

# **Deforestation and Degradation in Southern Central African savannas**

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

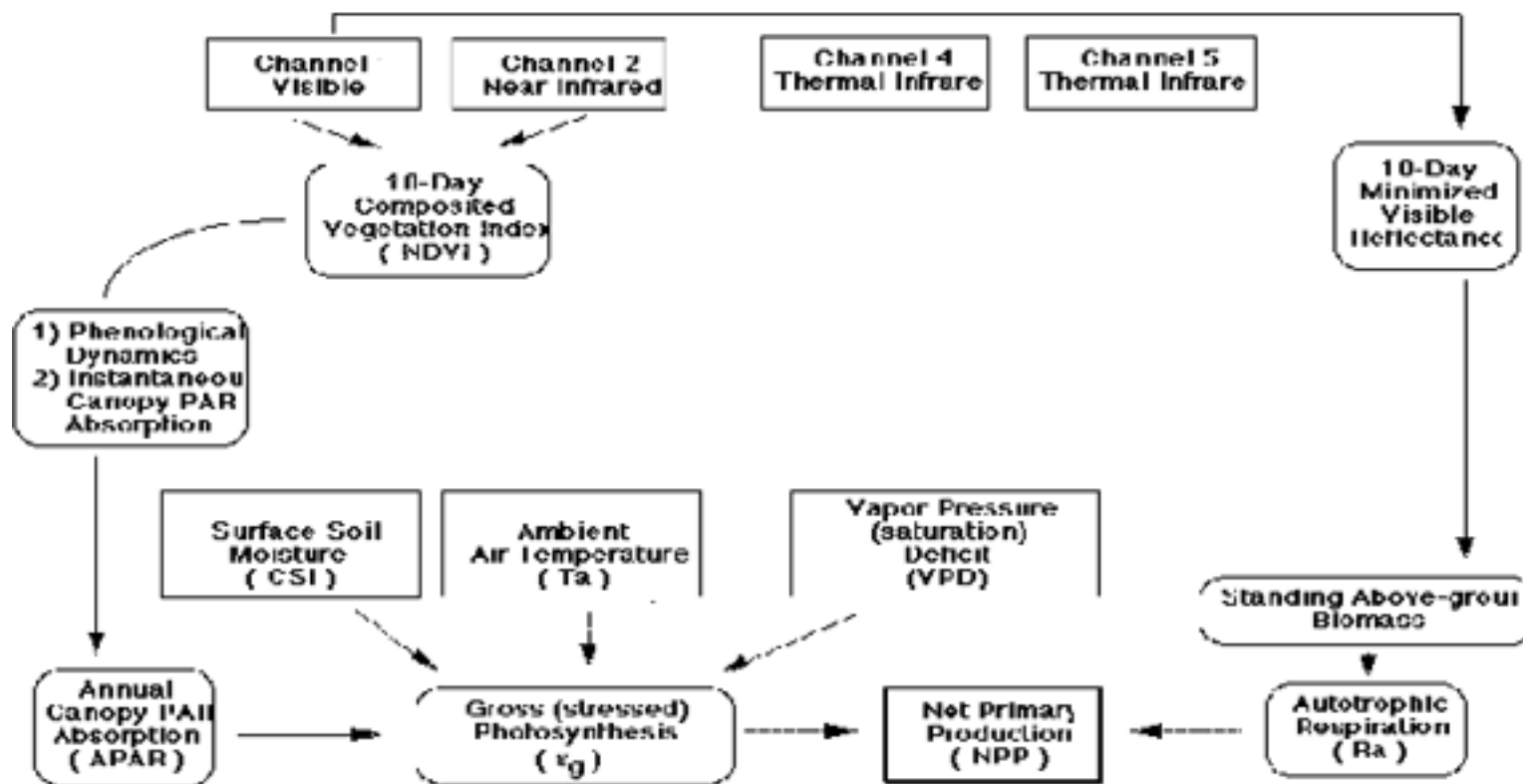
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## NPP monitoring using GLO-PEM model

# Model Outline

GLOBAL PRODUCTION EFFICIENCY MODEL (GLO-PEM)  
REMOTE SENSING OF CANOPY LIGHT ABSORPTION,

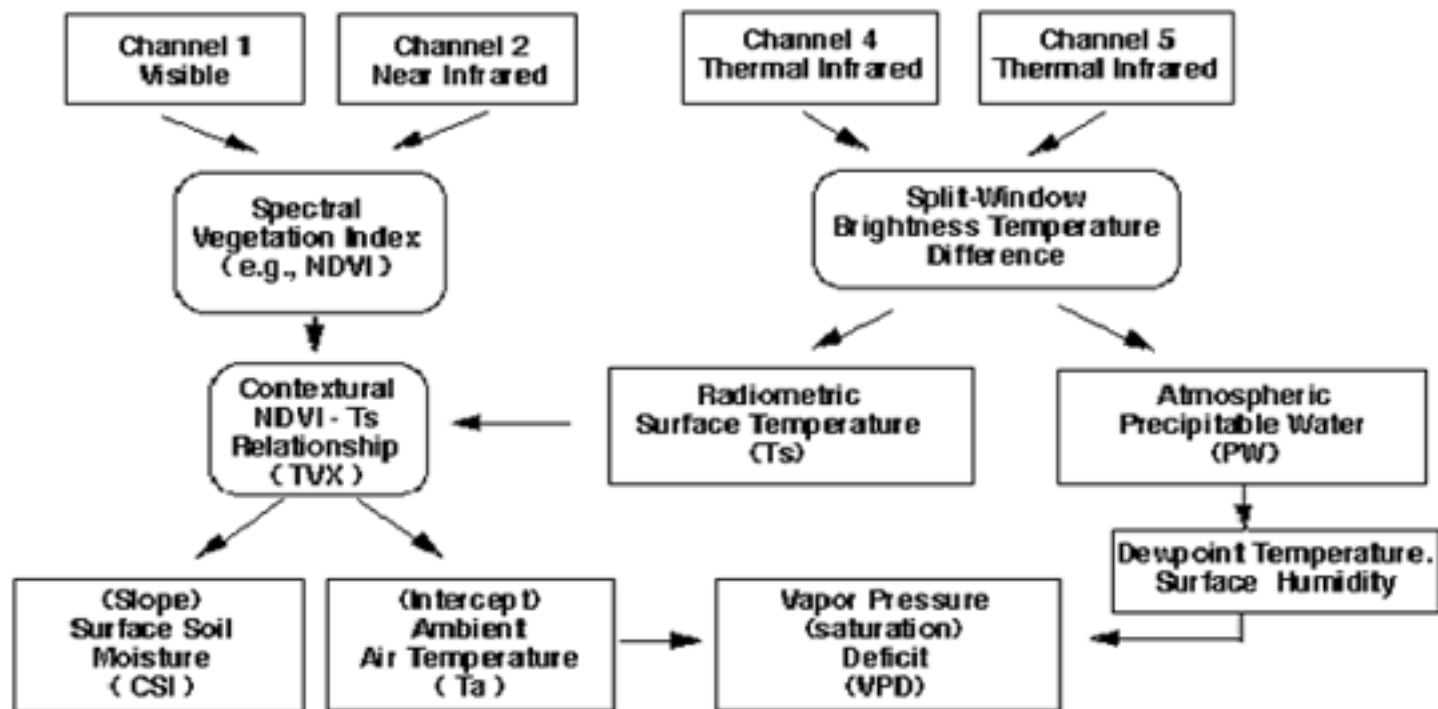
GROSS AND NET PRIMARY PRODUCTION  
(<http://www.geog.uiowa.edu/glopem/>)



## NPP monitoring using GLO-PEM model

# Model Outline

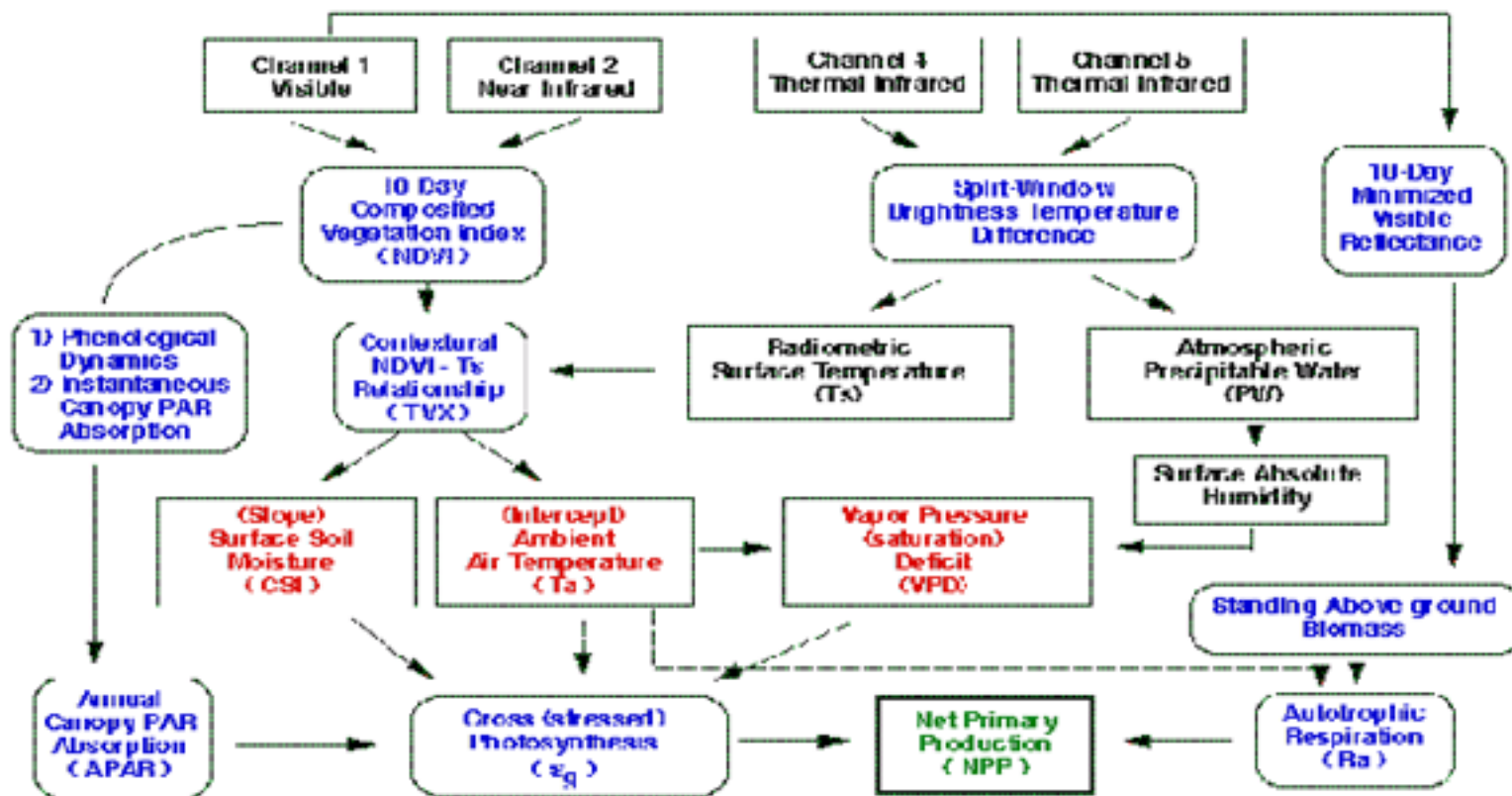
GLOBAL PRODUCTION EFFICIENCY MODEL (GLO-PEM)  
REMOTE SENSING OF ENVIRONMENTAL VARIABLES..



## NPP monitoring using GLO-PEM model

# 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 ( $T_a$ )
- $T_a$  inferred from TVX relationship, except where:
  - Slope is flat or positive:  $T_a = T_s - 1\text{stdev}$  (or)  $T_s$  @ NDVI avg
  - $R^2 < 0.5$ ; small sample size or variance of  $T_s$  or NDVI low
  - Other conditions apply / thresholds are exceeded
    - (e.g., clouds, sparsely vegetated areas)
- $T_s$  calculated with new LUT approach
  - Varies with emissivity (CERES), atmos water vapor
  - Coeffs specific to AVHRR instruments (NOAA-7 to 13)



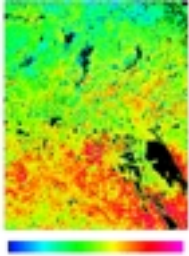
## New developments

- 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)

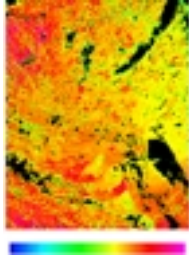
NPP monitoring using GLO-PEM model  
Validation: BOREAS

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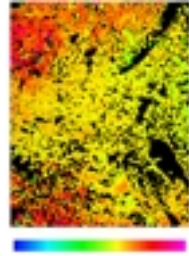
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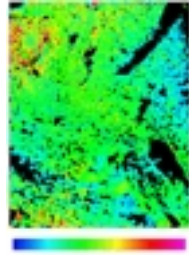
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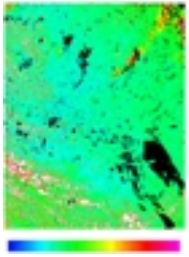
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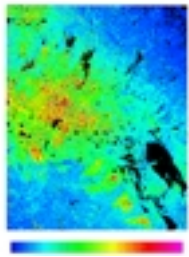
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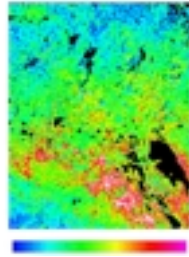
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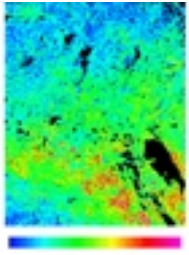
BOREAS



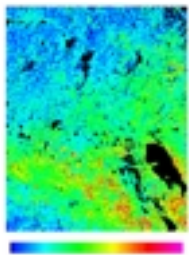
2000-2007



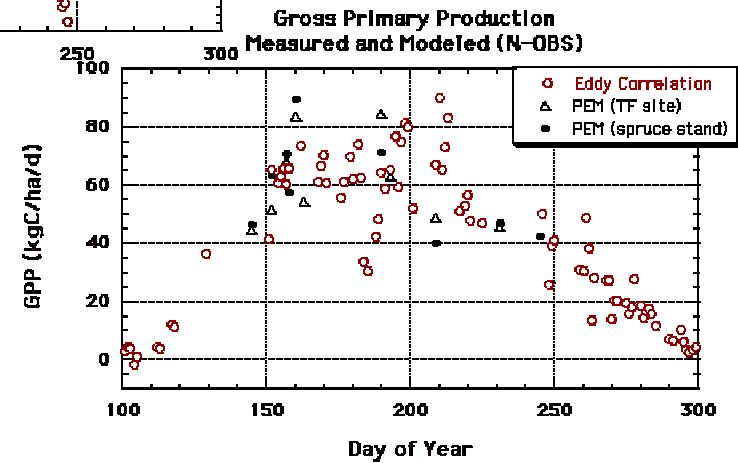
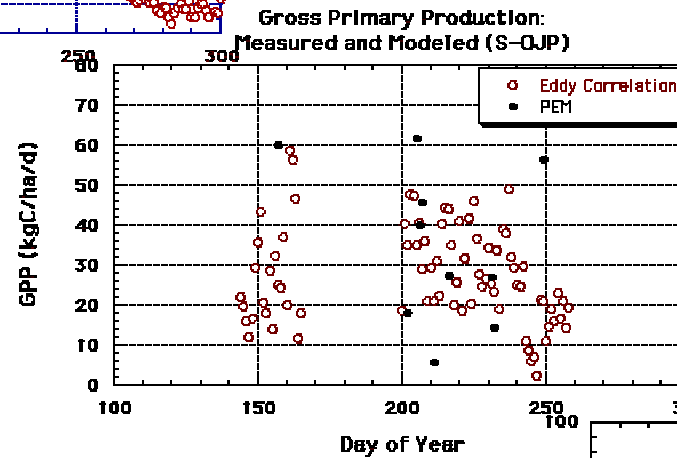
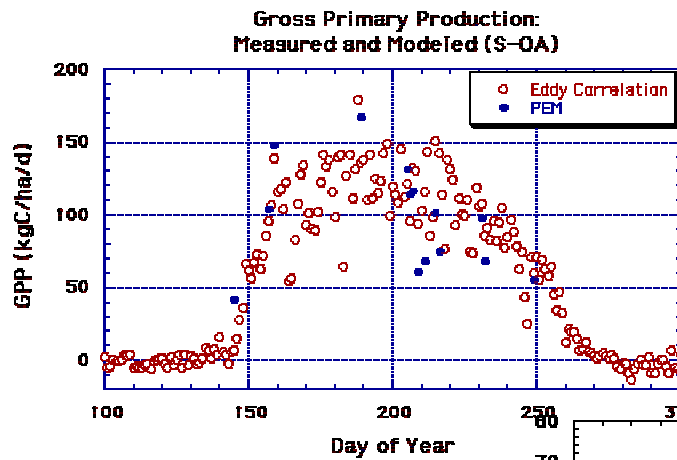
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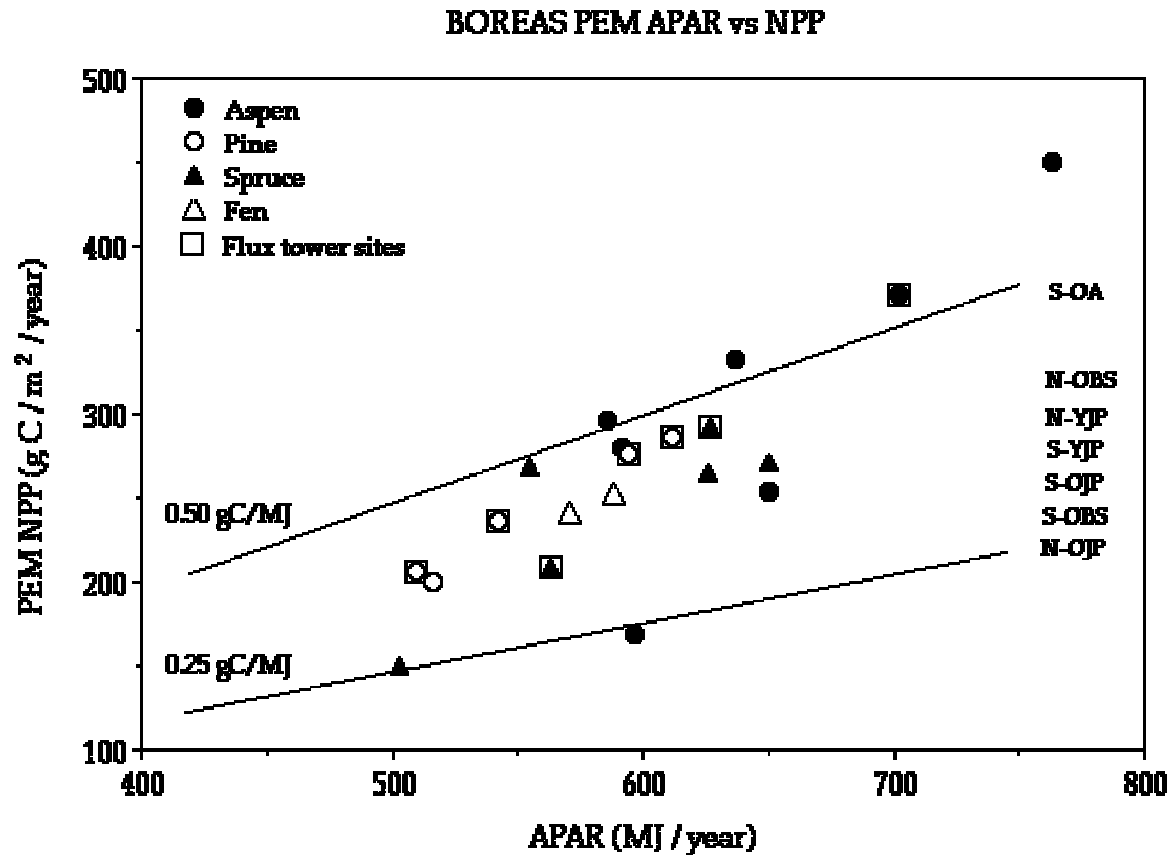
NDZ



# Validation of glo-pem npp model in boreas



# Glo-pem modeled light use efficiency in boreas



# PIK NPP Model Intercomparison

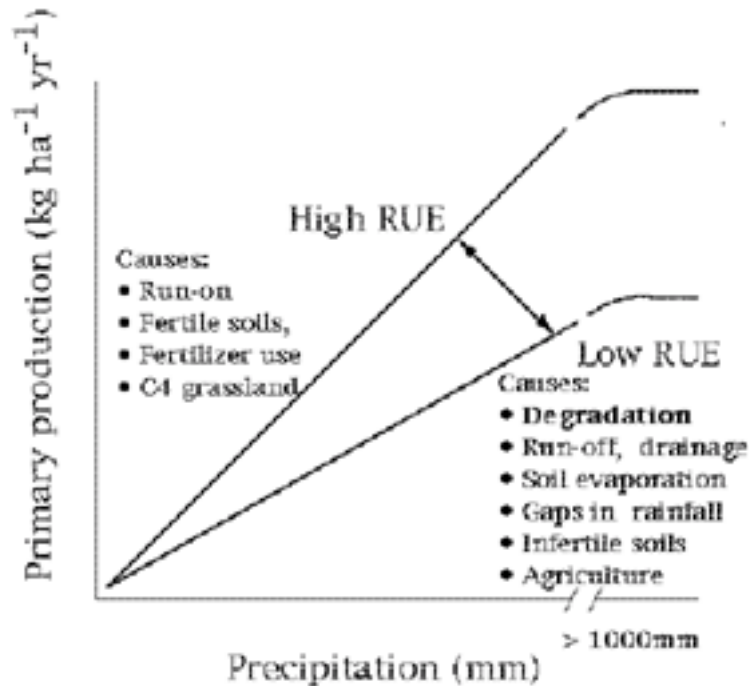


# Rain Use Efficiency Theory

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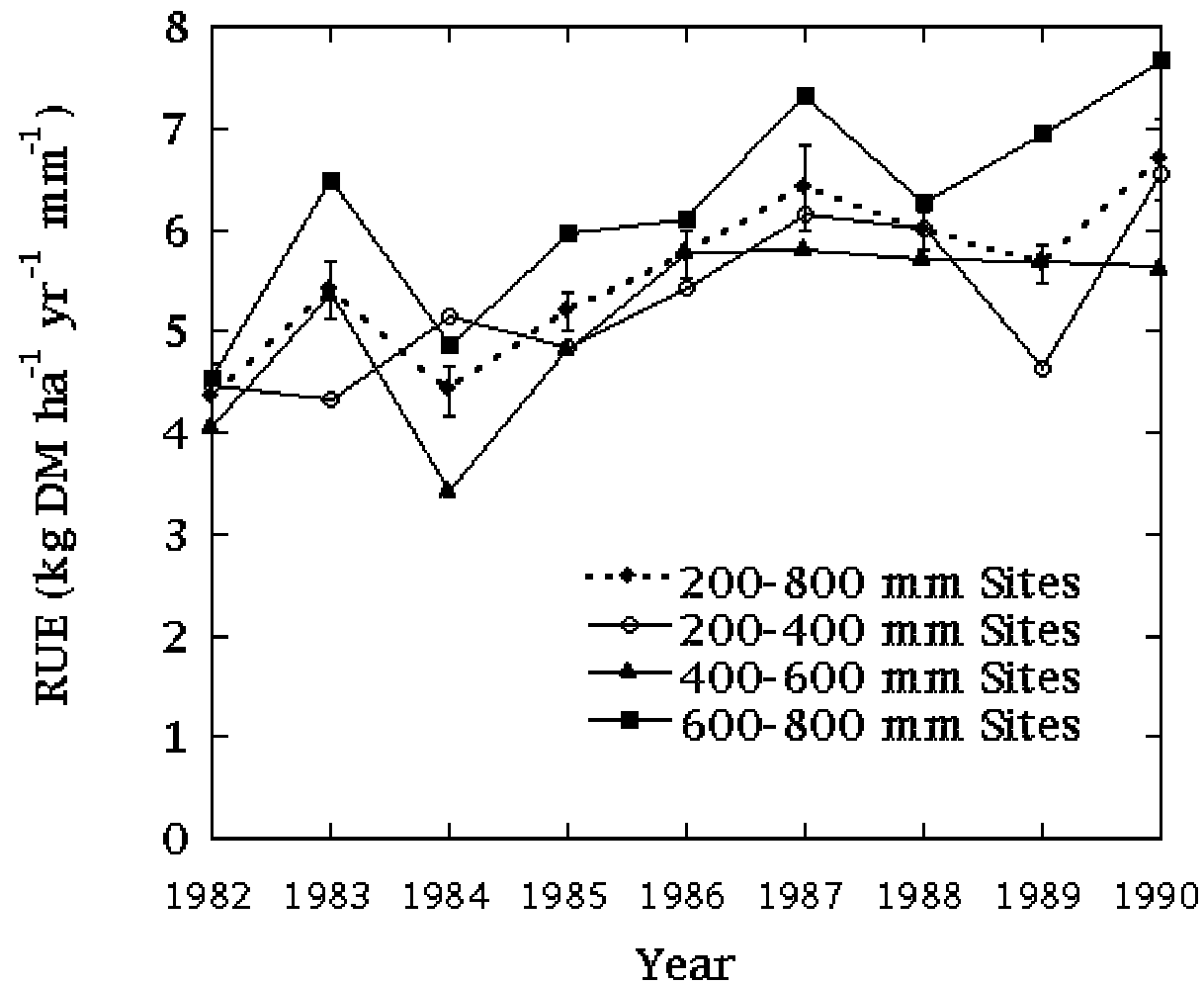
## Rain Use Efficiency Theory

# Outline of Theory



- $RUE = P_n / T = P_n / (T + E + I) + (D + R) + (\Delta W + \Delta W_p)$
- $P_n$  = 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
- $\Delta W$  = change in water content of the soil
- $\Delta W_p$  = change in water content of the vegetation

# Sahelian multitemporal results





# Rain Use Efficiency Theory

# Significance of RUE as an objective index of degradation

Global Change Biology (2008), 14, 209–221

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

S. D. PRINCE, E. BROWN DE COLSTOUN AND L. KRAYBILL  
Geography Department, University of Maryland, College Park, MD 20742–2028, USA

### Abstract

Desertification is regarded as one of the major 20th century and the African Sahel is often cited. Previous attempts to map the occurrence and have been unsatisfactory, mainly because of the indicators. We explore here the properties of the rain-use efficiency (RUE) index and rain gauge data. Negative RUE values are shown to be an indicator of the entire Sahel were possible using satellite data the 1981 drought. The results suggest that RUE reflected in only little variation in the RUE of the region, RUE seems to be in step with drought and not supporting the claim of widespread taking place in the 19-year period that is used systematic increase in RUE for the Sahel as a trend contained within the region did have positive. *Keywords:* AVHRR, degradation, desertification, rainfall, Sahel

### ECOLOGY

## The Sahara Is Not Marching Southward

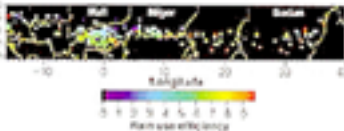
From a satellite perspective, the supposed steady encroachment of desert into Africa's Sahel appears instead to be a fluctuating climate variation

Twenty-five years ago, the Sahel—the narrow band of heavily habitable semi-arid lands stretching across Africa at the southern edge of the Sahara—was thought to be on the verge of disappearing. Images beamed around the world showed deep drought, starving millions, and food shortages of up to 50% in many areas. In fact, the Sahel is not a permanent desert. Sub-Saharan Africa has a long history of “desertification” driven by human activity, especially overgrazing of the vast drylands. Though it is not getting any wetter or even bushier in dozens of square kilometers of arid land every year, desertification proved an overrating of arid and semi-arid lands.

For the past decade, however, scientists armed with satellite studies have been fighting the idea that such desertification is widespread or likely to be reversed. Now, they have satellite images to show their case.

More than most of what has been called desertification was instead the reflection of natural wet and dry cycles of rainfall.

“We’re not trying to up desertification is not happening,” says climatologist Shaban Nadi of Florida State University in Tallahassee, lead author of one of two recently published satellite studies. “While using the weather of the Sahel with rainfall variability at the border of forests is wrong.” The studies show that annual climate variation has shifted the desert’s edge, with no net effect on the amount of vegetation. Although people may be degrading the drylands of the Sahel, mainly by changing the mix of plants, they aren’t expanding the desert.



Two views of the Sahel, based on satellite data, show an average of the amount of green plants produced per unit of rainfall, but humans can change the mix of plants and grass.

## 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 happening recently published studies and scepticism.

Images from an American satellite show that, in the past 15 years, the Sahara has moved rapidly to and from rainfall. The movements as 300 kilometres in a few years alone period, “there is no progress of the desert,” says Dr Sharon Ni-

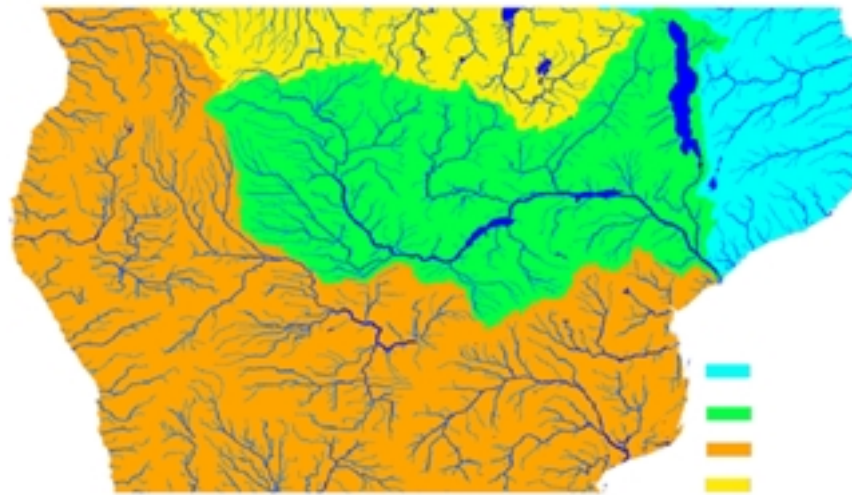
## REMOTE SENSING

### Study Shows No Long-Term Growth of Sahara Desert

By Stephen Pringle  
The Sahara Desert is not becoming more desolate, according to a new study. The research, published in the journal *Global Change Biology*, shows that the amount of green vegetation in the Sahel has remained relatively stable over the past 15 years. This finding challenges the long-standing view that the desert is expanding southward. The study used satellite data to measure the amount of vegetation in the Sahel, and found that the amount of green plants produced per unit of rainfall has remained relatively stable. This suggests that the desert is not expanding southward as previously thought. The study also found that the amount of green plants produced per unit of rainfall has remained relatively stable, which is a positive sign for the region. The study was led by Dr. Stephen Pringle, a climatologist at Florida State University. He says that the study shows that the desert is not expanding southward as previously thought. The study also found that the amount of green plants produced per unit of rainfall has remained relatively stable, which is a positive sign for the region. The study was led by Dr. Stephen Pringle, a climatologist at Florida State University. He says that the study shows that the desert is not expanding southward as previously thought. The study also found that the amount of green plants produced per unit of rainfall has remained relatively stable, which is a positive sign for the region.

# Future Developments

## Hydrological modeling to separate runoff and soil moisture components



River Catchments  
Coastal Mozambique  
Zambeze  
Limpopo/Okavango  
Zaire

- $RUE = P_n / T = P_n / (T + E + I) + (D + R) + (\Delta W + \Delta W_p)$
- $P_n$  = net primary production (NPP)
- $P_r$  = precipitation      All in volume water/time.
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- $R$  = run-off
- $\Delta W$  = change in water content of the soil
- $\Delta W_p$  = change in water content of the vegetation

# High Resolution Remote Sensing

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## Database

Clickable Interactive Query of TM, JERS, and SIRC Data

Enter a name for map #:

By entering a name for a map the map is non-editable and the map can be reloaded

Fit this button first

Choose a data Source:

Choose a Year (Required for TM and JERS):  
(JERS available for 92 thru 97)  
all   
1992 1993 1994 1995 1996 1997 1998  
       
1992 1993 1994 1995 1996 1997 1998 1999 2000 2001

Choose a Month (Required for TM and JERS):  
all   
Jun Feb Mar Apr May Jun  
       
Jul Aug Sep Oct Nov Dec

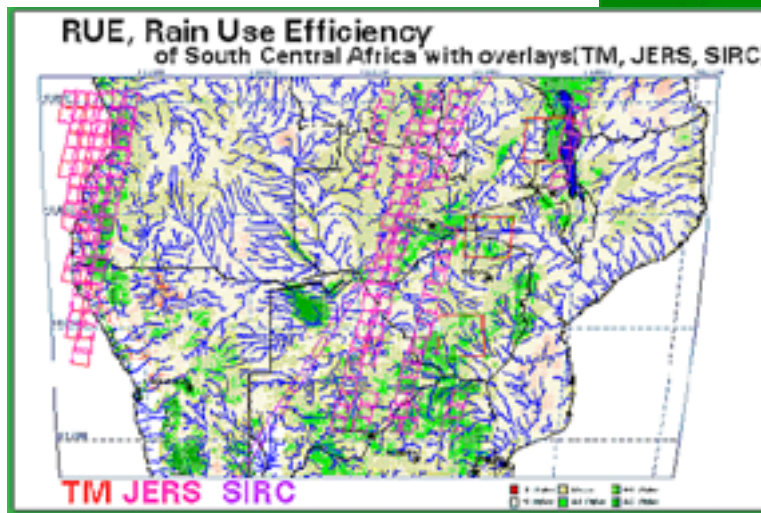
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Row   
Path   
Row

SIRC Fields:  
Flight Path  
Number 1                 
Number 2

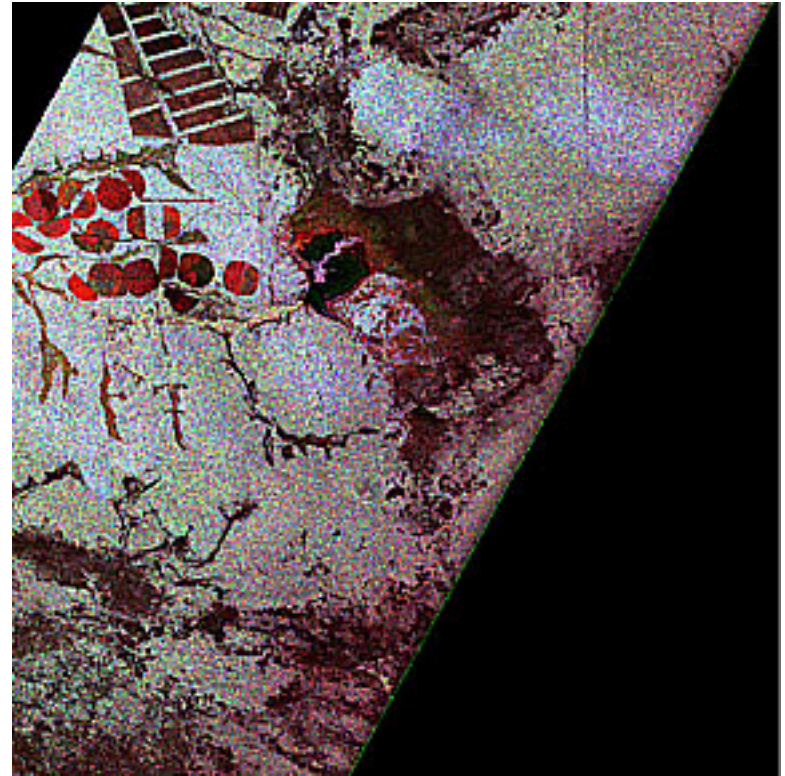
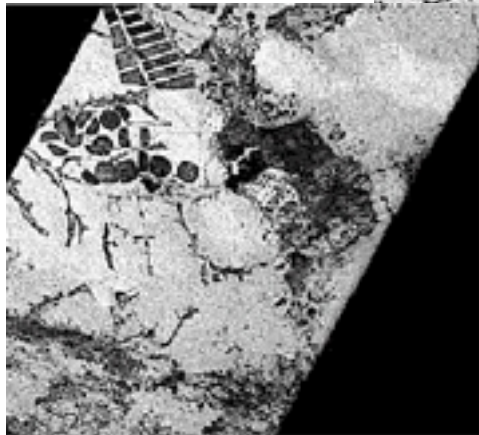
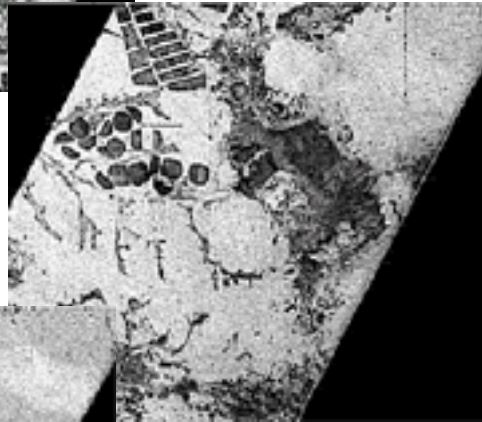
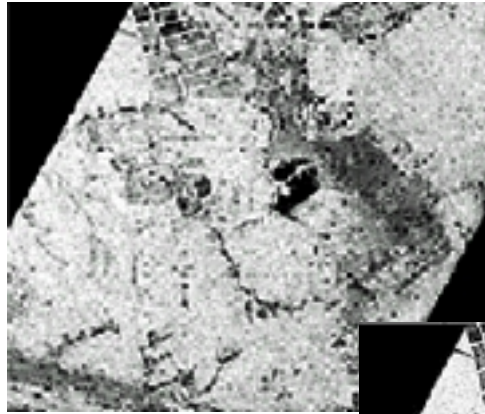
Choose a color for polygons

Hit this button to Draw Selected Data on Map  
You can keep adding polygons with this button

But if you want a new base map to draw on, click here



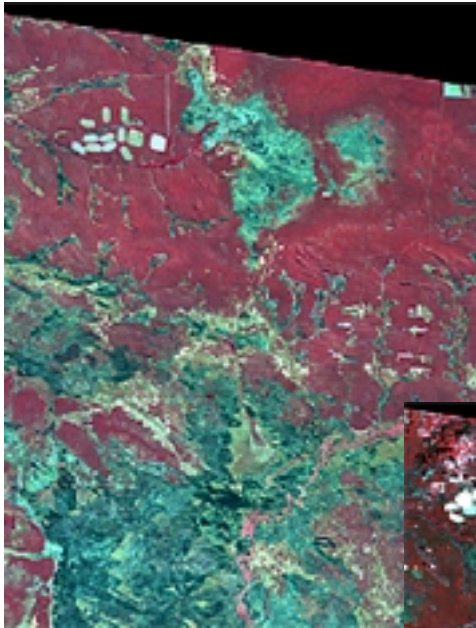
# SIR-C



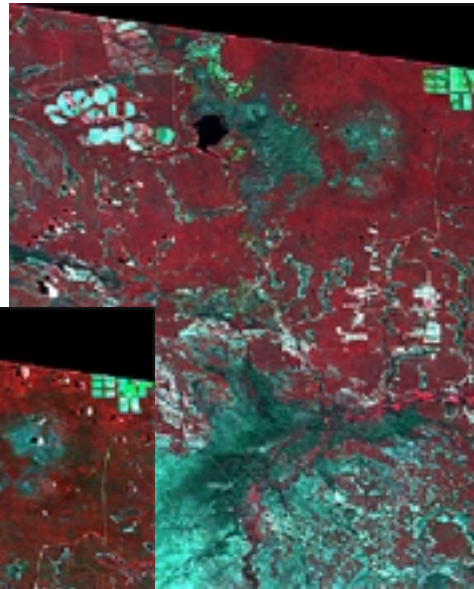
## High Resolution Remote Sensing

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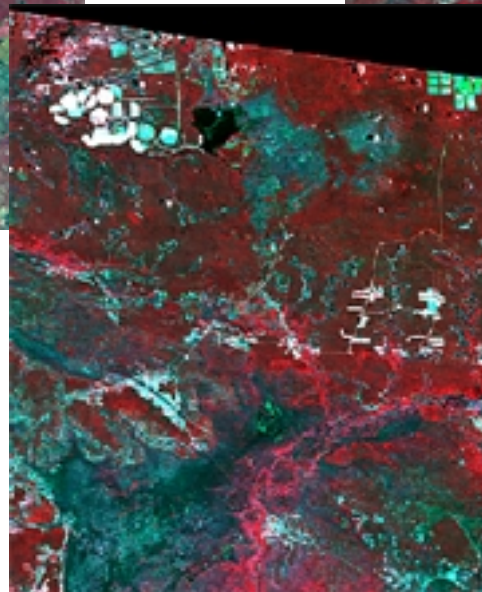
- 3 TM images & SIR-C 3-band image of Muncumpua, Zambia



1984

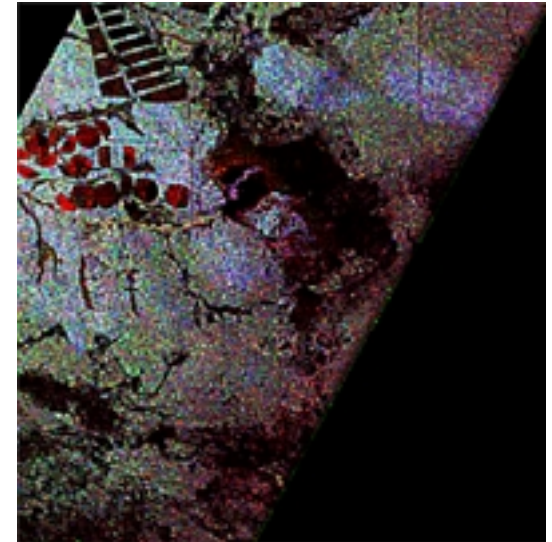


1994



1986

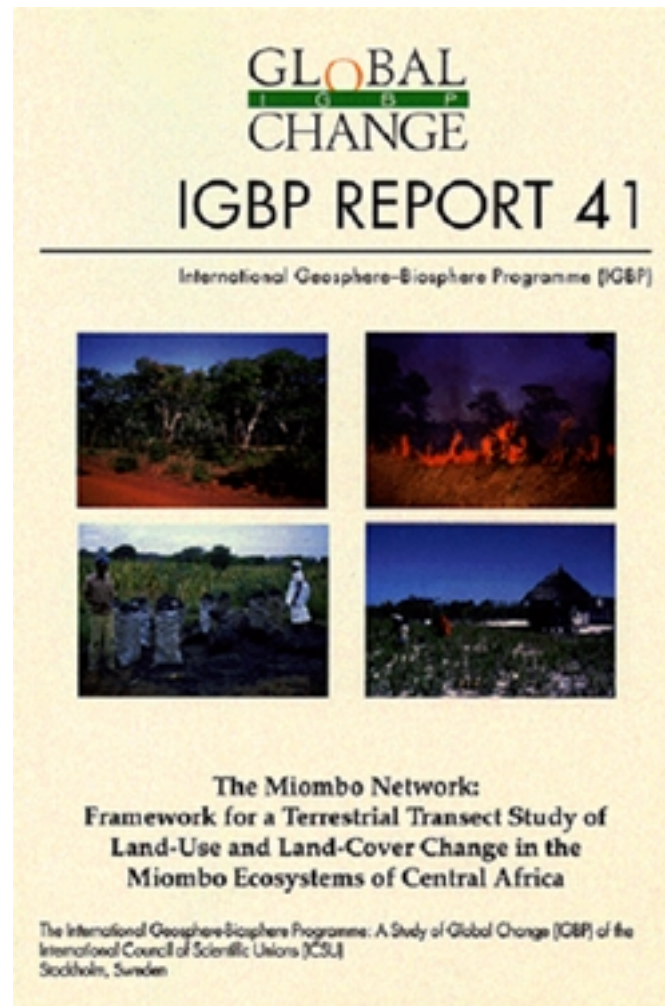
SIR-C



# Field Studies

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# Miombo Network

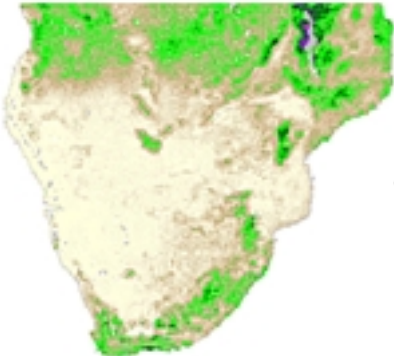




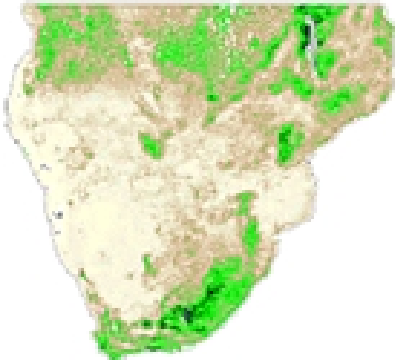
# Net Primary Production

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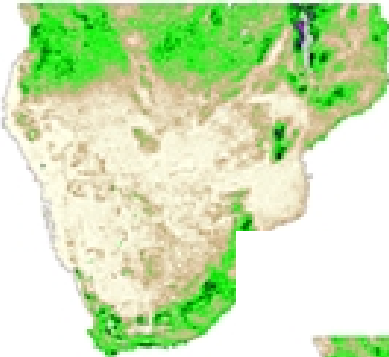
# 7 years NPP



82-83



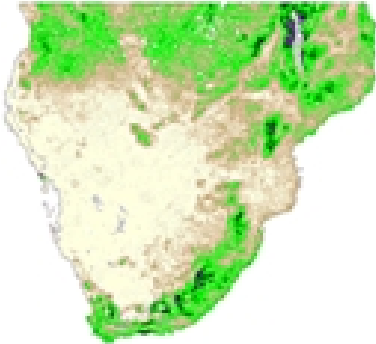
88-89



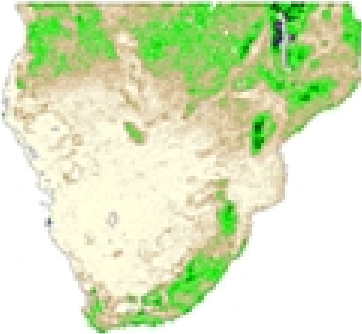
83-84



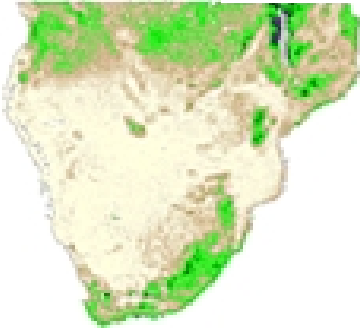
87-88



84-85



85-86

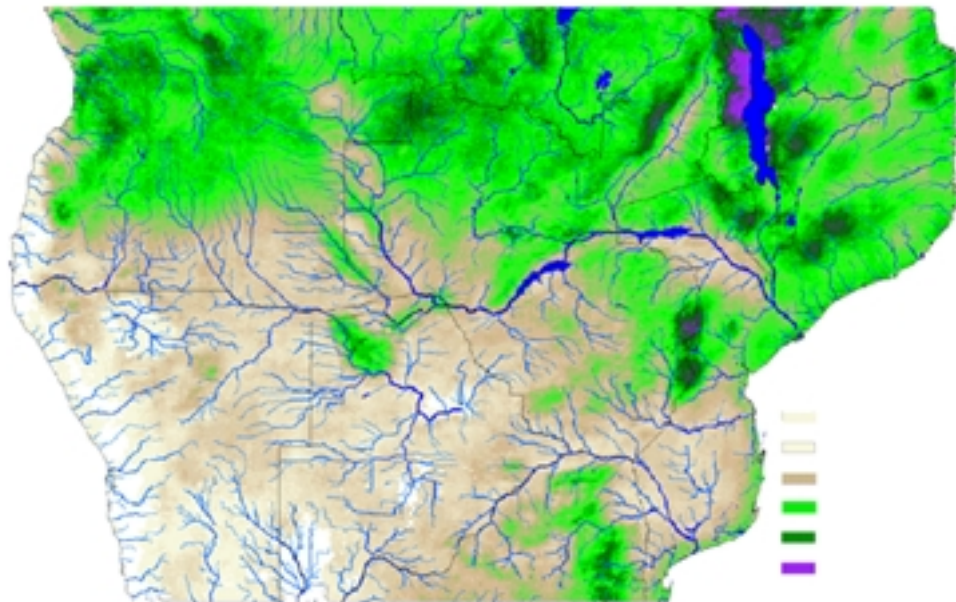


86-87

Results: NPP

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# Mean NPP



Mean NPP from 1982 to 1989

NPP g/m<sup>2</sup>/yr

7

118

452

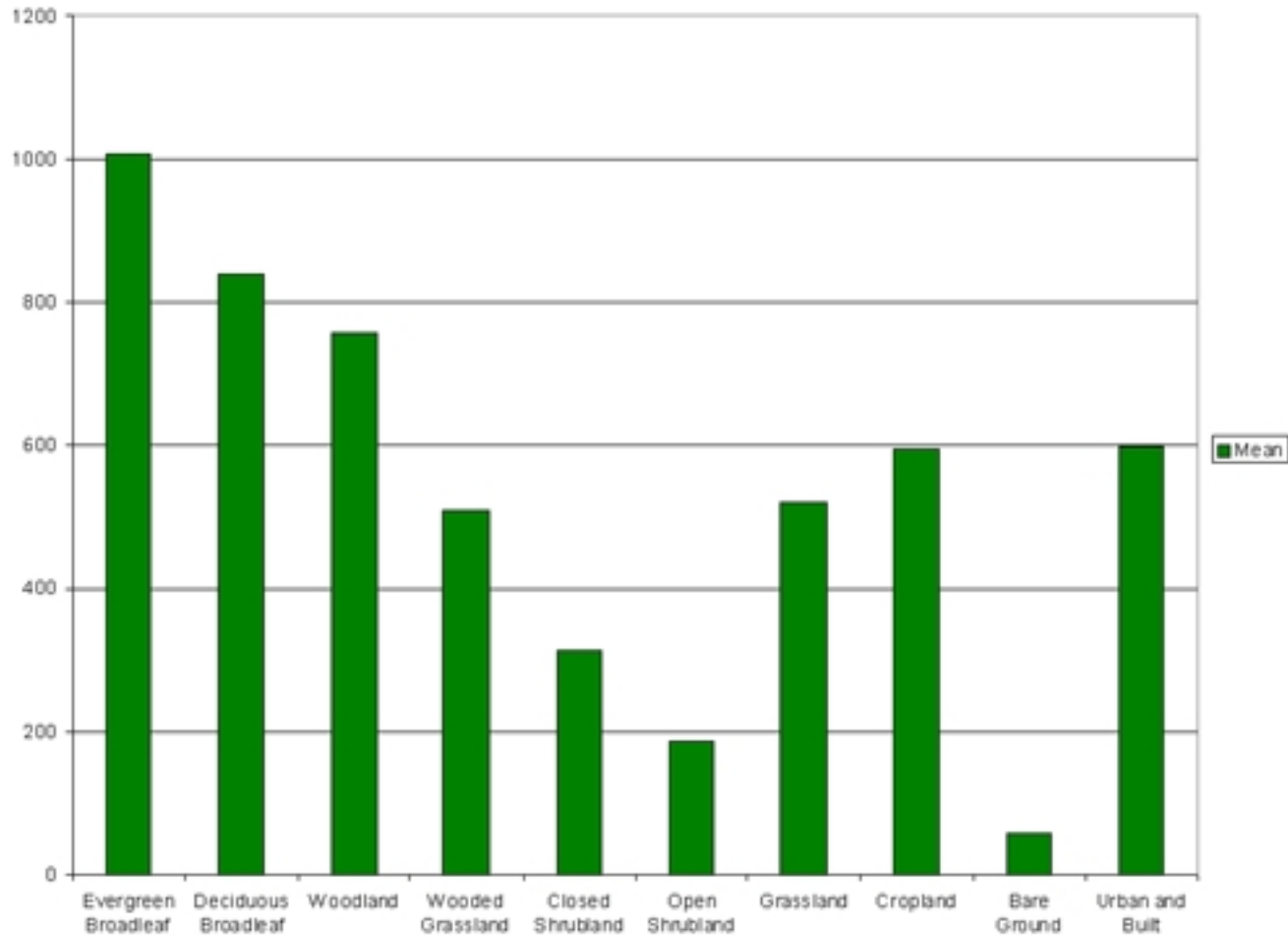
780

1014

1500

Results: NPP

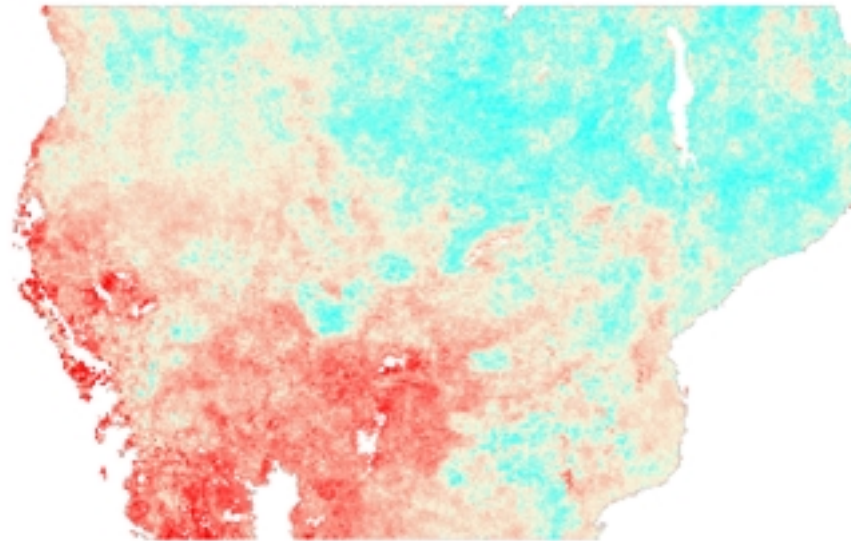
## Mean npp by land cover class



Results: NPP

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## Coefficient of Variation of interannual NPP

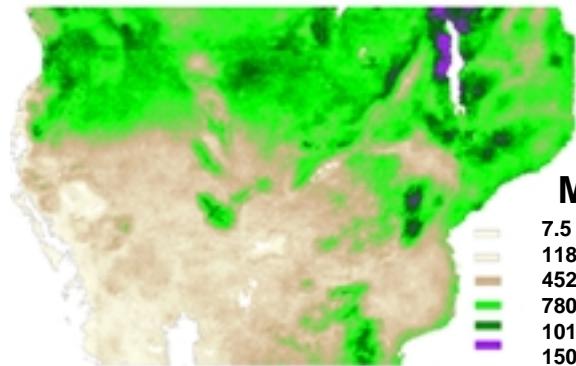


**RUE- overall assessment of  
performance as a measure of  
degradation**

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# Normalizing effect of rainfall on regional NPP

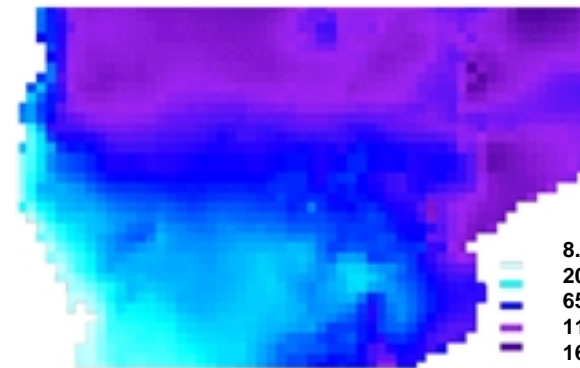
Mean NPP



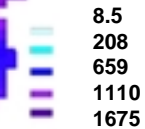
Mean NPP 82-89



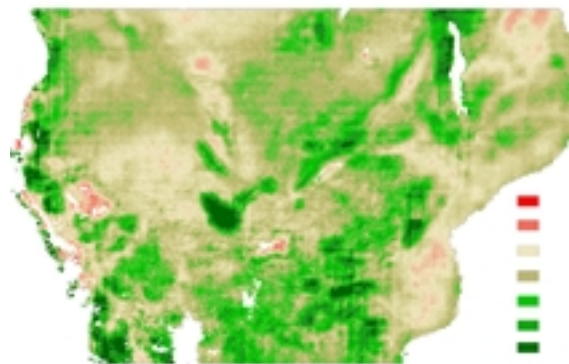
Mean precipitation



Mean Precip.  
82-89



Mean RUE

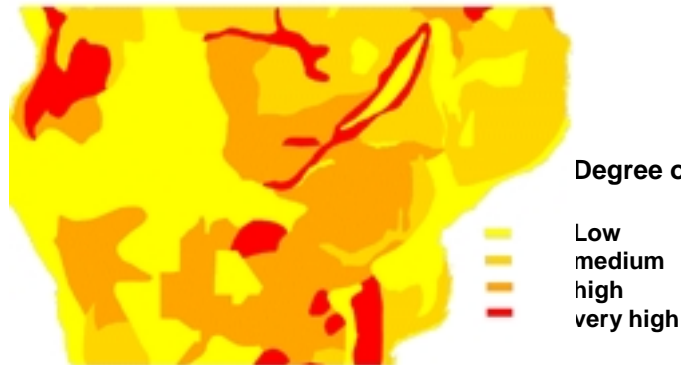


Mean RUE 82 89

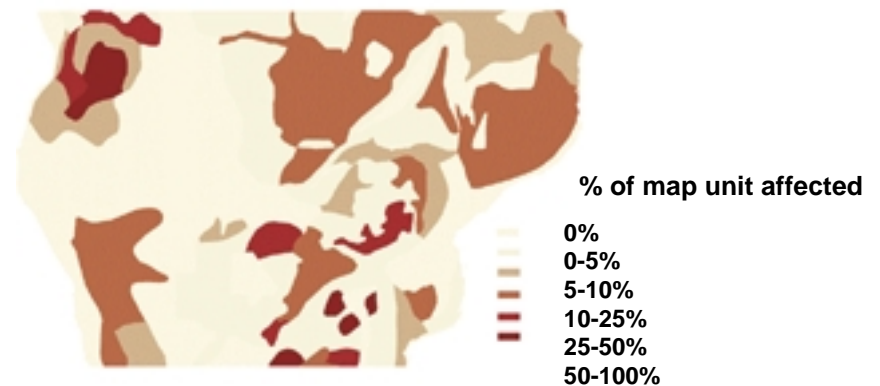


## Areas of agreement, low RUE

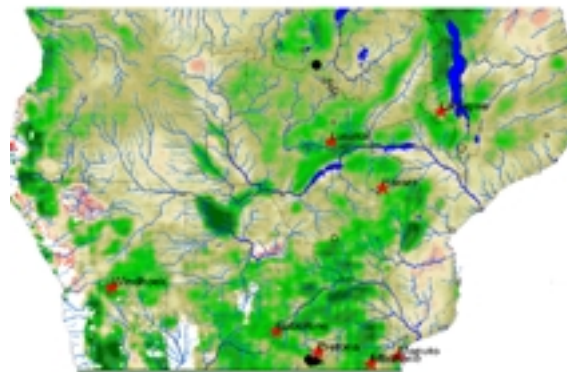
Degree of human induced soil degradation



Extent of human induced soil degradation



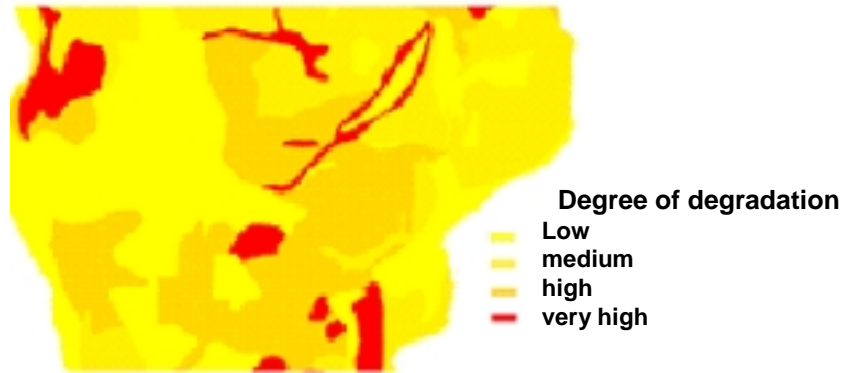
1. Congo Shaba Province
2. Zambia Copperbelt
3. Botswana NE, Mkgadikgadi
4. Namibia N Windhoek
5. RSA N of Mbabane, Pretoria
6. Zimbabwe N & E borders
7. Angola Huambo



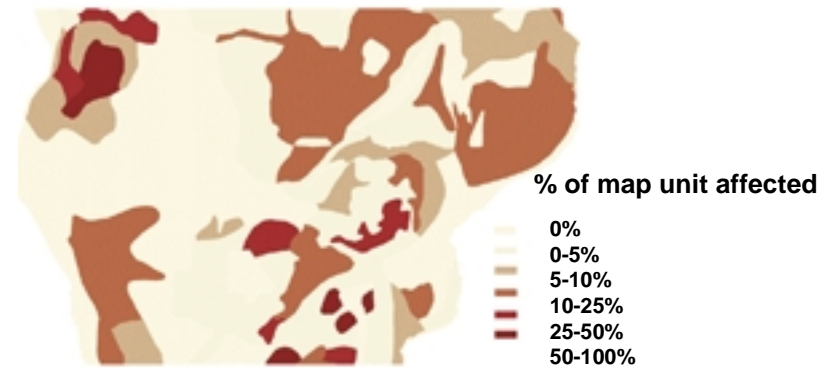


## Areas of agreement, high RUE

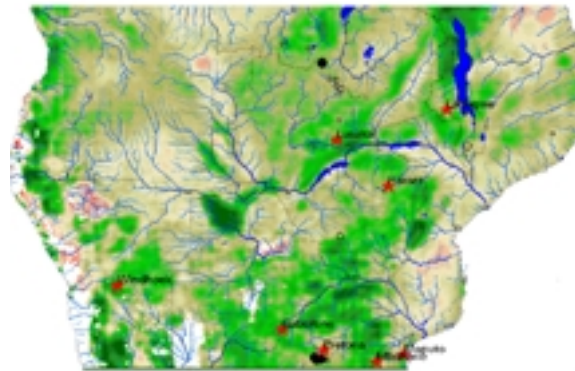
Degree of human induced soil degradation



Extent of human induced soil degradation

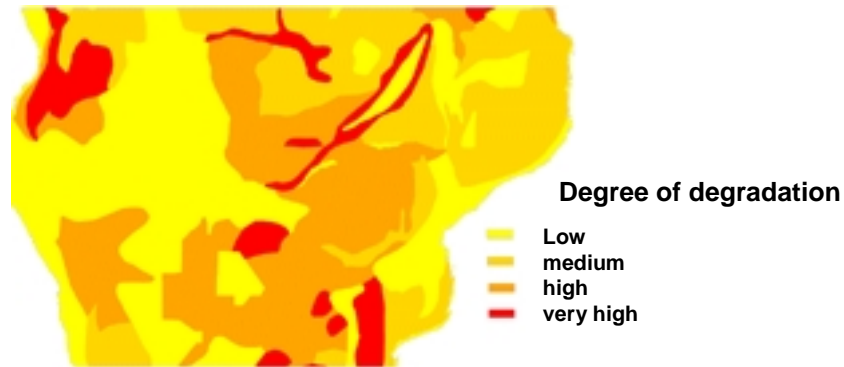


1. Malawi N Province
2. RSA Nylsstrom Transvaal, N Drakensberg
3. Zimbabwe Metabeleland
4. Namimima E of Windhoek

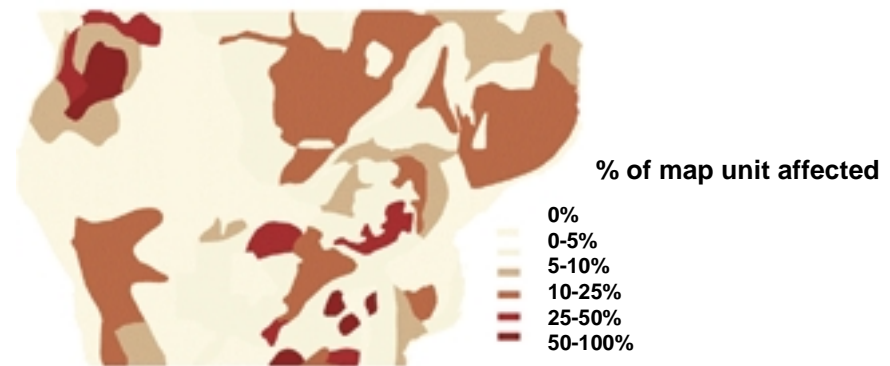


# Areas of Disagreement RUE low/GLASOD not degraded

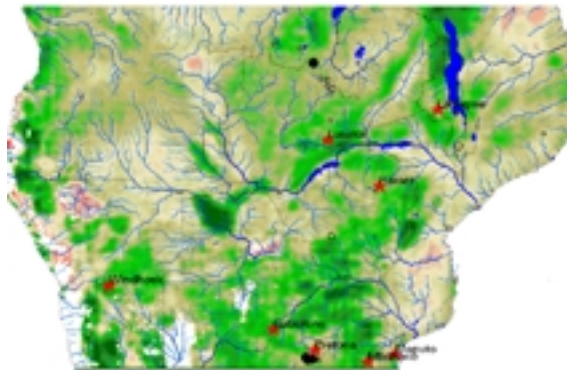
Degree of human induced soil degradation



Extent of human induced soil degradation



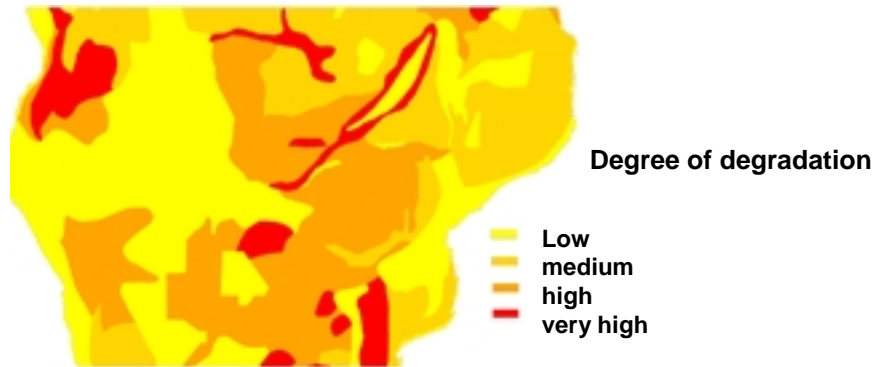
1. Zambia Luangwa Valley
2. Mozambique Tete Province
3. Botswana Chobe Province
4. Namibia/Angola Herero/Cubango
5. Mozambique Sofala-Imhambane



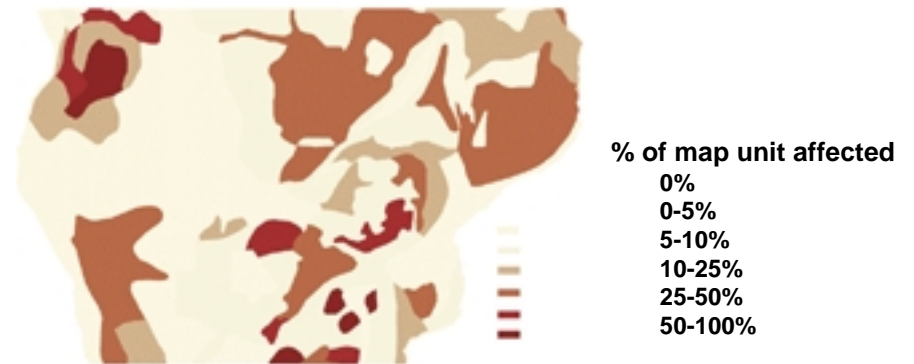
# Integrated assessment and degradation monitoring

## Areas of Disagreement RUE high/GLASOD degraded

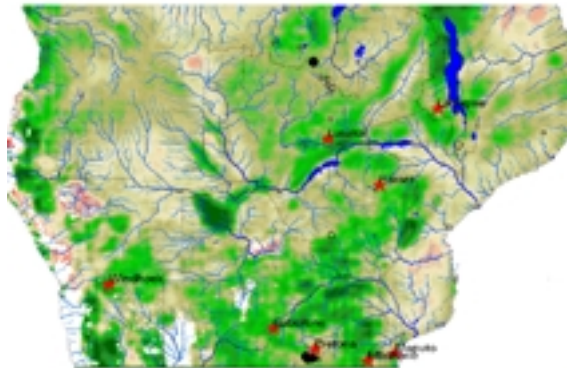
Degree of human induced soil degradation



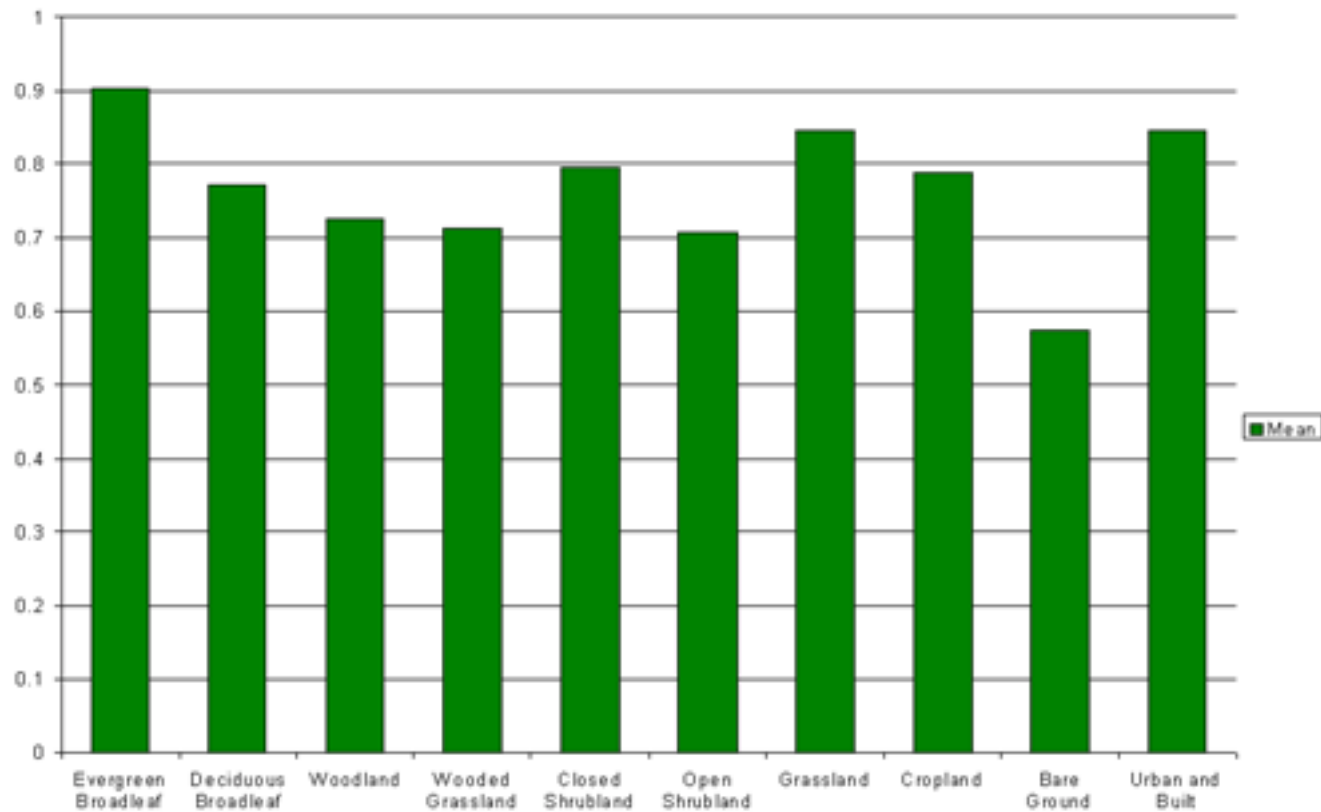
Extent of human induced soil degradation



1. Zambia, Luangwa Valley escarpments



# Mean rue by land cover class



# **Interpretation of rue in southern central Africa**

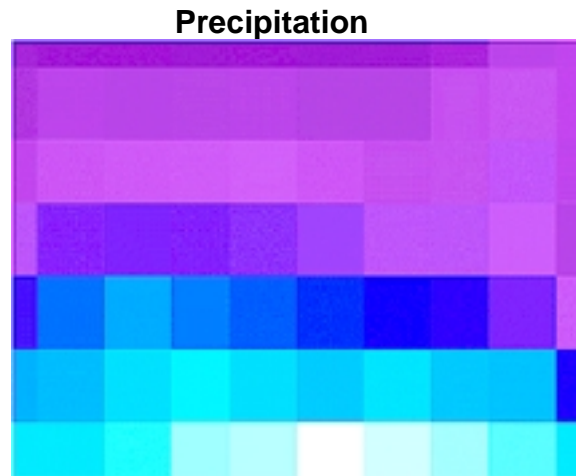
---

Results: RUE

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



NPP



Precipitation

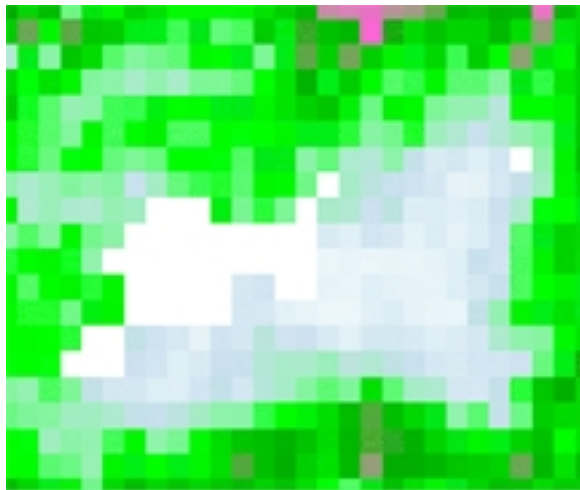


RUE

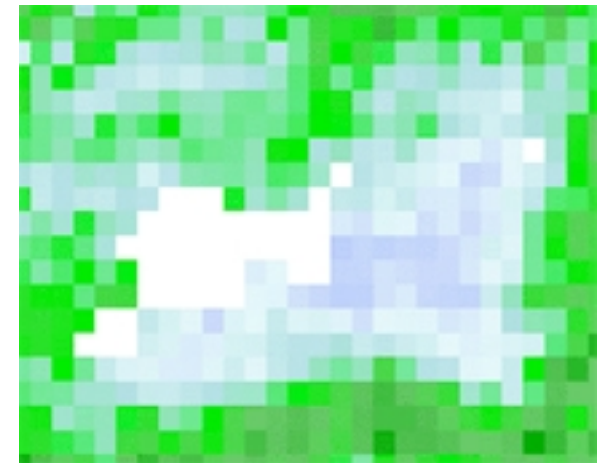
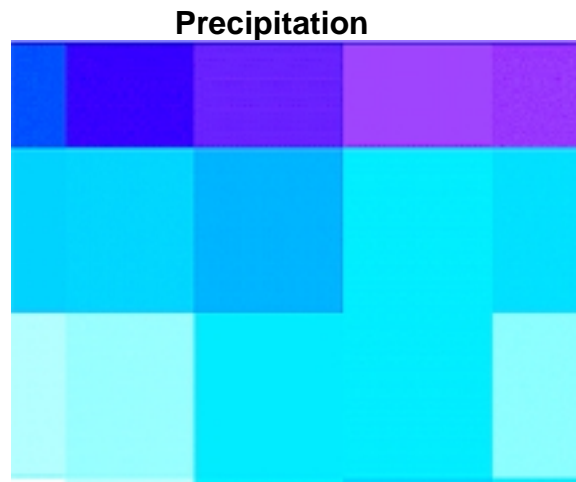


Results: RUE

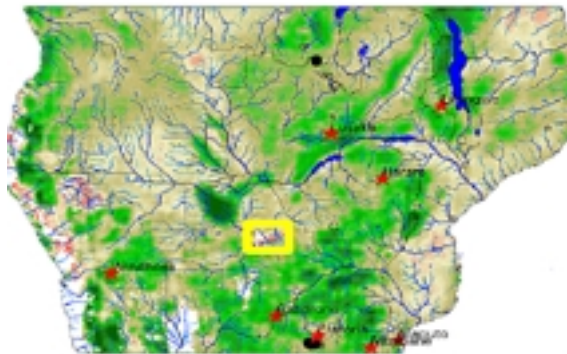
# Degraded: naturally susceptible regions Mkgadikgadi pans region



NPP

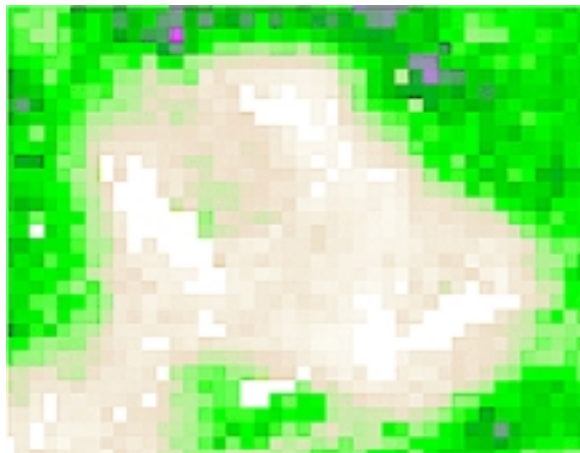


RUE



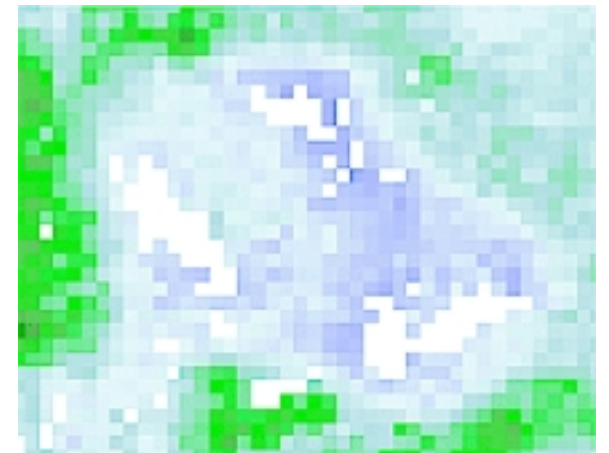
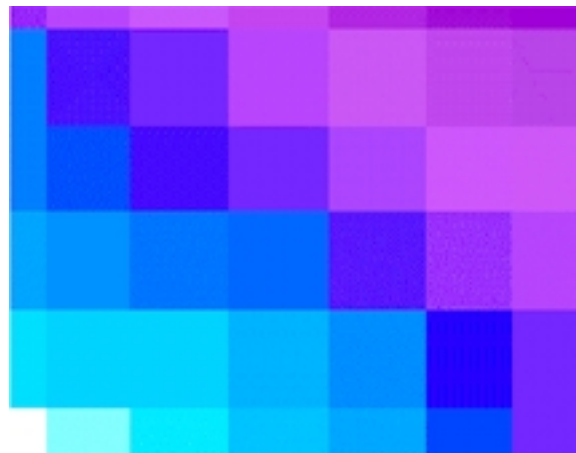
Results: RUE

# Degraded: naturally susceptible regions Etosha pan region



NPP

Precipitation



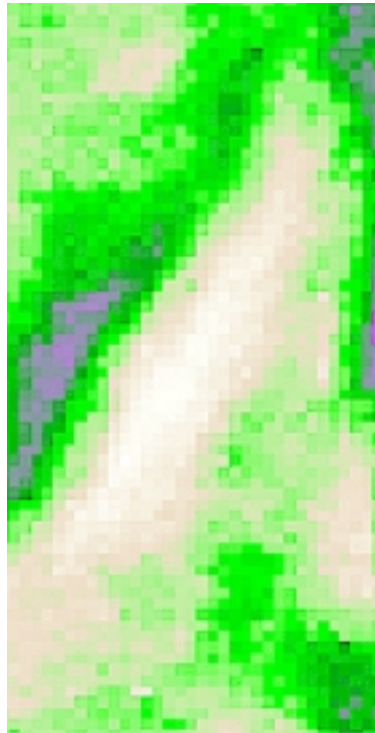
RUE



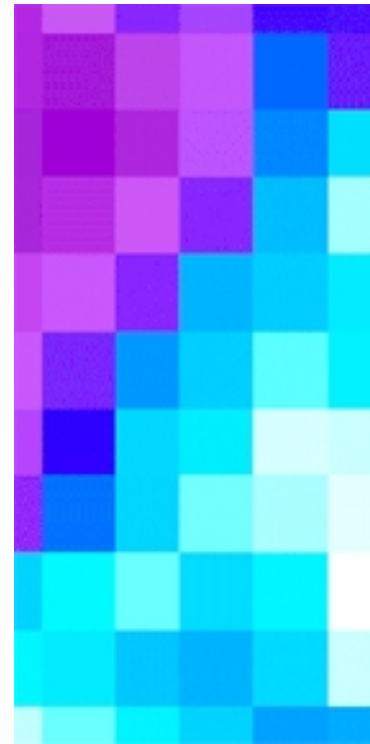


Results: RUE

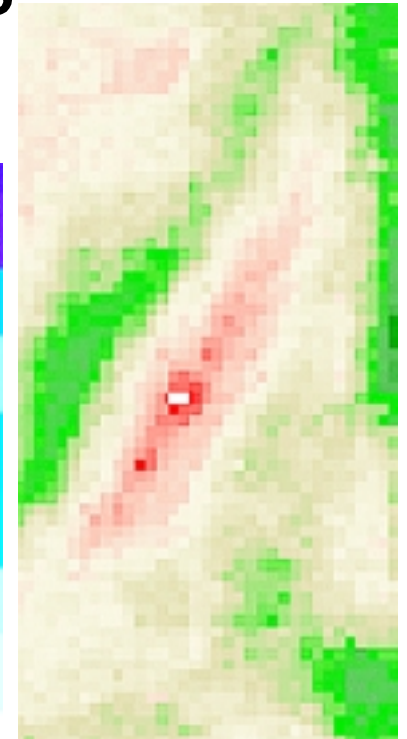
# Degraded: naturally susceptible regions Luangwa valley



NPP



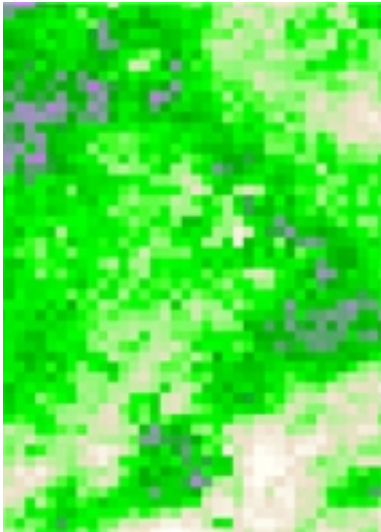
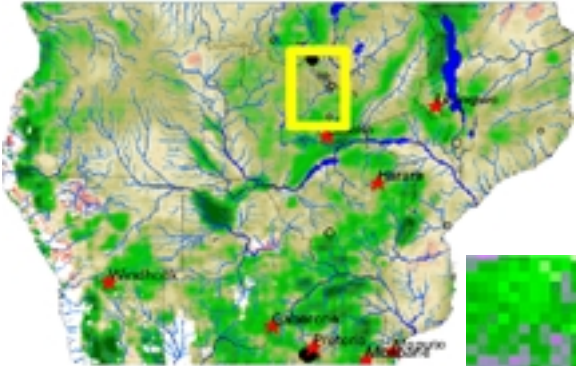
Precipitation



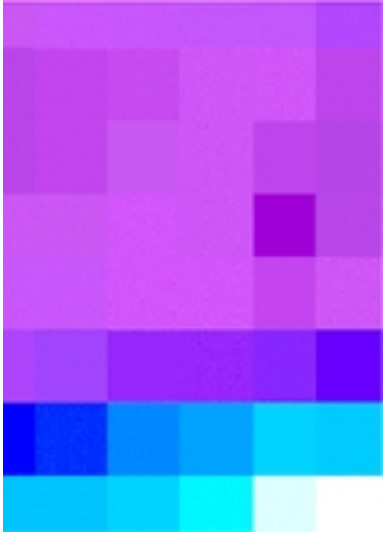
RUE

Results: RUE

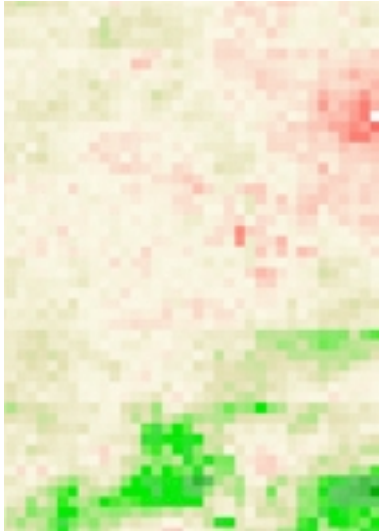
# Degraded: human induced Zambian Copperbelt



NPP



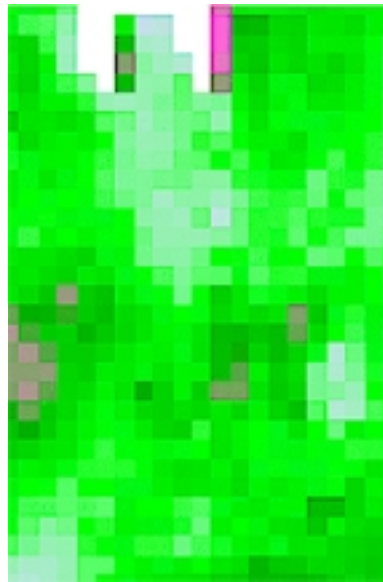
Precipitation



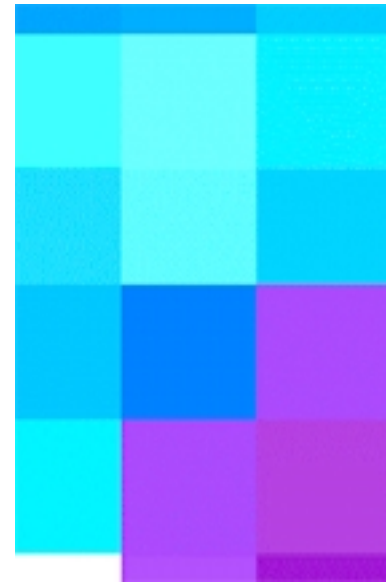
RUE

Results: RUE

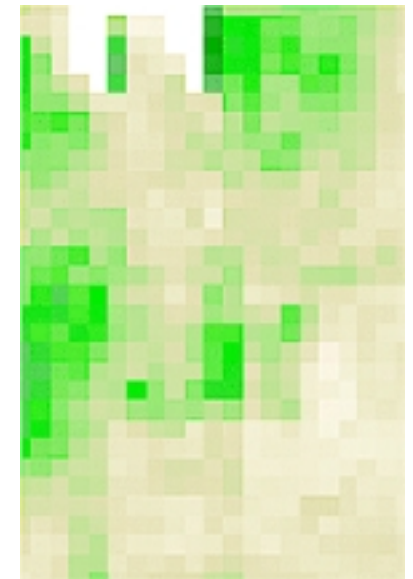
# Degraded: human induced Malawi Namwera highlands



NPP



Precipitation



RUE

# High Resolution Degradation Features

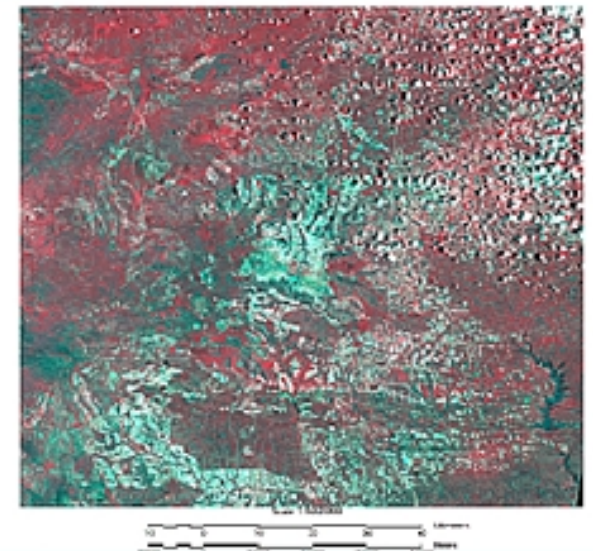
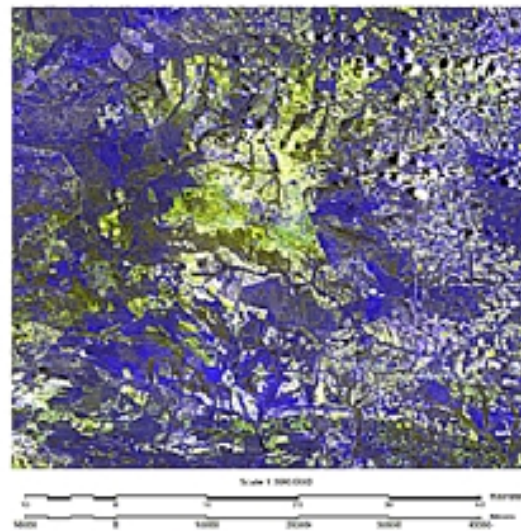
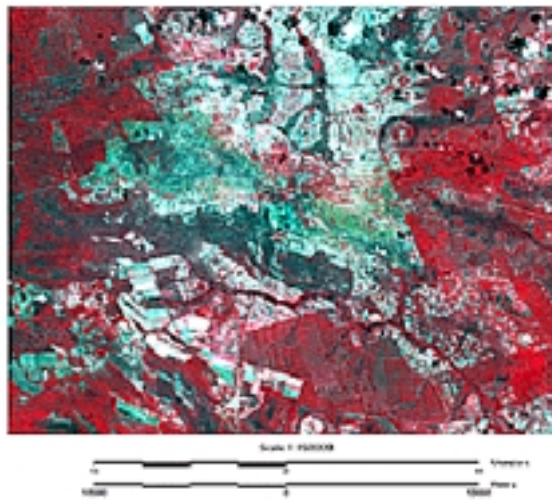
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High resolution degradation features

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# Degradation at Kabwe, Zambia

- 1986 17 Nov TM



# Next Steps

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# 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

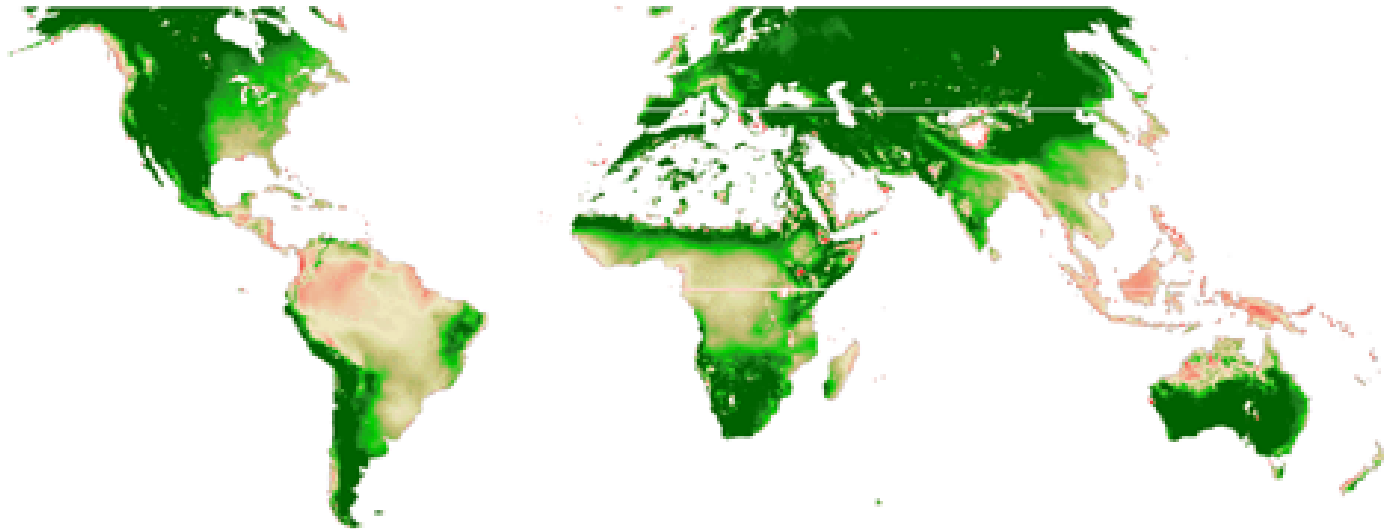
- Comparisons with local degradation studies
  - Miombo network partners
  - Regional issues
    - e.g. Gwembe Valley, Botswana rangelands, Copperbelt
- Identify sources of site biophysical data
  - Local scale modeling
  - Comparison with coarse resolution satellite inferences
- Explore integrated assessments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



Next Steps

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# Potential for global scale interpretation



# **Integrated assessment and degradation monitoring**

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# Integrated Assessment

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Strategy for addressing complex problems  
across scales

Land cover, land use  
in southern Africa

# Integrated Assessment

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## 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

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**Objective:  
to arrive at an informed judgement**

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

# Integrated Assessment

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## 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

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## 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

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## Stakeholders

