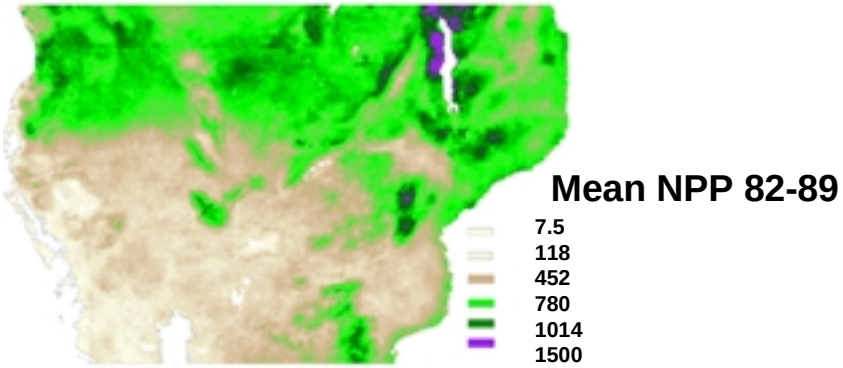
Coefficient of Variation of interannual NPP



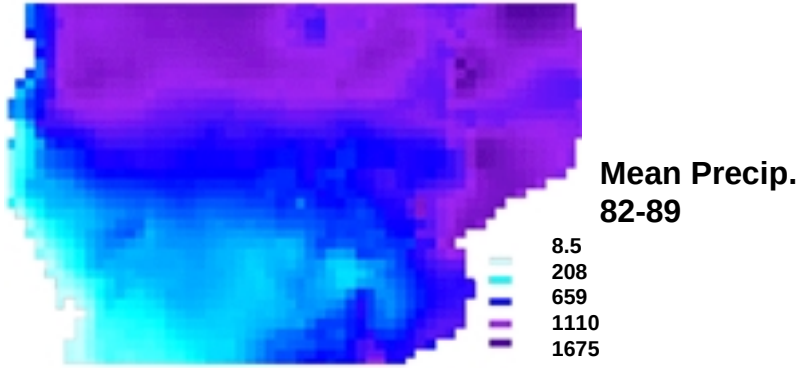
RUE- overall assessment of performance as a measure of degradation

Normalizing effect of rainfall on regional NPP

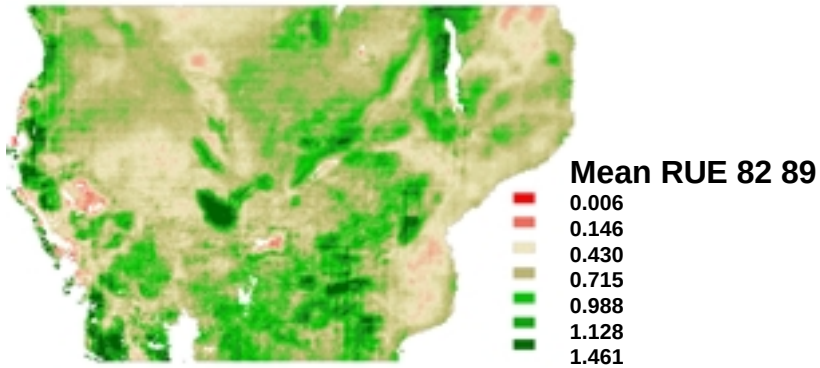
Mean NPP



Mean precipitation

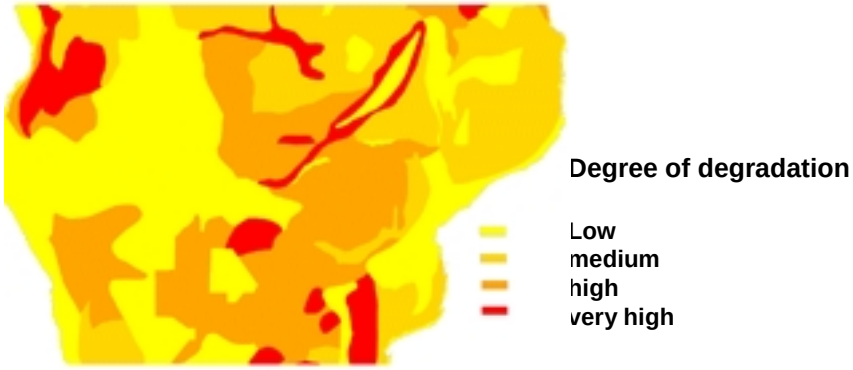


Mean RUE

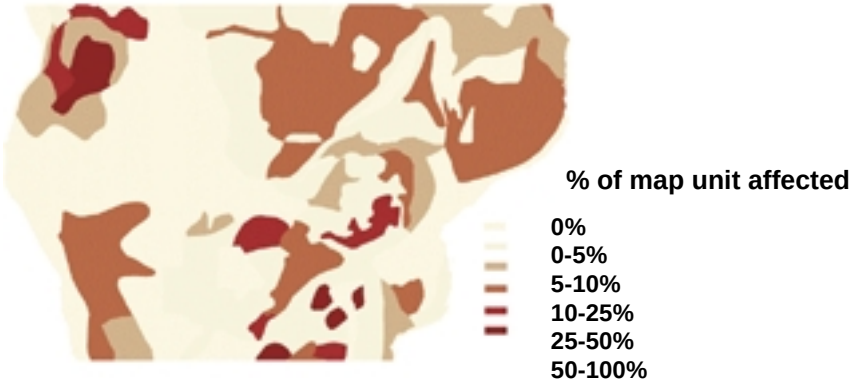


Areas of agreement, low RUE

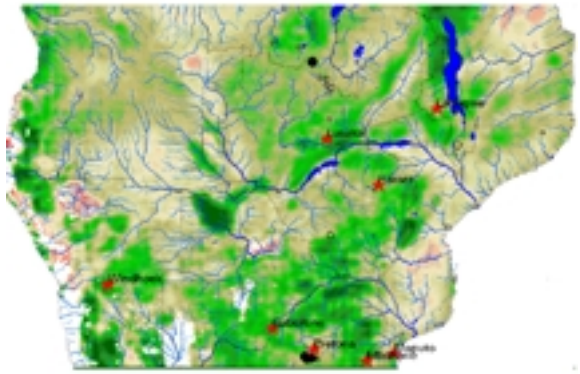
Degree of human induced soil degradation



Extent of human induced soil degradation

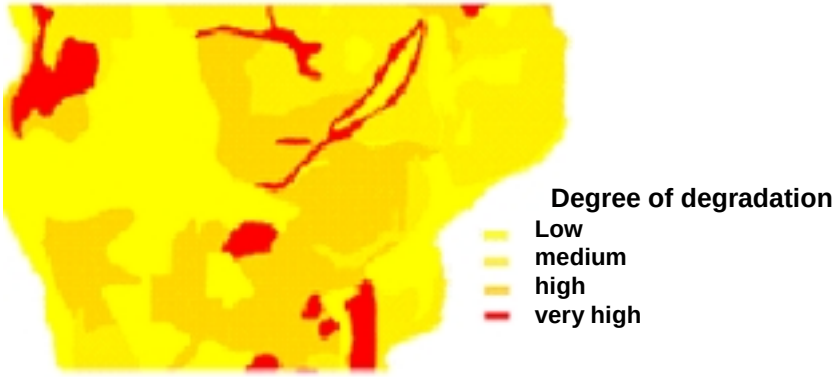


1. Congo Shaba Province
2. Zambia Copperbelt
3. Botswana NE, Mkgadikgadi
4. Nambia N Windhoek
5. RSA N of Mbabane, Pretoria
6. Zimbabwe N & E borders
7. Angola Huambo

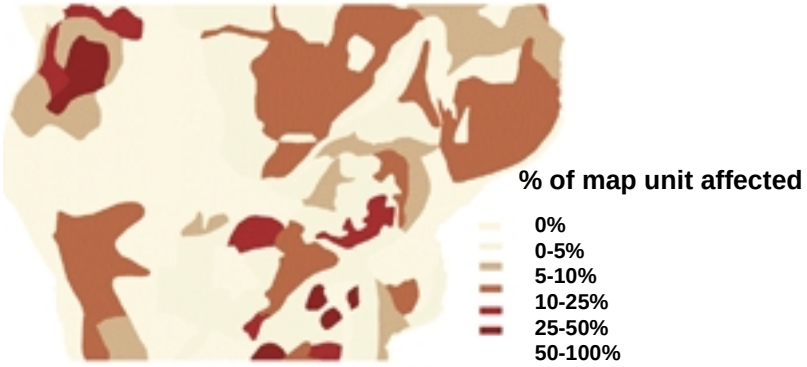


Areas of agreement, high RUE

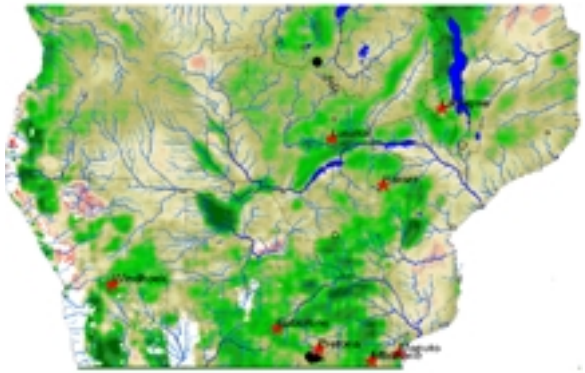
Degree of human induced soil degradation



Extent of human induced soil degradation

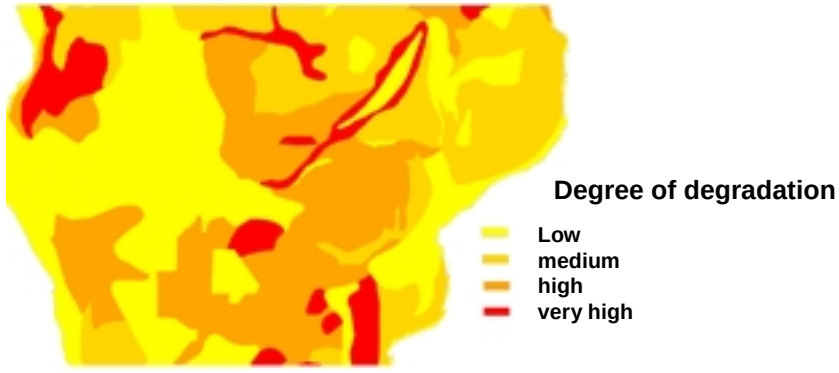


1. Malawi N Province
2. RSA Nylsstroom Transvaal, N Drakensberg
3. Zimbabwe Metabeleland
4. Namimia E of Windhoek

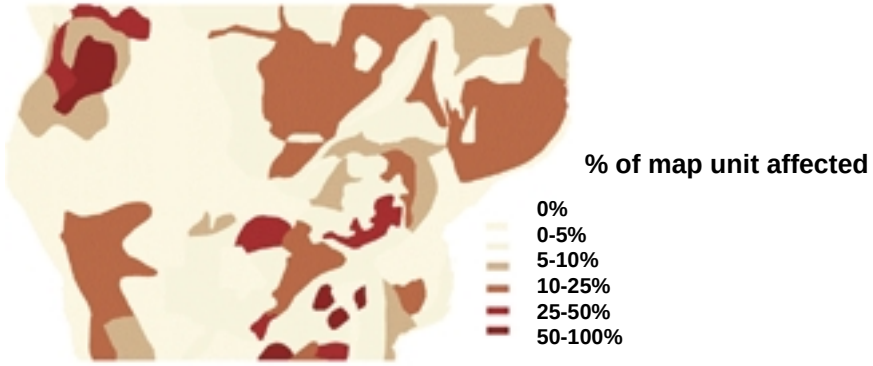


Areas of Disagreement
RUE low/GLASOD not degraded

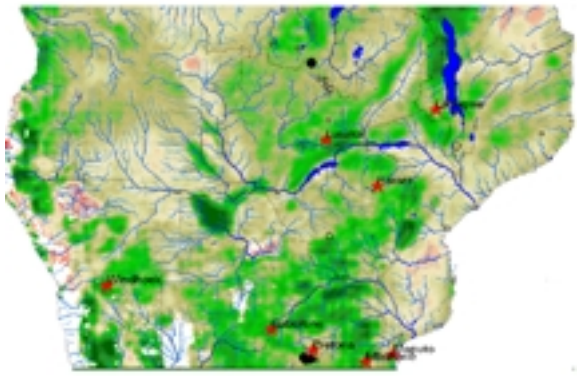
Degree of human induced soil degradation



Extent of human induced soil degradation

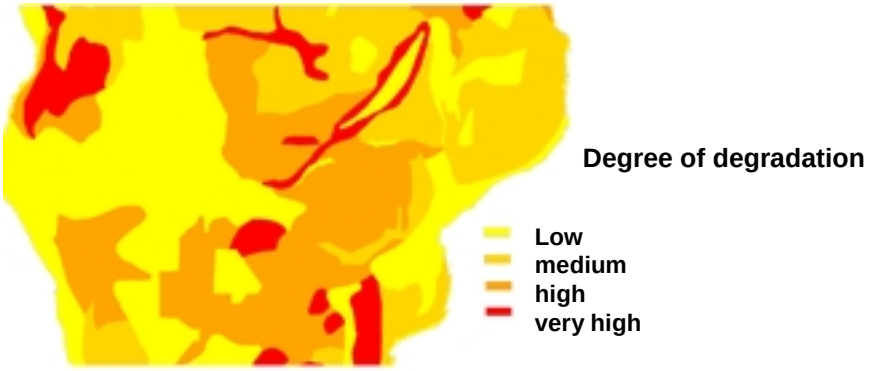


1. Zambia Luangwa Valley
2. Mozambique Tete Province
3. Botswana Chobe Province
4. Nambia/Angola Herero/Cubango
5. Mozambique Sofala-Imhambane

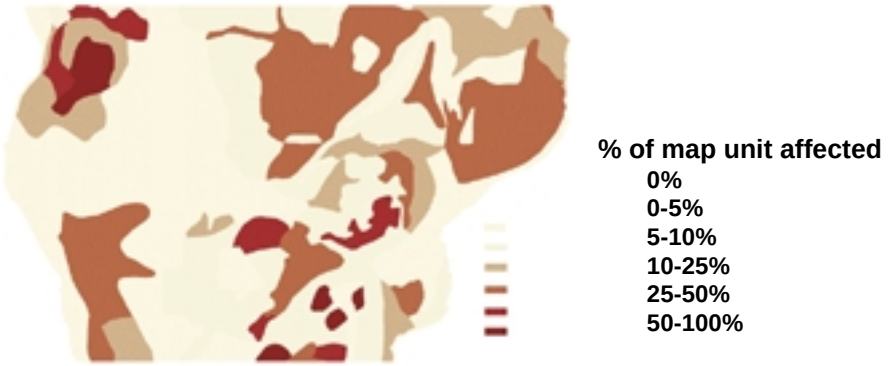


Areas of Disagreement
RUE high/GLASOD degraded

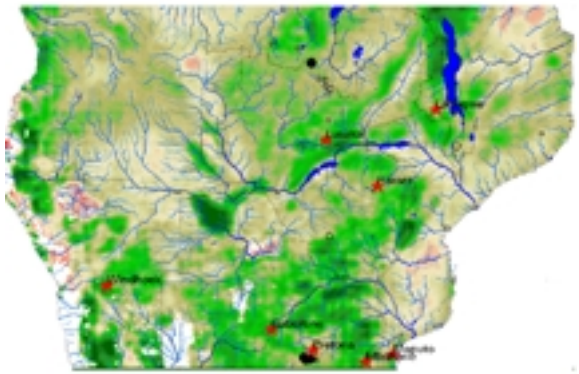
Degree of human induced soil degradation



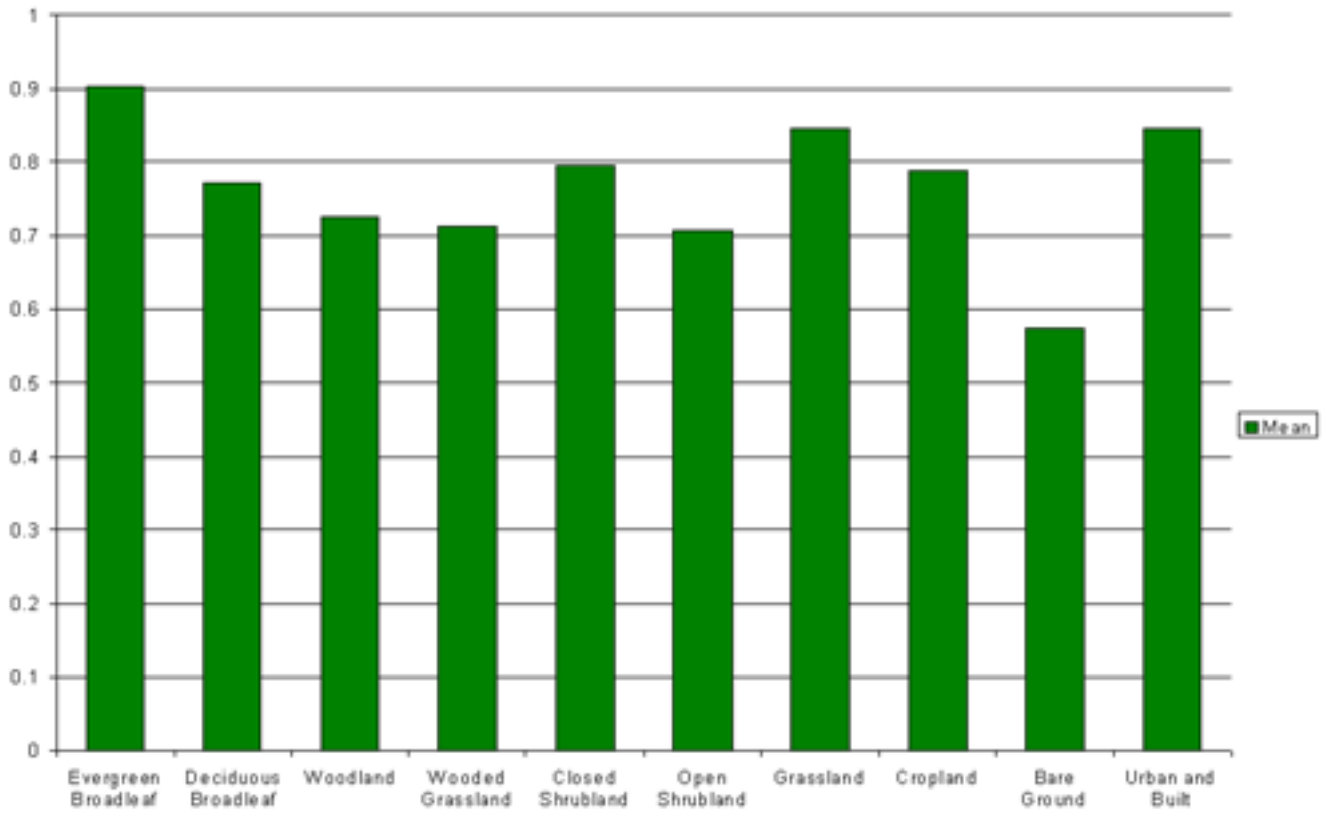
Extent of human induced soil degradation



1. Zambia, Luangwa Valley escarpments



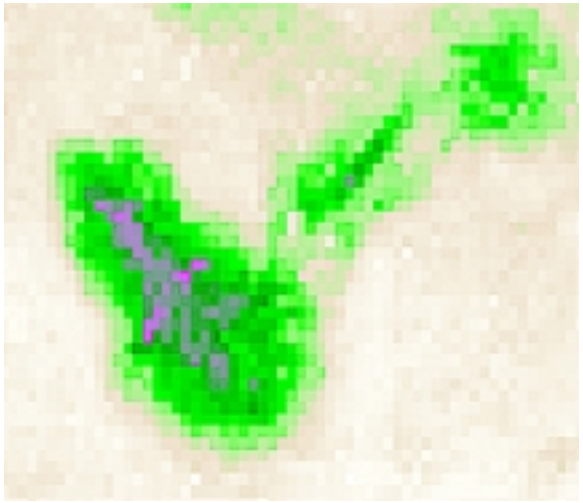
Mean rue by land cover class



Interpretation of rue in southern central Africa

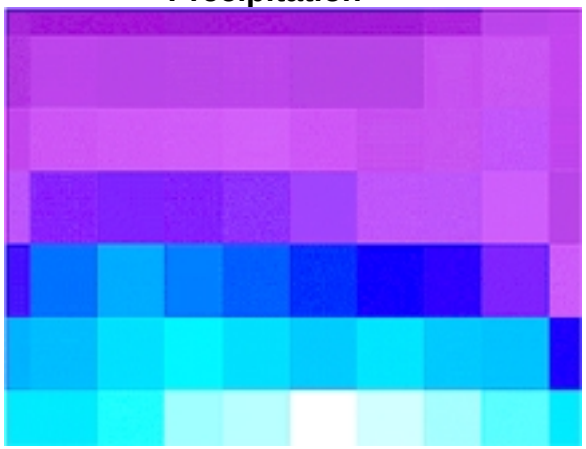
Results: RUE

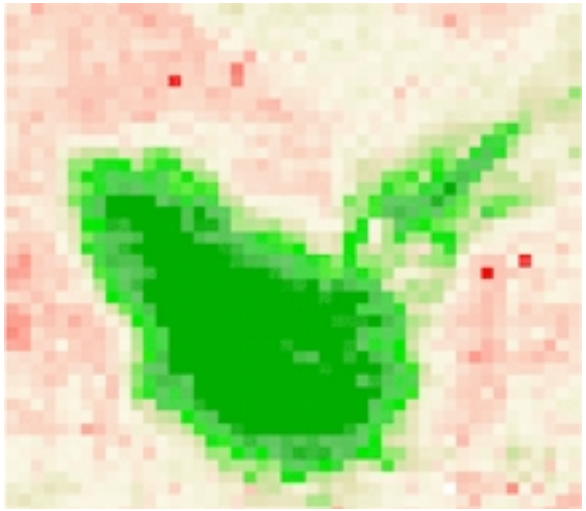
Not degraded: high rue caused by run-on of water from elsewhere



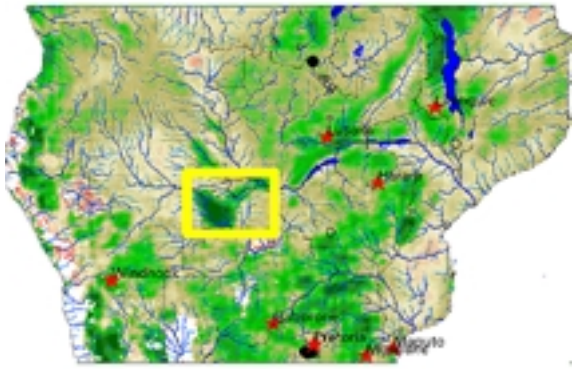
NPP

Precipitation



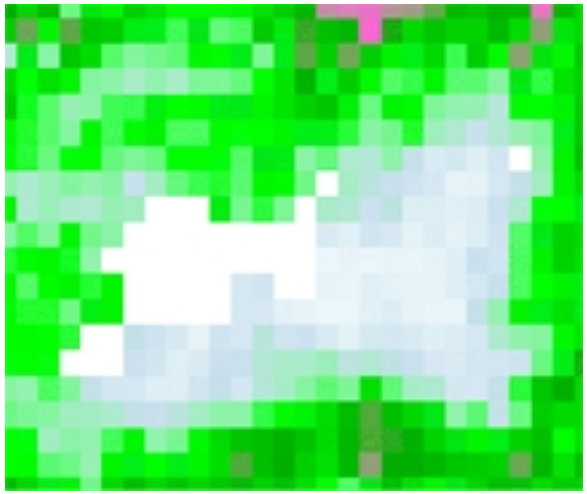


RUE



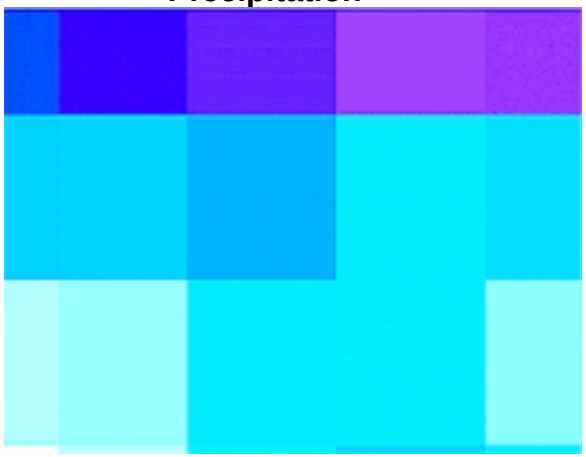
Results: RUE

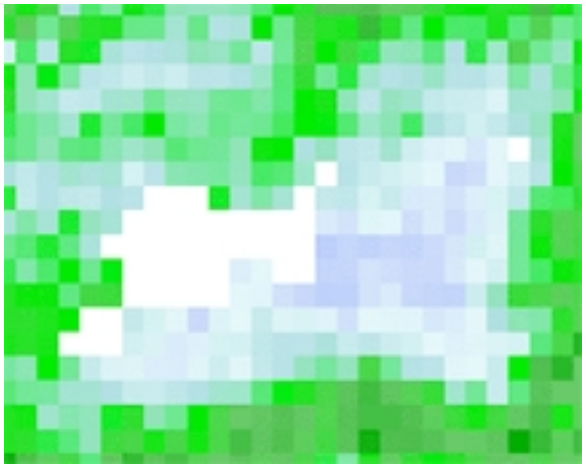
Degraded: naturally susceptible regions Mkgadikgadi pans region



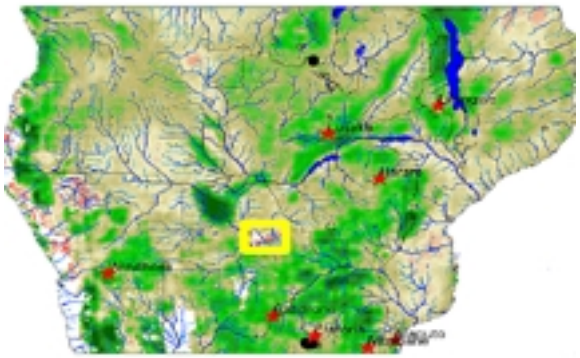
NPP

Precipitation





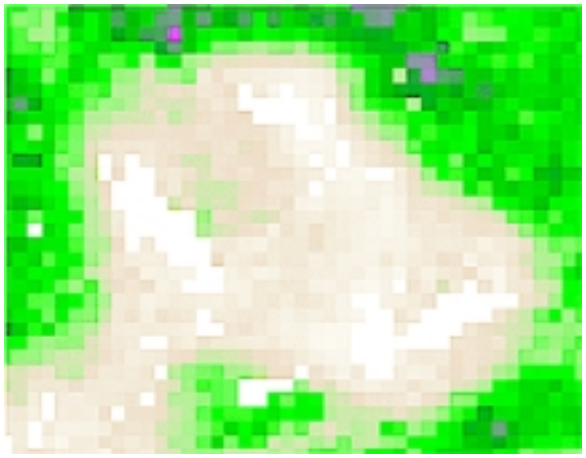
RUE

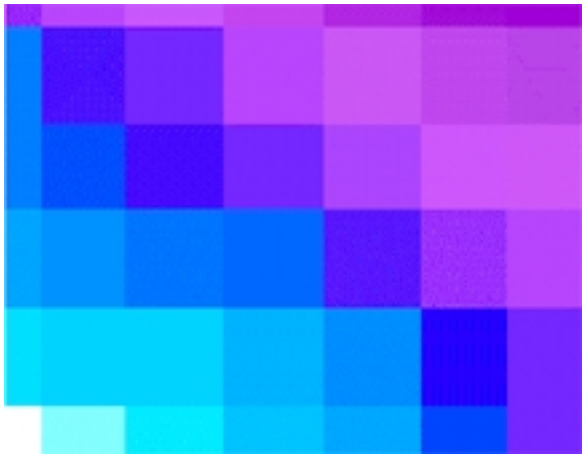


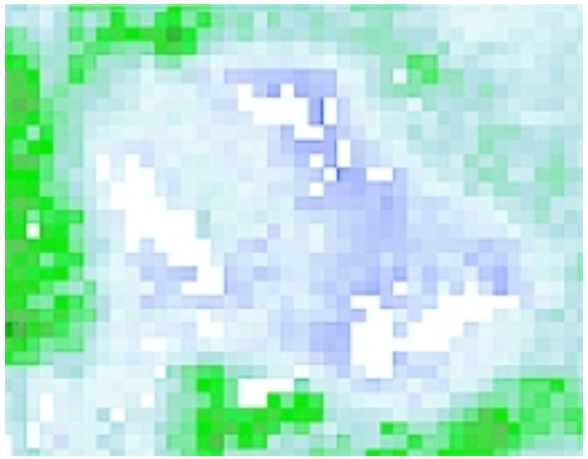
Results: RUE

Degraded: naturally susceptible regions Etosha pan region

Precipitation

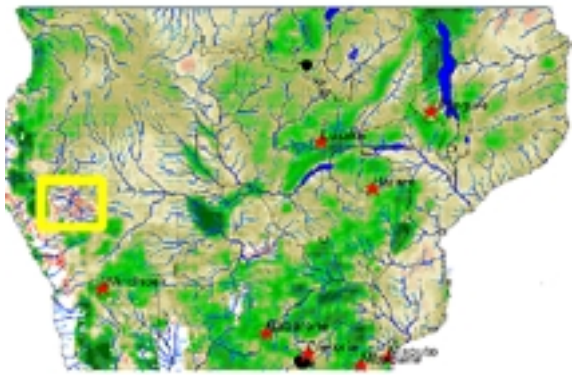






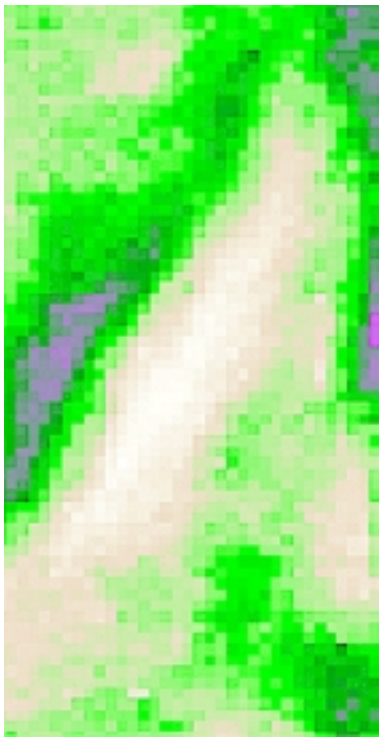
RUE

NPP



Results: RUE

Degraded: naturally susceptible regions Luangwa valley



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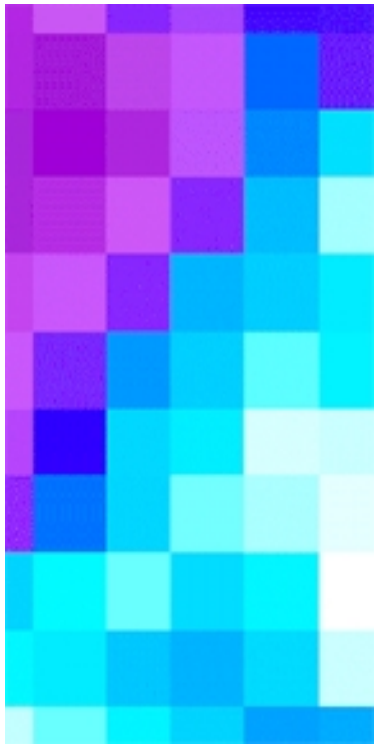
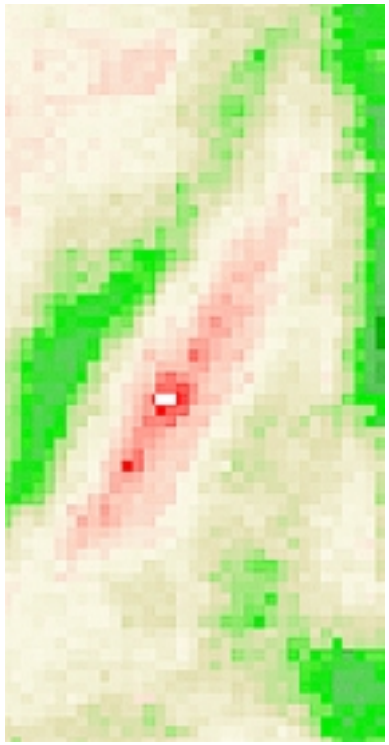


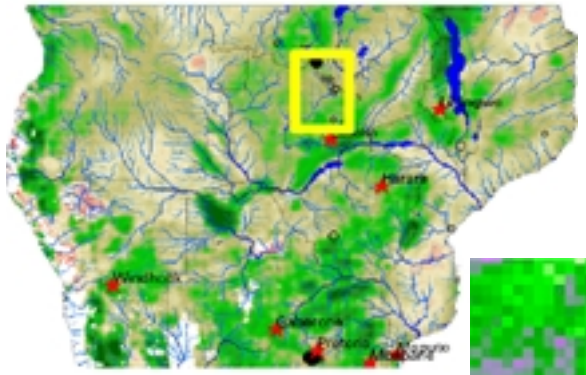
Precipitation

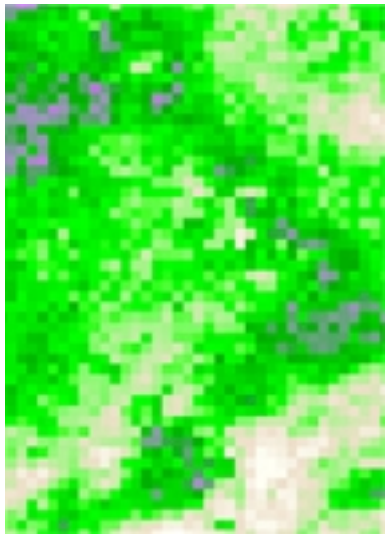


RUE

Results: RUE

Degraded: human induced Zambian Copperbelt





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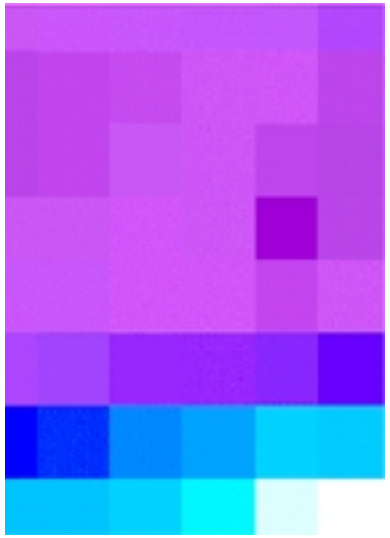

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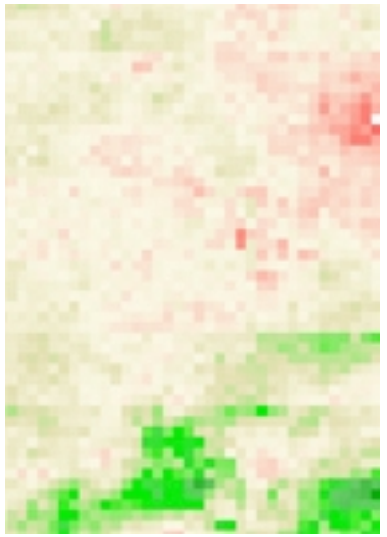
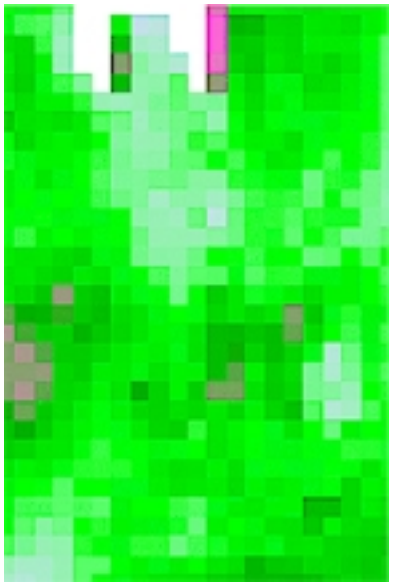


RUE

Results: RUE

Degraded: human induced Malawi Namwera highlands



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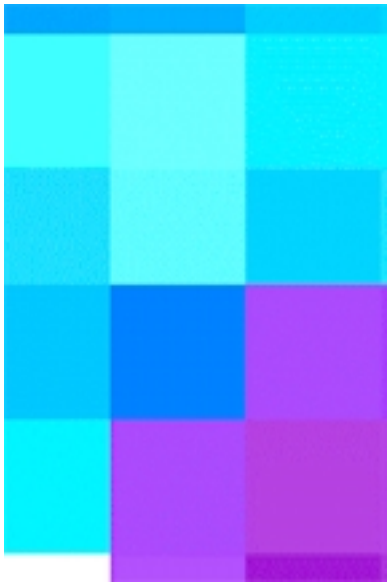

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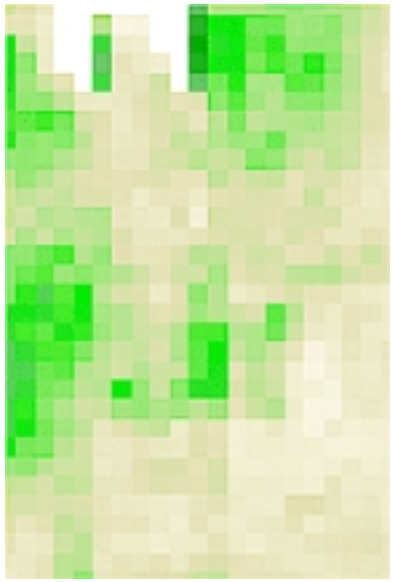
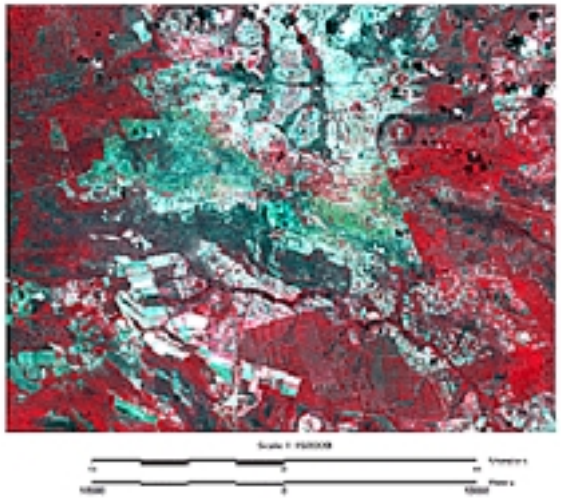


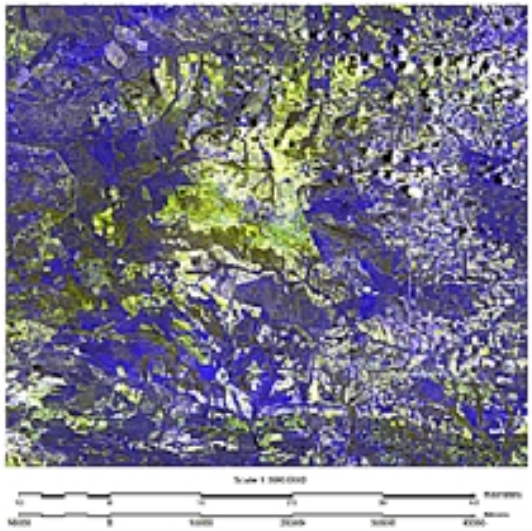
RUE

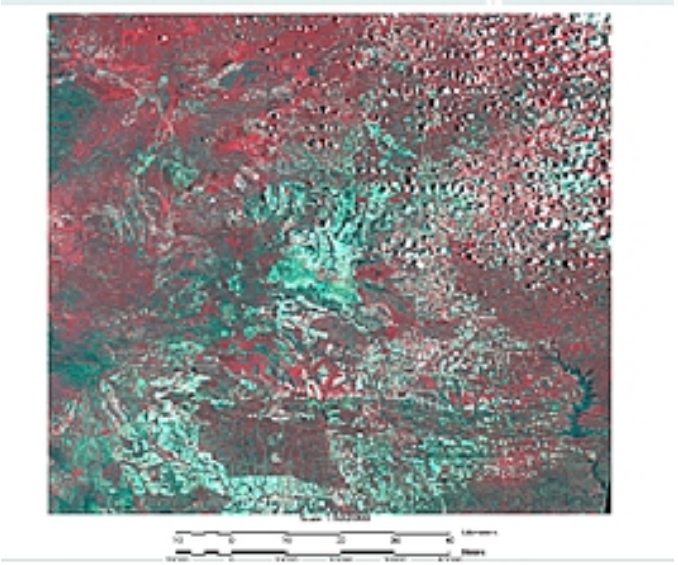
High Resolution Degradation Features

Degradation at Kabwe, Zambia

- 1986 17 Nov TM







Next Steps

Potential for local - Sub-national scale interpretation

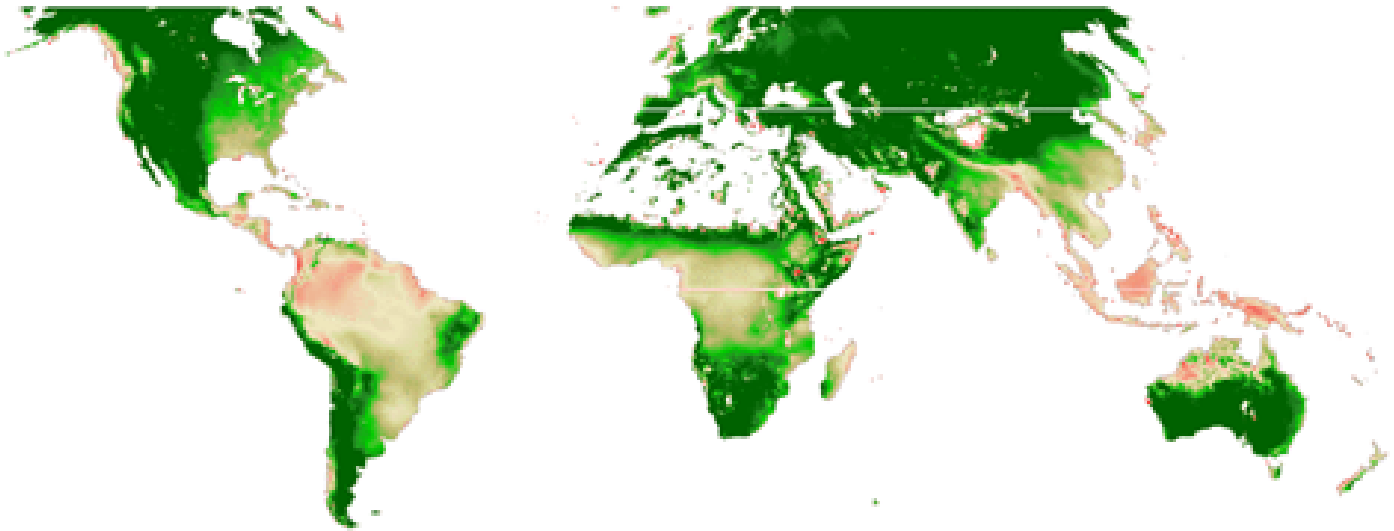
AIM FOR FINER SPATIAL RESOLUTION

- Rainfall data
  - Raingauge network
  - Geostationary meteorological satellite
  - Separate soil moisture and runoff from rainfall
- NPP
  - PAR 30-100 km multi-annual from METEOSAT
  - 1-8 km AVHRR or MODIS/ASTER data
- Air temperature
  - Diurnal Ta (METEOSAT)

Potential for field scale interpretation

- Comparisons with local degradation studies
  - Miombo network partners
  - Regional issues
    - e.g. Gwembe Valley, Botswana rangelands, Copperbelt
- Identify sources of site biophysical data
  - Local scale modeling
  - Comparison with coarse resolution satellite inferences
- Explore integrated assessments
  - Multiple resolution data sets for participants

Potential for global scale interpretation



Integrated assessment and degradation monitoring

Integrated Assessment

Strategy for addressing complex problems across scales

Land cover, land use
in southern Africa

Integrated Assessment

Definition:

An interdisciplinary and participatory process
of combining, interpreting, and communicating
KNOWLEDGE from diverse scientific disciplines to
achieve a better understanding of complex phenomena

Integrated Assessment

Objective:
to arrive at an informed judgement

Relevant Information: physical, chemical, biological, psychological, socio-economic, and institutional phenomena

Integrated Assessment

Southern Africa

Example:

Gwembe Tonga - Lake Kariba region - Zambia
Building on work by Thayer Scudder and Elizabeth Colson

- Long historical record
- Focussed studies of agricultural traditions
- Forced migration
- Adjustment to new biophysical environment

Allocative Resources:
- Grazing Land
- Agricultural Land
- Livestock
- Crops

Authoritative Resources
- Decision-makers
- Land tenure
- Commercial crop vs subsistence

Integrated Assessment

Methods

Existing Information or studies
Rapid Rural Appraisals
Participatory Rural Appraisals

Discussions with stakeholders in the local areas
•Focus on how they handle uncertainty and
•Issues of equity

Broad Categories
•regional economy
•conflict resolution
•government and NGO organizations
•Household interactions
•Agricultural networks

Integrated Assessment