2nd StatGIS conference: 11.11.2014

Dr. Maik Netzband

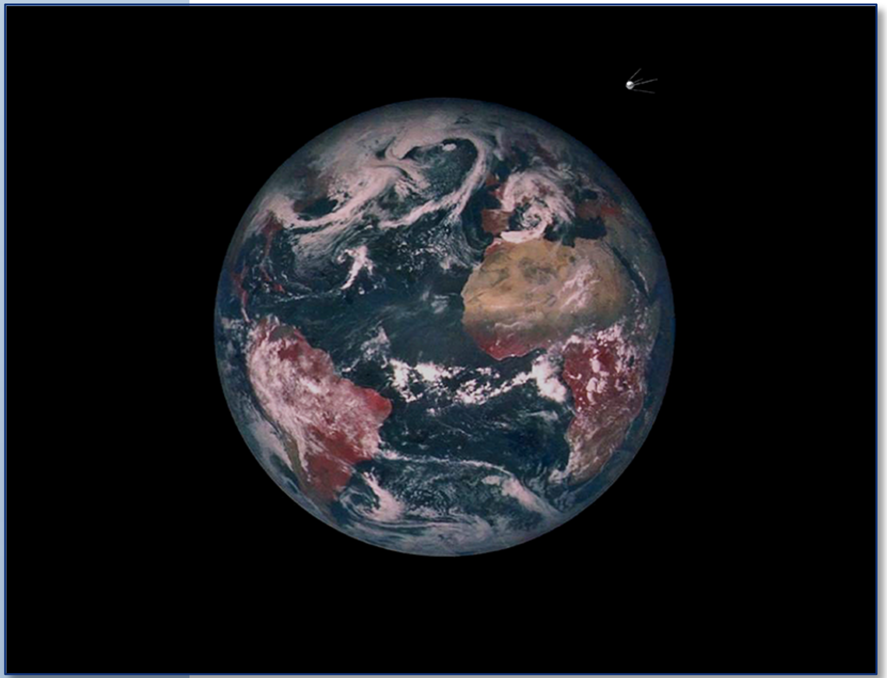
Remote Sensing and GIS for Biodiversity Research

european social fund in the czech republic
EUROPEAN UNION
MINISTRY OF EDUCATION, YOUTH AND SPORTS
OP Education for Competitiveness
INVESTMENTS IN EDUCATION DEVELOPMENT

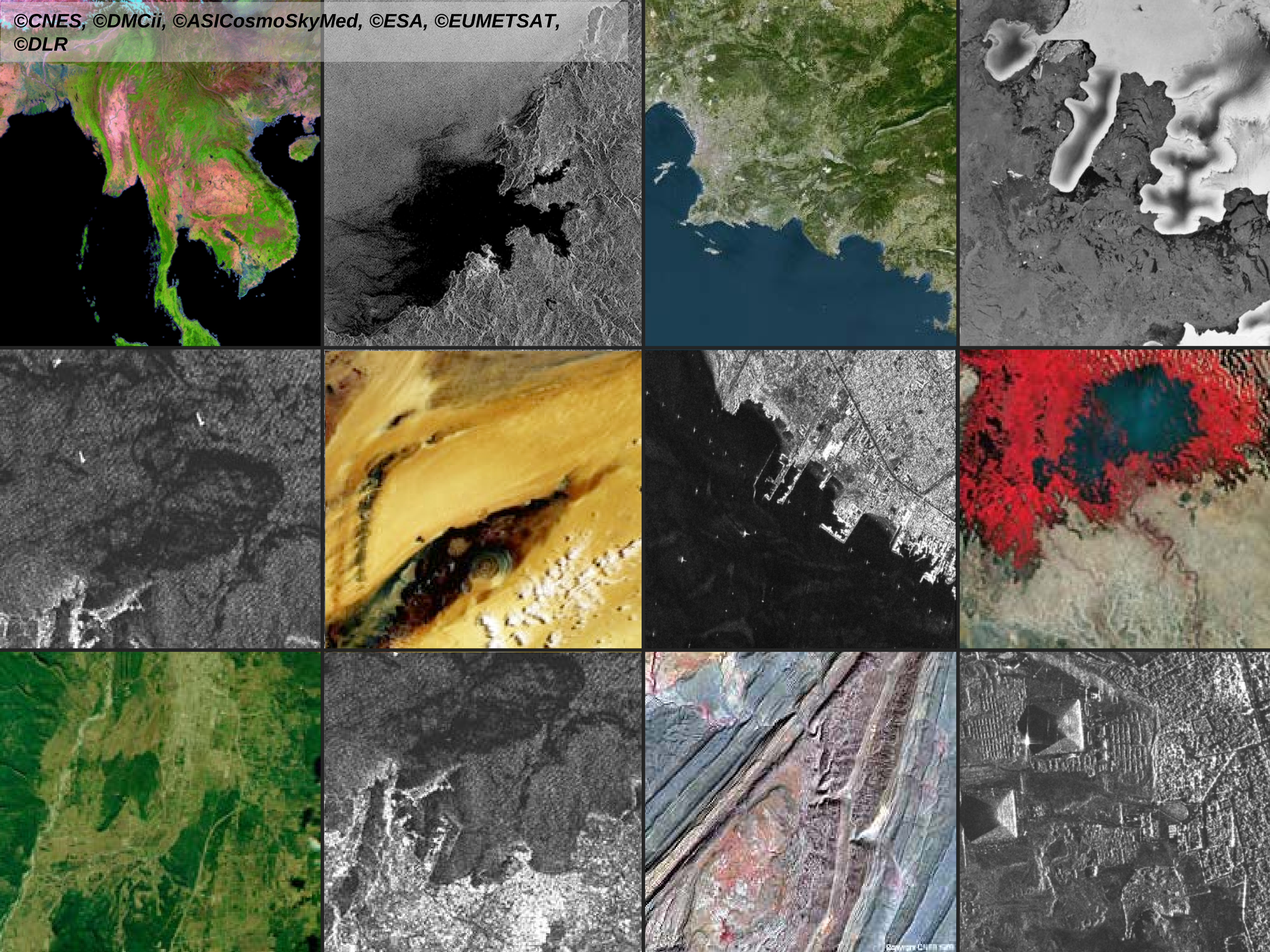
6983 artificial satellites launched from

to

4th October 1957 ***30th June 2013***



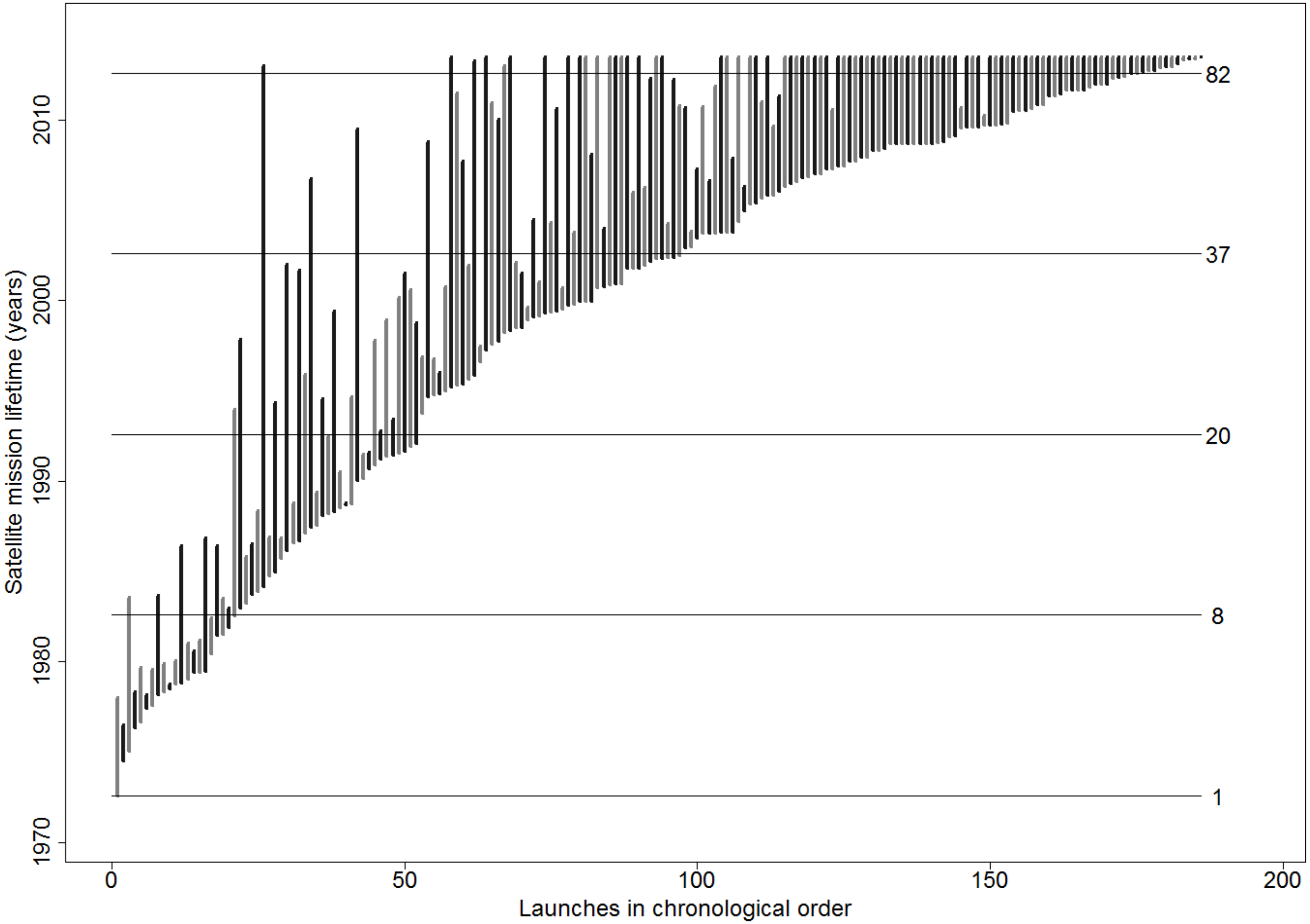
Images NASA Clementine mosaic, grupo sputnik and ESA beehive adapted ASB



The lifespan of all near-polar orbiting, land imaging, civilian satellites shown in chronological order

90

currently operational



Source Belward and Skoien, PERS 2013

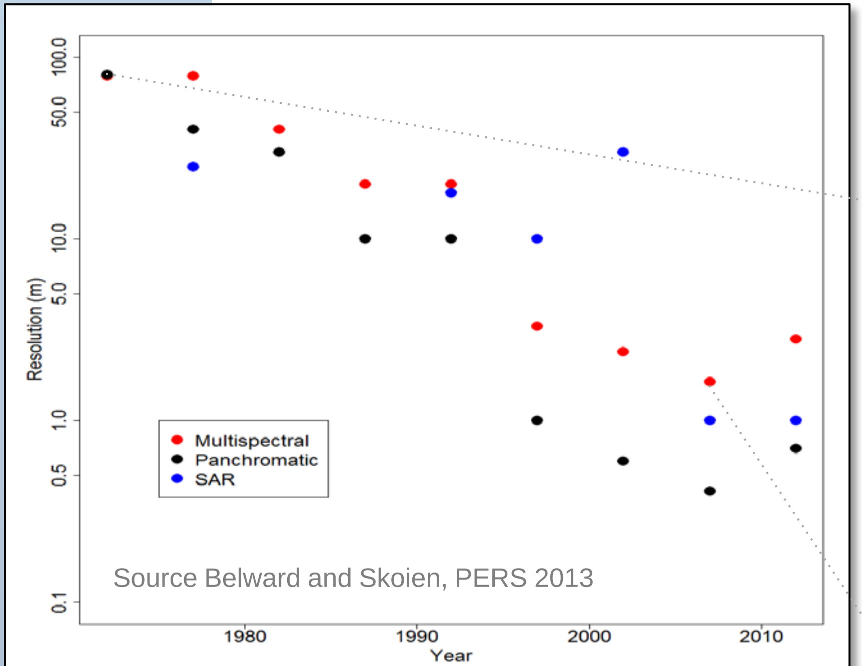
Introduction

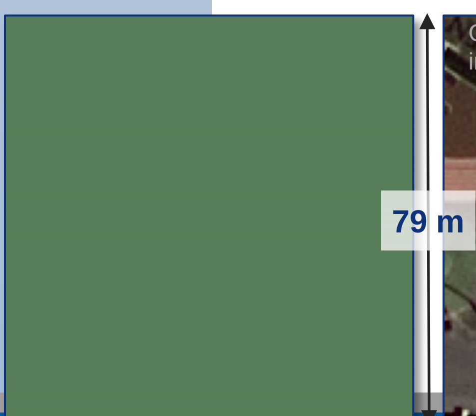
- It is nearly impossible to acquire such detailed spatial information purely on the basis of field assessment and monitoring.
- Remote sensing provides a **systematic, synoptic view of earth cover at regular time intervals**
- Coupled with Geographical Information Systems (GIS), it can provide **information about landscape history, topography, soil, rainfall, temperature and other climatic conditions**, as well as about **present day habitat and soil coverage** - factors on which the distribution of species depend.
- **Relationships between species distribution patterns and remotely sensed/GIS data**, if known, can be used to predict the distribution of single species or sets of species over large areas.

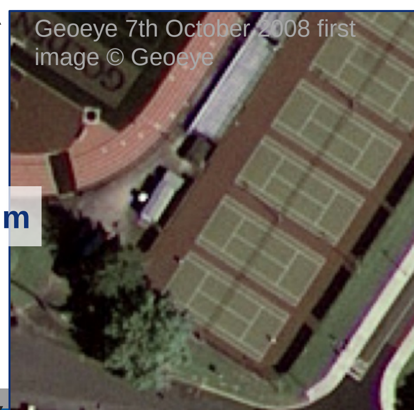
Introduction (cont.)

- Several studies prove the **utility of remote sensing**, or remote sensing coupled with GIS, to **understand the distribution of biodiversity**.
- The term '**biodiversity**' is restricted to its most commonly used form, i.e. **species diversity** (Stoms and Estes 1993). Several terms - **biotopes, communities, ecosystems, ecotopes, habitats, landscape elements, vegetation communities** - have been used more or less synonymously. While the terms are reported here as used in the original studies, it must be recognized that their meaning in this context is similar (Forman and Godron 1987, Forman 1995).

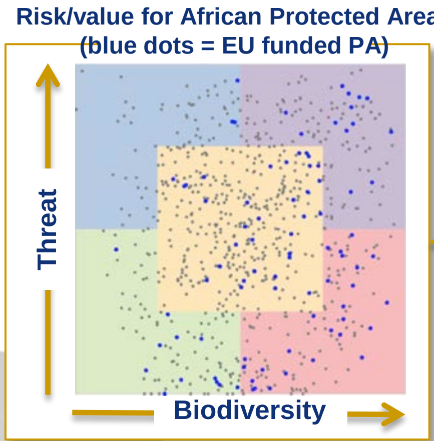
Changing spatial resolution

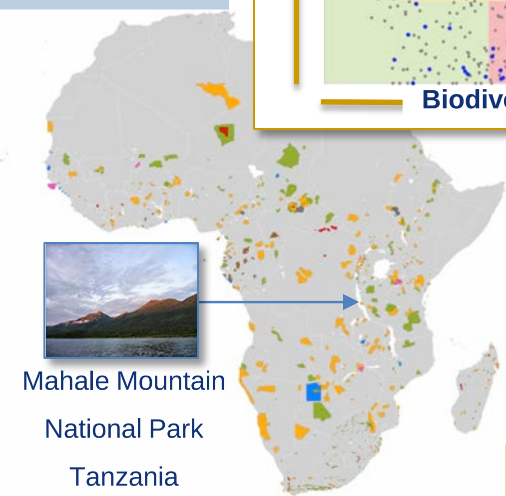


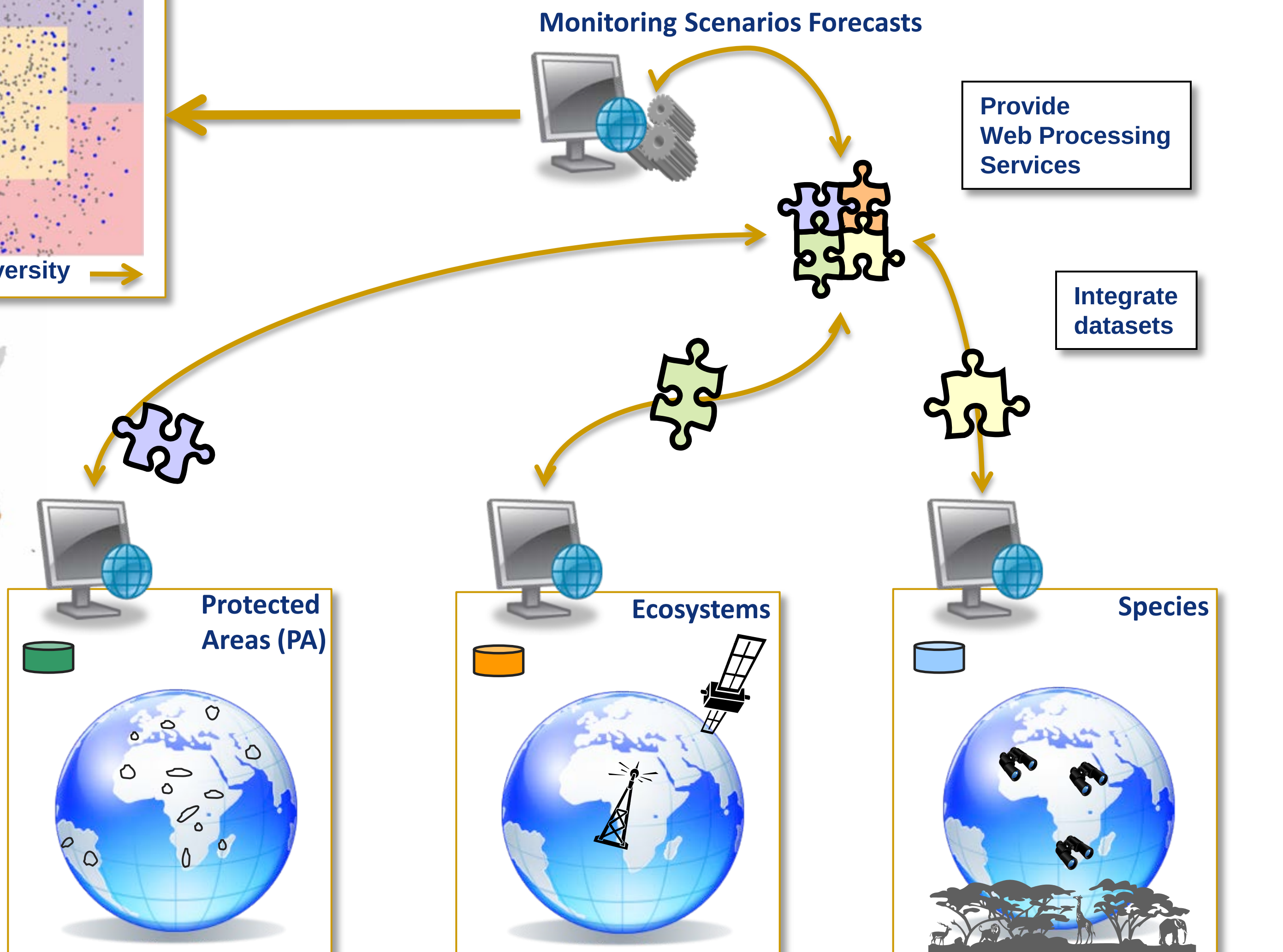




http://dopa.jrc.ec.europa.eu

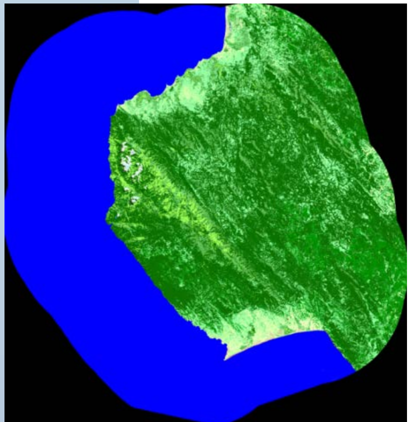




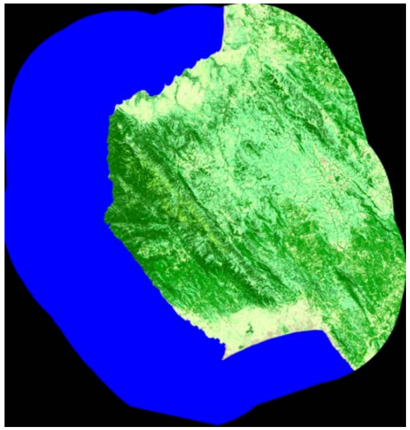


Source: Gregoire Dubois JRC

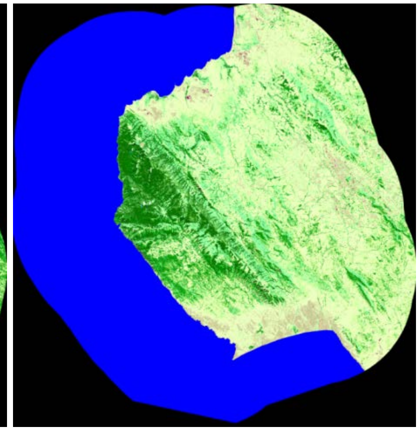
82 km



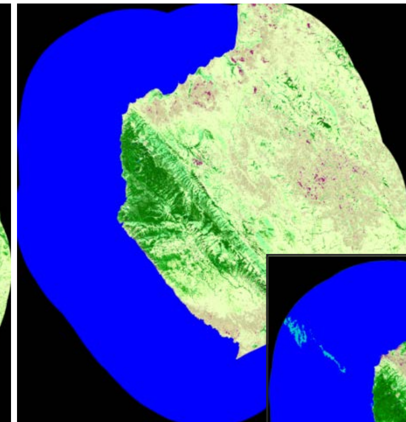
19Th May



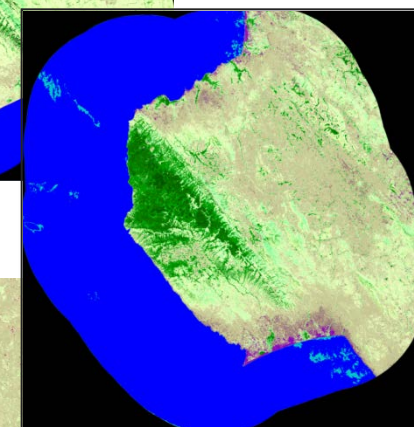
4Th June



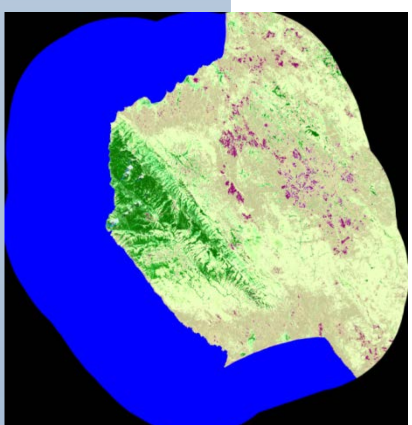
20Th June



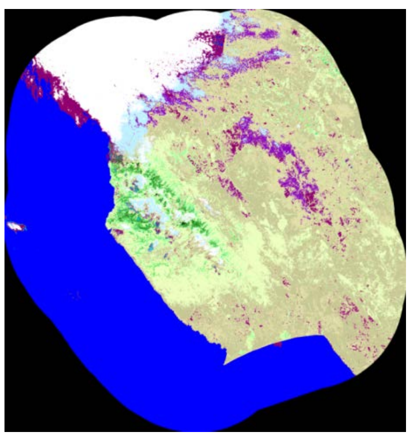
7Th July



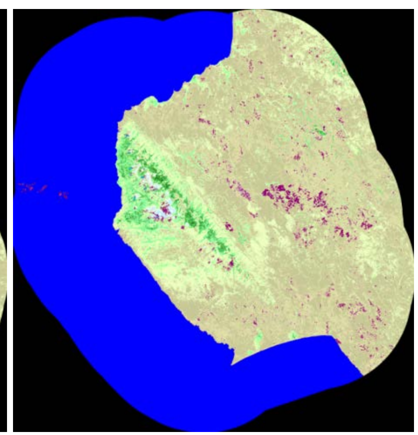
Seasonal composite



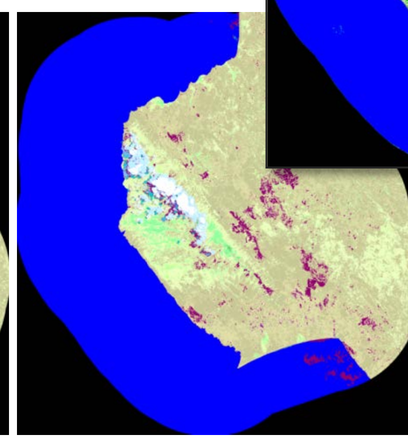
22Th July



7Th August



23Rd August



8Th September

Mahale Mountain National Park, plus 20 km buffer

Single date and seasonal land cover classifications

Source: Dario Simonetti JRC

Issues of scale

- All observations depend upon the **scale of study** - extent as well as grain. **Extent** refers to the **size of the study area** investigated, while **grain** is the **resolution of the remote sensor** - radiometric, spatial, spectral and temporal.
- As extent increases, the level of detail (grain) that can be maintained, given constraints on time, effort and money, will decrease, and *vice versa*. The amount of information that can be retrieved, on numbers of species or numbers of habitat types, critically depends on these factors.

Spatial Resolution

- determines the **amount of information** in a remotely sensed image **of a given area**. The spatial resolution used **should be** such that the **information required** (adequate accuracy of classification) **is available** using the least amount of data.
- If spatial resolution is **too low**, **discrimination** of object classes becomes **difficult**.
- If **too high**, orders of magnitude smaller than that of the objects classified, intraclass **variability** may **increase** and **classification accuracy decrease** correspondingly
- The **ratio of spatial resolution to the size of the objects** being classified (whether tree crowns, single plant species or patches of a species) thus plays a **crucial role** in deciding whether species separation during classification is adequate or not.

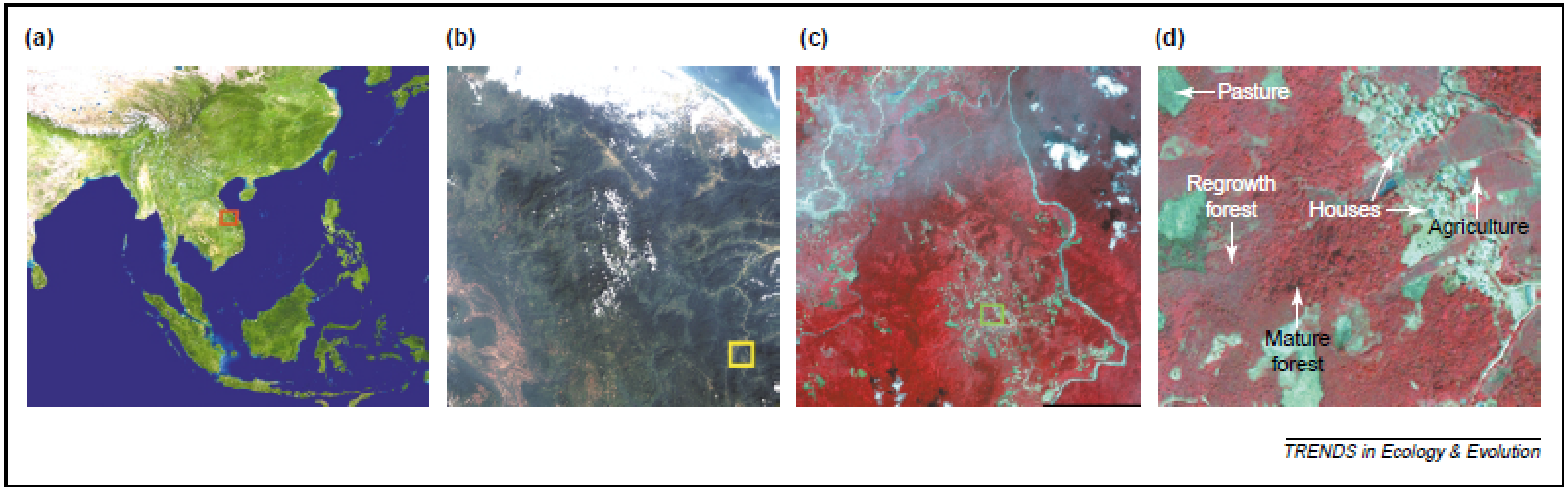


Fig. 1. Satellite images from three sensors at different spatial resolutions. (a) MODIS mosaic Southeast Asia. (b) Landsat 7 ETM + scene of central Vietnam. (c) IKONOS scene for 108.6 km^2 region near Song Thon Dac Pring; False color (= Color IR, Red, Green) and pan-sharpened. (d) IKONOS closeup showing different land-use types. Figure courtesy of AMNH/Ned Gardiner; IKONOS imagery from Space Imaging.

http://tree.trends.com

Spatial Resolution

- Most remote sensing studies of **species diversity** concentrate on **land area**, although a few investigations on freshwater and marine ecosystems have been made.
- **Animal** species **cannot be normally observed** using remote sensors, unless of very high spatial resolution.
- Relatively **few studies of animal species** distribution have therefore been carried out using remotely sensed data. **Most direct observations of individual plants or animals require them to be fairly macroscopic and slow moving, if not sessile**. The vast majority of macroscopic sessile organisms on land are colonies of lichens or plants. Thus most, if not all, remote sensing studies of vegetation concentrate on larger plants on land areas.

Spectral Resolution

- Different species of plants **respond differently** to light in the electromagnetic spectrum. In theory, remotely sensed data of adequate spectral resolution can be used to distinguish between plants of different species.
- A challenging task is to identify the appropriate spectral bands:
  - **Near infrared, middle infrared and thermal infrared bands** have been strongly recommended for species discrimination.
  - **Near infrared** data responds to **green biomass**, and is believed useful for differentiating species that differ in their foliage content.
  - The **middle infrared band responds to leaf water content**, and has been demonstrated useful for the separation of succulent plants (onion and *Aloe vera*) from non-succulents (cabbage, carrot and grasses).
- Thermal infrared demonstrated to permit the separation of species not possible from near to middle infrared wavelengths:

Ecological variable	Sensor[b] Space (S)/ Airborne (A)	Spatial resolution	Revisit time	Spectral resolution	Description	Website
Direct approaches						
Species composition	TM/ETM + (S), ALI (S), HYPERION (S), ASTER (S), IKONOS (S), Quickbird (S), AVIRIS (A), CASI (A)	<1–30 m	16 days (ETM, ALI, Hyperion); 4–16 days (ASTER); 2–5 days (IKONOS); 2–4 days (Quickbird); N/A for aircraft	V/NIR, SWIR, ASTER also has TIR	These sensors are being tested for their ability to measure directly canopy community, and perhaps species, type based upon unique spectral signatures	c–i
Land cover	MODIS (S), TM/ETM + (S), ASTER (S), ALI (S), IKONOS (S), Quickbird (S)	<1–1000 m	1–2 days (MODIS); 16 days (TM/ETM +); 4–16 days (ASTER); 2–5 days (IKONOS); 2–4 days (Quickbird)	V/NIR, SWIR, MODIS and ASTER also have TIR	Can discriminate different land surfaces at various resolutions; land cover classification is considered a first-order analysis for species occurrence	c–e,h,i,k
Indirect approaches						
Primary Productivity						
Chlorophyll	SeaWIFS (S), MODIS (S), ASTER (S), TM/ETM + (S), ALI (S), Hyperion, (S), IKONOS (S), Quickbird (S), AVIRIS (A), CASI (A)	<1–1000 m	1 day (SeaWiFS); 1–2 days (MODIS); 4–16 days (ASTER); 16 days (TM/ETM + , ALI, Hyperion); 2–5 days (IKONOS); 2–4 days (Quickbird); N/A (AVIRIS, CASI)	V/NIR, SWIR, MODIS and ASTER also have TIR	Measure reflectance to assess presence/absence of vegetation and relative greenness measures enabling detection of ocean and land surface chlorophyll useful for calculating productivity and plant health	c,d,f–k
Ocean color and circulation	TOPEX/Poseidon (S), AVHRR (S), MODIS (S), SeaWiFS (S)	1–10 km	10 days (TOPEX/Poseidon); 1 day (AVHRR); 1–2 days (MODIS); 1 day (SeaWIFS)	TOPEX/Poseidon; (microwave) AVHRR, MODIS, SeaWIFS (V/NIR, SWIR, MODIS and AVHRR also have TIR)	Circulation patterns can be inferred from changes in ocean color, sea surface height, and ocean temperature, important for understanding larval transport and movement of pathogens and sediment	j–m
Climate						
Rainfall	CERES (S), AMSR-E (S)	20–56 km	1–2 days (CERES, AMSR-E)	Microwave	Enable detection of precipitation and surface moisture at coarse resolutions; such data parameterize models of species occurrence based on drought tolerance	n,o

Ecological variable	Sensor[b] Space (S)/ Airborne (A)	Spatial resolution	Revisit time	Spectral resolution	Description	Website
Vertical canopy structure	SLICER (A), LVIS (A)	1–10 m	N/A (SLICER, LVIS)	V/NIR	Provides 3D measurements via laser pulses; provides biomass estimates and information about vegetation structure	r,s
Soil moisture	AMSR-E (S)	5.4–56 km	1–2 days	Microwave	Can be estimated over rel. large areas; data parameterize models of species occurrence based on moisture requirements	o
Phenology	MODIS (S), TM/ETM + (S), ASTER (S), ALI (S), HYPERION (S), IKONOS (S), Quickbird (S)	1–1000 m	1–2 days (MODIS); 16 days (TM/ETM +, ALI, Hyperion); 4–16 days (ASTER); 2–5 days (IKONOS); 2–4 days (Quickbird)	V/NIR, SWIR, MODIS and ASTER also have TIR	Information on leaf turnover and flowering/fruiting cycles can be inferred from comparisons of time series of images. Provides for identification of species tied to certain phenological events	c–e,h,i,k
Habitat Structure						
Topography	SRTM (S), ATM (A), ASTER (S), IKONOS (S), SLICER (A), LVIS (A)	90 m SRTM; 30 m/15 m ASTER; 1–15 m IKONOS, SLICER, LVIS	N/A (SRTM); 4–16 days (ASTER); 2–5 days (IKONOS); N/A (SLICER, LVIS)	Microwave SRTM; V/NIR and SWIR for others	Digital elevation models derived from radar signals via interferometry (SRTM); image stereo pairs (ASTER) or discrete-return (usually) LIDAR signals. Many species are constrained by microhabitats resulting from changes in altitude; elevation also determines watershed flows	e,h,p–s

Temporal Resolution

- **Multi-date image based classifications** demonstrably **improve species identification**.
- Species of trees with similar spectral reflectance during certain **phenological stages** typically have **different phenologies**. Images taken on dates in which two species are at different phenological stages makes it easier to distinguish species

Remote sensing for the assessment of species distribution

Existing studies of species distribution patterns using remote sensing, with or without additional GIS data, can be essentially categorized into three types.

1. **Direct mapping of individuals and associations** – mapping individual plants or associations of single species existing in relatively large, spatially contiguous units that can be distinguished using the remote sensor.
2. **Mapping of habitats** using remotely sensed data, and predicting species distribution based on habitat requirements.
3. Investigations of **direct relationships between spectral radiance** values recorded from remote sensors, **and species distribution patterns** recorded from field observations.

Mapping species coverage based on habitat classication

Modelling the distribution and abundance of single species using habitat maps from remote sensing has been carried out often enough to demonstrate its applicability, in cases where detailed information on habitat requirements is available (e.g. Gratto-Trevor 1996, Lavers and Haines-Young 1997, Tucker *et al*. 1997). However, **fewer studies have been carried out to attempt to correlate the distribution of sets of species, or communities, with habitat maps** derived from remote sensing.

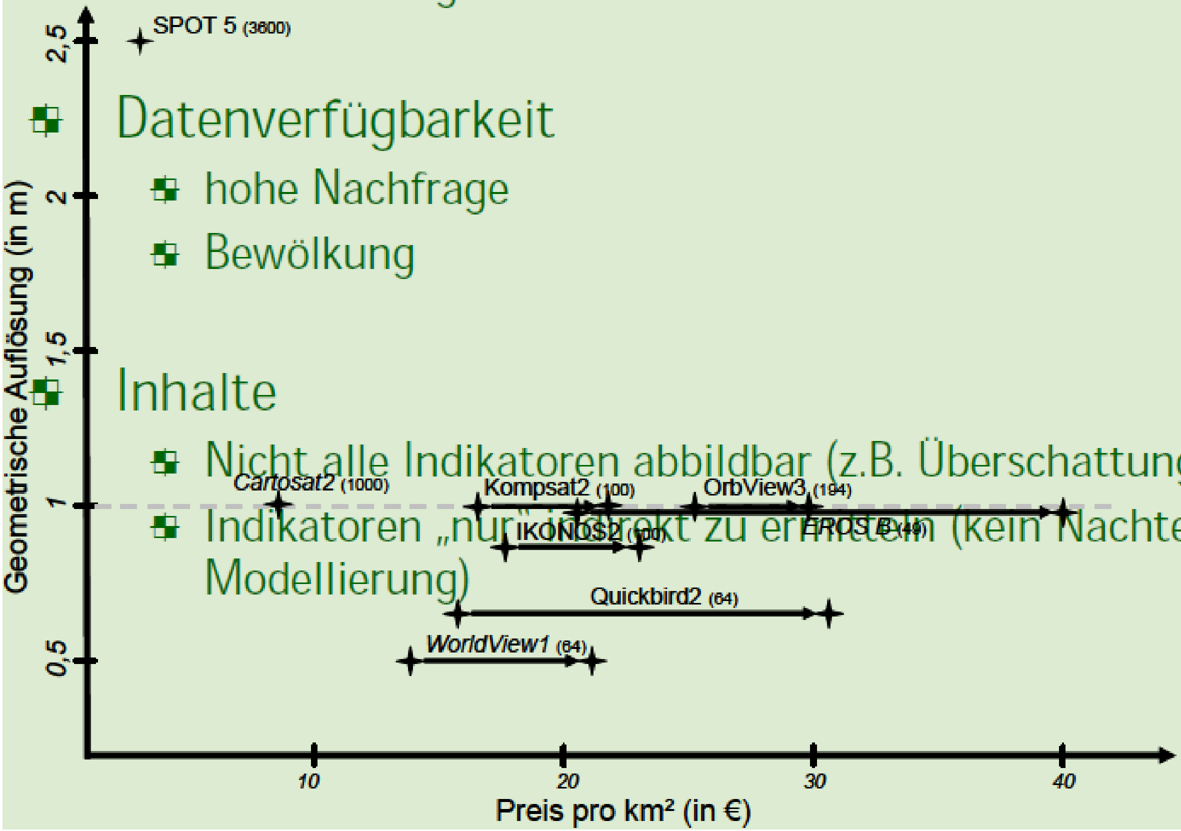
WELCHE INDIKATOREN SIND FERNERKUNDUNGSTAUGLICH?

Ebenen / Aspekte	Genetische Biodiversität	Artenvielfalt	Biotop-vielfalt
Struktur	-	(x)	x
Komposition (Muster)	-	(x)	x
Funktion	-	-	(x)[1]
Bemerkungen	(Hyperspektral-sensoren?)	Nur Pflanzen; hohe Auflösung	[1]) Trends nur multitemporal messbar

verändert nach Kenneweg, 2(

Grenzen & Schwierigkeiten

- Kosten
  - für Satellitendaten
  - Für Erhebung von Ground-Truth Daten
- Datenverfügbarkeit
  - hohe Nachfrage
  - Bewölkung
- Inhalte
  - Nicht alle Indikatoren abbildbar (z.B. Überschattung)
  - Indikatoren „nur" indirekt zu ermitteln (kein Nachteil: siehe Modellierung)



Conclusions

- While the **use of remote sensing for biodiversity assessment is increasingly encouraged**, the **literature** on means and methods for vegetation mapping remains confused, **often contradictory**. This is due in large part to the **large variability in structure, composition and historical characteristics of vegetation types**.
- This overview attempts to **evaluate the potential of remote sensing for the critical task of biodiversity assessment**, to meet different objectives are diverse spatial scales.
- To summarize, **direct estimations of spectral values may be useful for the limited purpose of indicating areas with higher levels of species diversity, but can be used over spatial extents of hundreds of square kilometers**.

Conclusions

- **Habitat maps** appear capable of **providing information on the distributions of large numbers of species in a wider variety of areas**, however this is restricted to the **spatial scale of tens of square kilometers**. In smaller, local areas with limited species diversity, direct mapping can provide detailed information on the distribution of certain canopy tree species or associations.
- The techniques described **require the use of information collected at the field level, as well as from the remote sensor**. The addition of intermediate scales of study may assist in the extrapolation of information from the field level to the global level.

Isn‘ t Biodiversity Research & RS already a long-lasting friendship?

GMES Global Monitoring for Environment and Security Satelliten-Fernerkundungsdaten von Bund und Ländern: Gemeinsamer Datenpool kann Kosten senken und Effizienz erhöhen (SATUM-Studie) GSE-NATURE - Datensatz

EON Earth **O**bservation for **N**atura 2000

SPIN Spatial **I**ndicators for European **N**ature Conservation

BioAssess The Biodiversity assessment tool project

EuMon EU-wide monitoring methods and systems of surveillance for

species and habitats of Community interest

HABITALP Diversität und Monitoring alpiner Lebensräume

ALARM Assessing **La**rge scale **R**isks for biodiversity with tested **M**ethos

BIOMASS Vegetationserfassung mit mehrfrequenten Fluzeugrasterdatdn für forstl. Planung

NP Bay. Wald Vegetations- und Totholzklassifizierung anhand von IRS-1C-Daten

SARA `04 Satellitengestütztes **Ra**ummonitoring für ausgewählte Natura 2000 LRT

SARA ENMAP Satellitengestütztes **Ra**ummonitoring mit dem Hyperspektralsatelliten **EnMap**

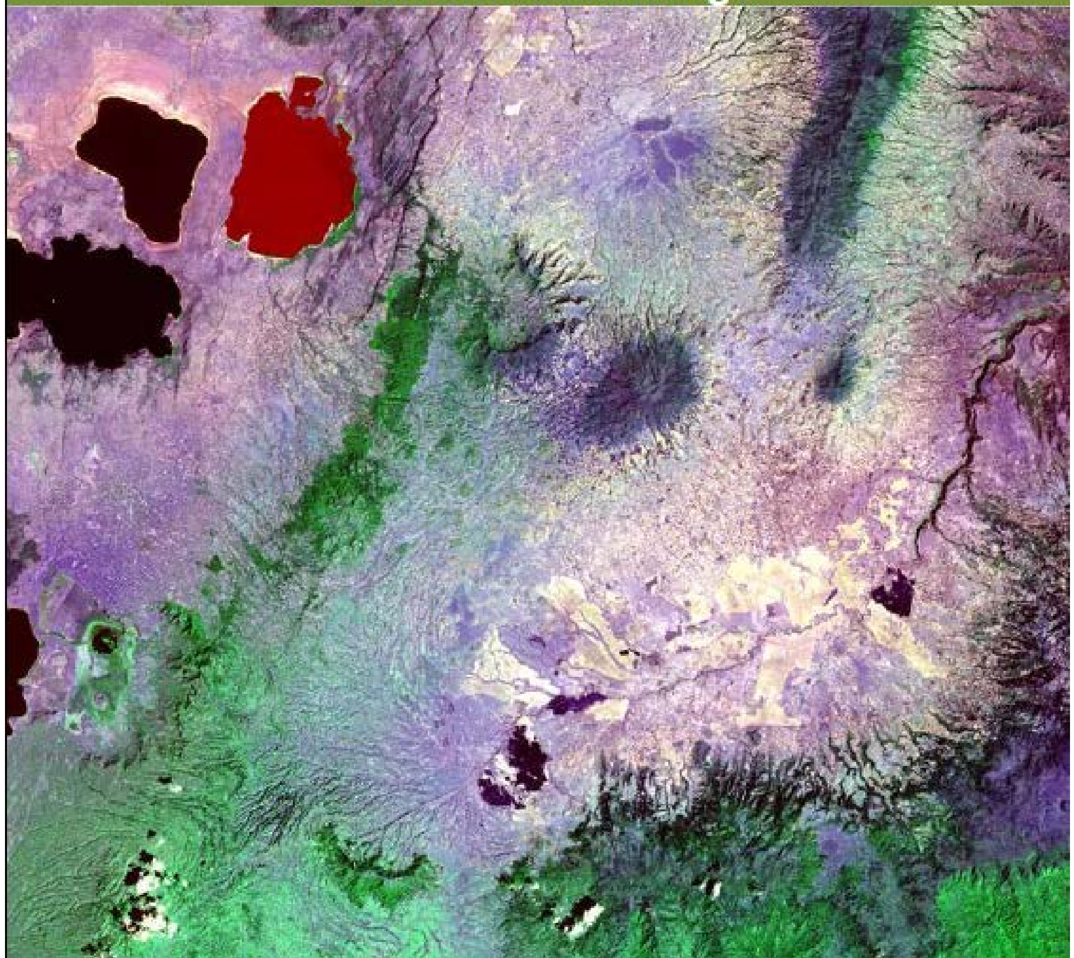
CARE-X Change Detection **A**nalyse für das flächendeckende Biodiversitätsmonitoring

mit **R**apid**E**ye und TerraSAR-**X** Satellitendaten

CambridgeConservationInitiative

transforming the landscape of biodiversity conservation

What do conservation practitioners want from remote sensing?



BirdLife BTO IUCN RSPB TRAFFIC UNEP WCMC UNIVERSITY OF CAMBRIDGE

What conservationists want

- Habitat extent, distribution and inventory
- Change in habitat extent and distribution
- Habitat structure and features
- Effectiveness of protected areas and other land management interventions
- Drivers of habitat loss, degradation and overexploitation of natural resources
- Impacts of climatic change on biodiversity
- Ecosystem services
- Remote sensing based alert systems for timely detection of damage to key sites

Habitat extent, distribution and inventory and Change in habitat extent and distribution

Extent

- Need reliable information on extent of habitat and associated species distributions
- Appropriate resolution (thematic, temporal, spatial) not always available

Change

- Surveillance of change in habitat extent is essential for many conservation activities.
- No widely available operational system for measuring changes in the extent of key habitats and associated species distributions

Drivers of habitat loss, degradation and effectiveness of management interventions

Drivers of loss

Conservationists want to know the drivers and pressures on biodiversity to understand processes.

Remote sensing-based data for assessing correlates of change (eg agric. intensification, roads, settlements, final land cover…)

Action effectiveness

Quantitative large-scale information on conservation management effectiveness is sparse

Improved access to remote sensing data or methods for tracking / analysing changes

Climate change and ecosystem services

Climate change

Long time series data on ecologically relevant indicators are important to conservationists

Access to remote sensing measurements of responses to climatic change (tree line, seasonality)

Ecosystem services

The monetary values of ecosystem services provided by wild species and the habitats need quantified.

Measures of e.g. hydrological variables where direct measurements are difficult.

General concerns about the applicability of remote sensing to conservation

1. Multi-temporal and real time analyses
2. Data verification
3. Access to and promotion of data sets
4. Information on data sets
5. Capacity needs

Remote sensors and conservationist workshop conclusions

- **Need to communicate and collaborate better**
  - Conservation priorities and data
- **Conservationists can make better use of existing data and tools**
- **A better knowledge of the data layers available and how to integrate**
- **Conservationists can have unreasonable expectations**
- **Move from proof of concept to delivering operational systems**

- **It all comes back to communication**

eStation Products

eStation products include:

- **Land and Vegetation indicators,**
- **Precipitation indicators and**
- **Fires indicators.**

The Land and Vegetation indicators:

Normalized Difference Vegetation Index (NDVI) used to measure and monitor plant growth, vegetation cover, and biomass production.

VGT4Africa (fCover) products which is the fraction of green vegetation covering a unit area of horizontal soil used to decouple vegetation and soil contributions in energy balance processes with particular attention to temperature and evapo-transpiration,

Normalized Difference water index used to assess and monitor water content and detect drought stress,

African Monitoring of Environment for Sustainable Development

eStation Products

***Dry matter productivity** (Biomass production)- The BP product computes the total biomass (Kg/ha) produced between the start and the end of the season. This product is based on the Dry Mater Productivity product and is of great importance for rangeland management and production assessment.*

***Small water bodies** indicating the free water, humid area and mix of free water and humid area. It provides useful information for several applications, including human activities, cattle management, epidemiology, biodiversity. In addition, long term time series of water occurrence in semi arid regions might be an interesting indicator of the impact of climate variation.,*

***Land surface temperatures and evapotranspiration-** It plays an important role in the physics of land surface as it is involved in the processes of energy and water exchange with the atmosphere. LST values are of special interest for meteorology, hydrology, agro meteorology, climatology and environmental studies.*

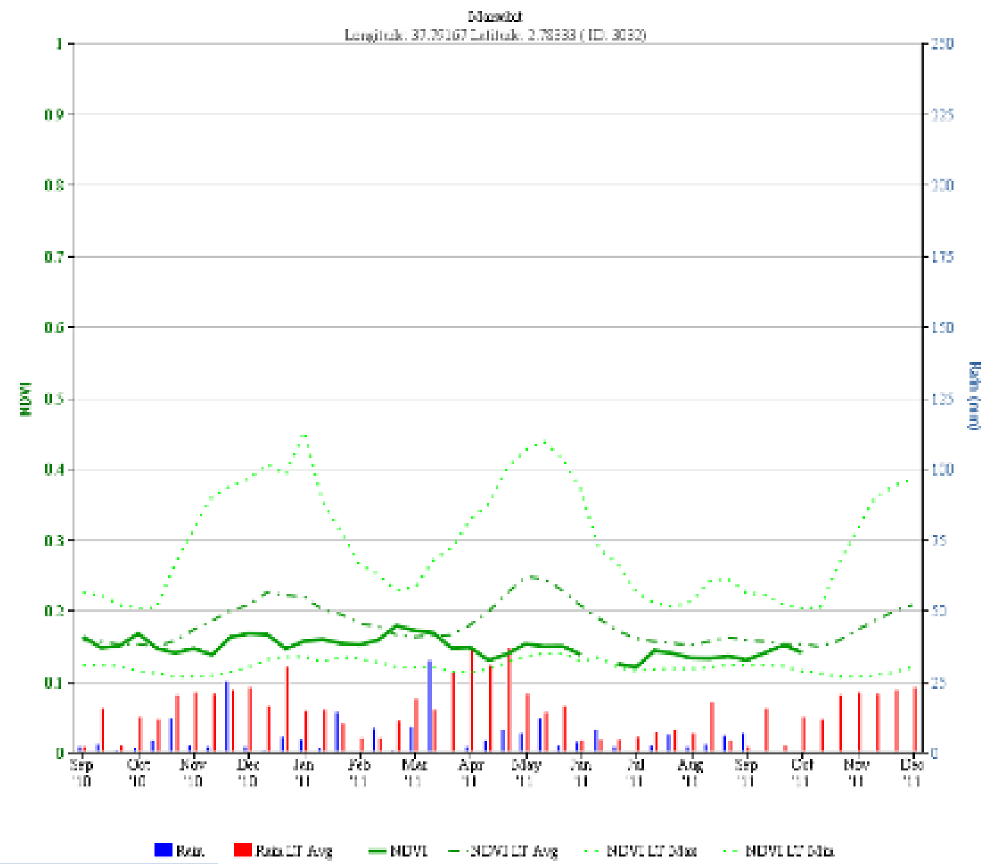
eStation Products

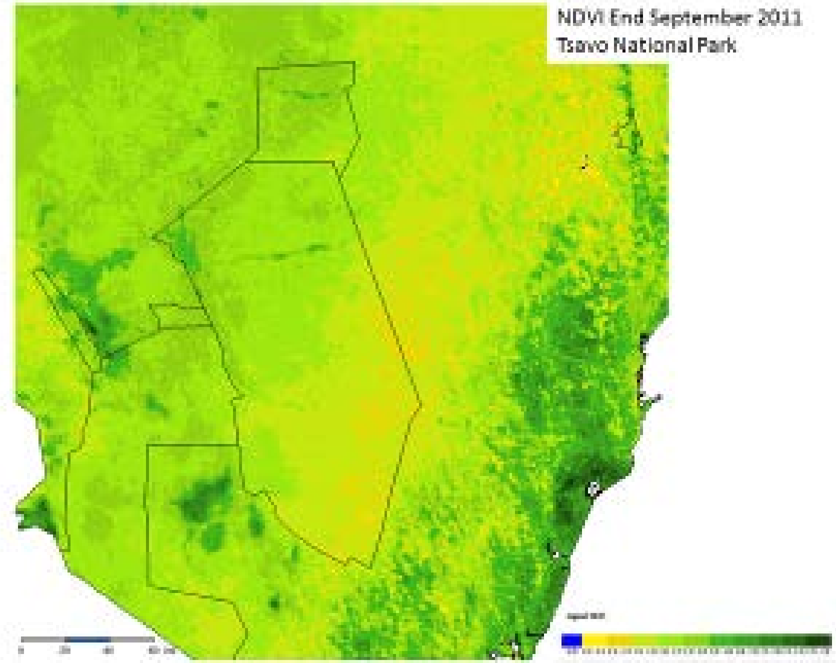
- **Daily rainfall estimates** *(precipitation) received every 10 days (decadal)-The RFE imagery combines Meteosat infrared data, rain gauge reports from the global telecommunications system, and microwave satellite observations to provide daily rainfall estimate in mm at an approximate horizontal resolution of 10 km. These products provide input for hydrological and agrometeorological models as well as climate information e.g. compare the current state of rainfall with previous time periods.*
- **Fire data from MODIS** *for monitoring of burnt areas and burnt biomass-This is the monthly product representing the Burnt Areas extension (burndate) and additionally a quality flag on the identification confidence.*

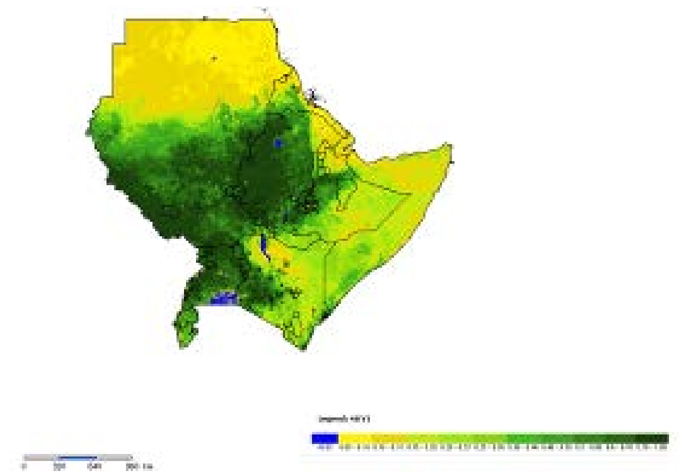
Estation Products Use

Eco-climatic conditions in Protected areas in the IGAD Region

NDVI

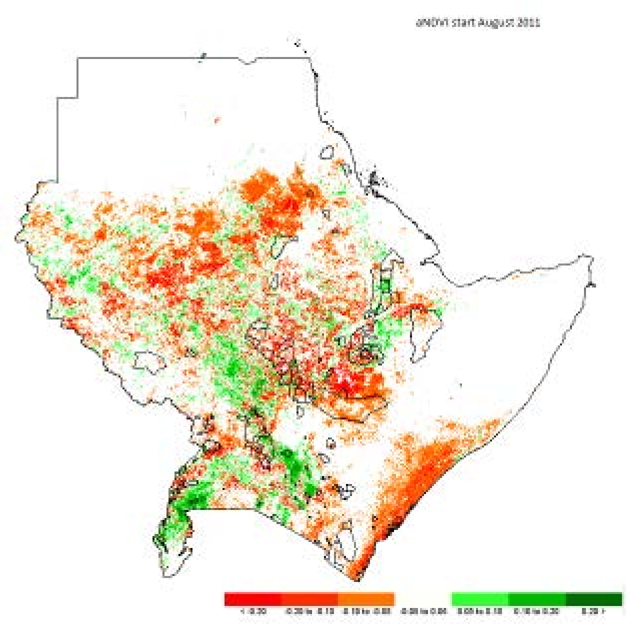


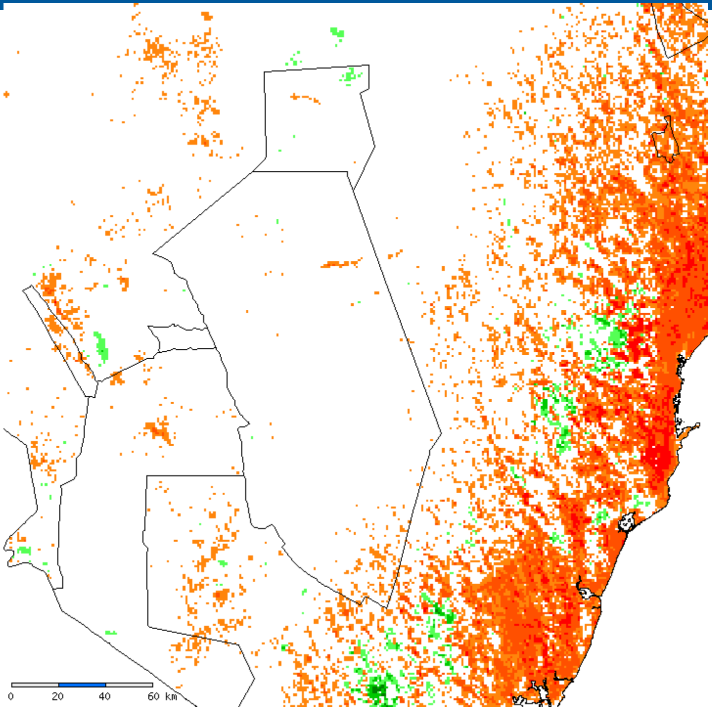


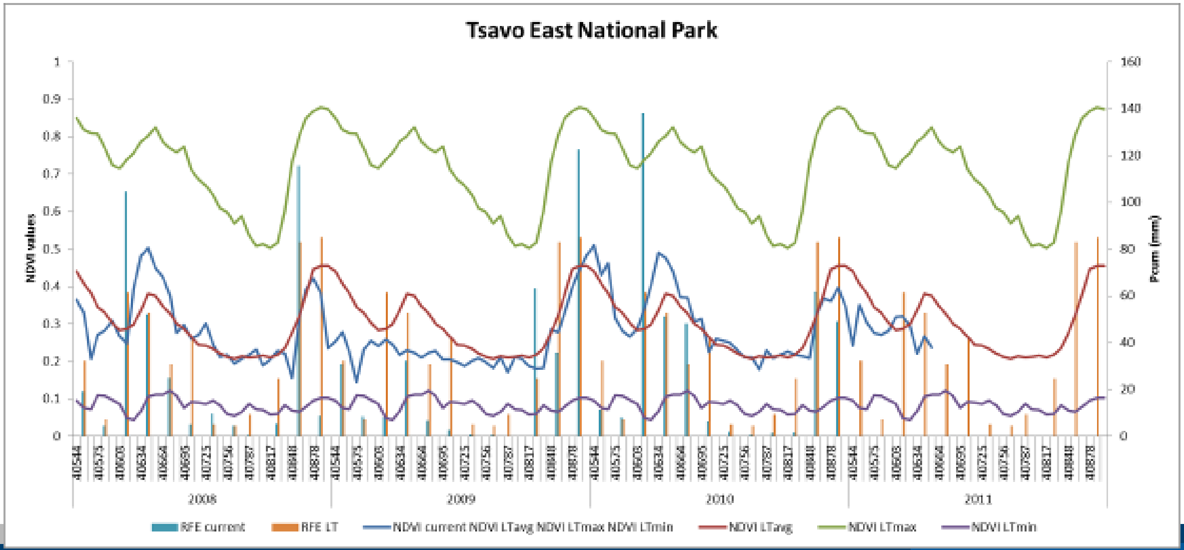


Estation Products Use

aNDVI

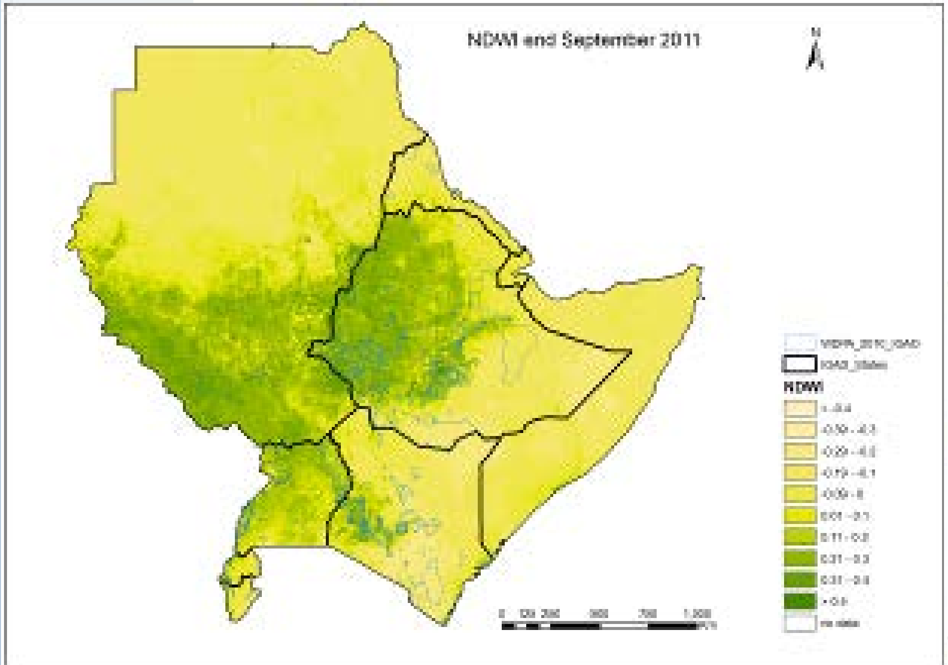


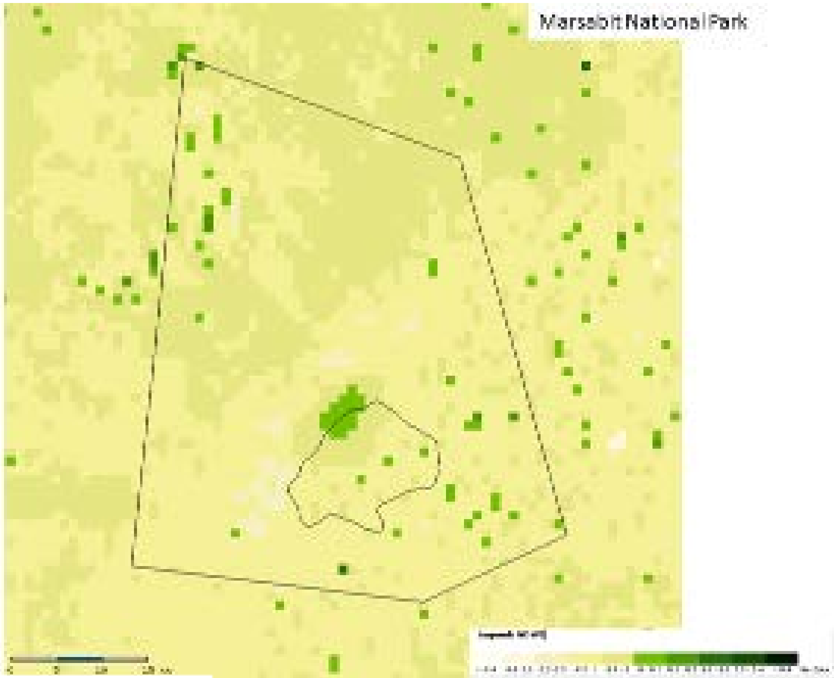


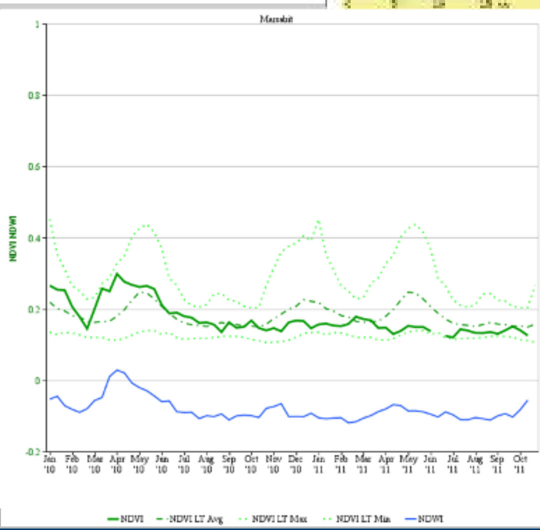


Estation Products Use

Normalized Different Water Index

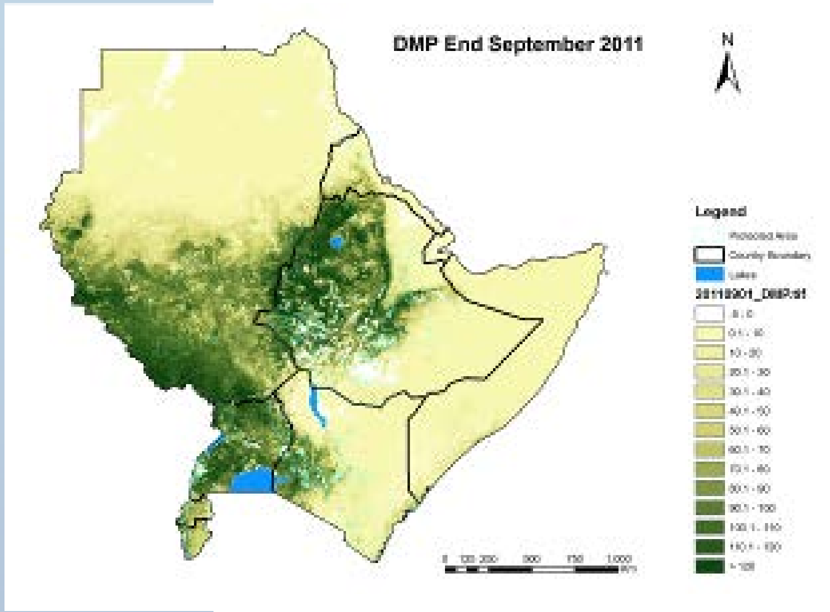


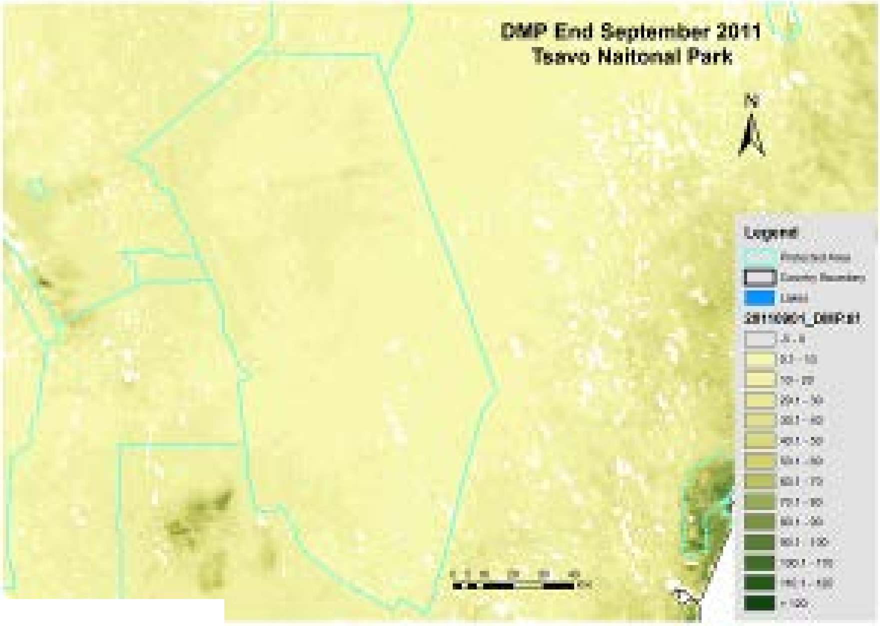


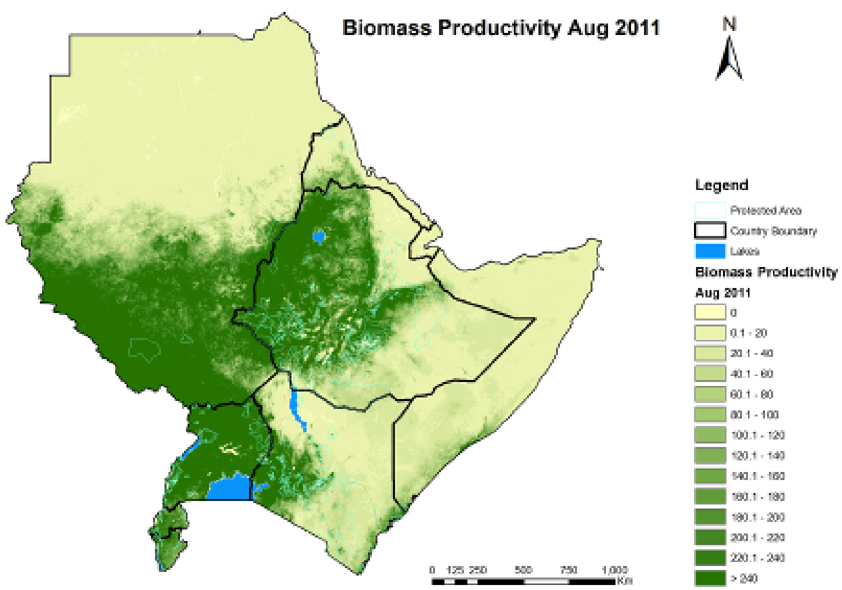


Estation Products Use

Dry Matter Productivity



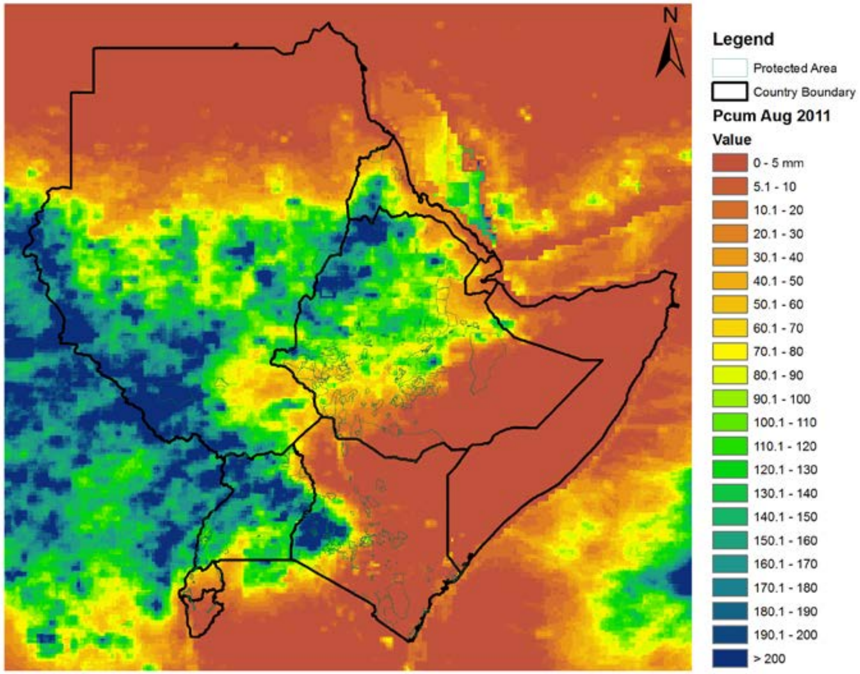




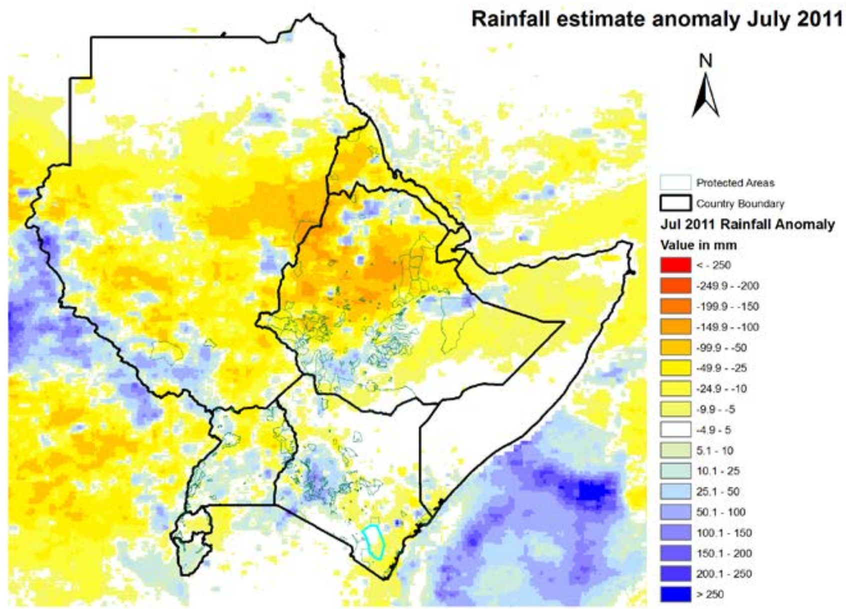
Biomass Productivity

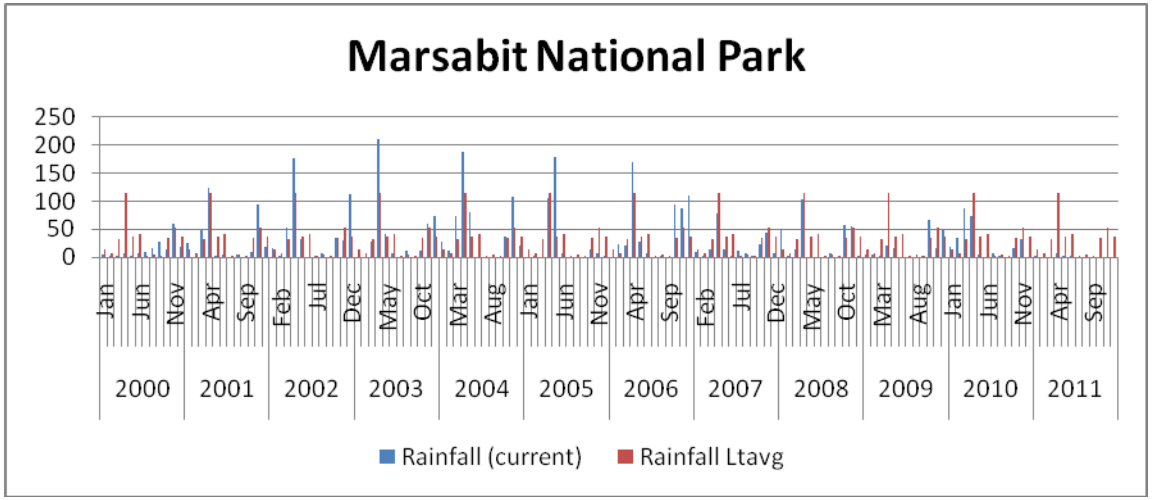
Estation Products Use

Precipitation cumulated



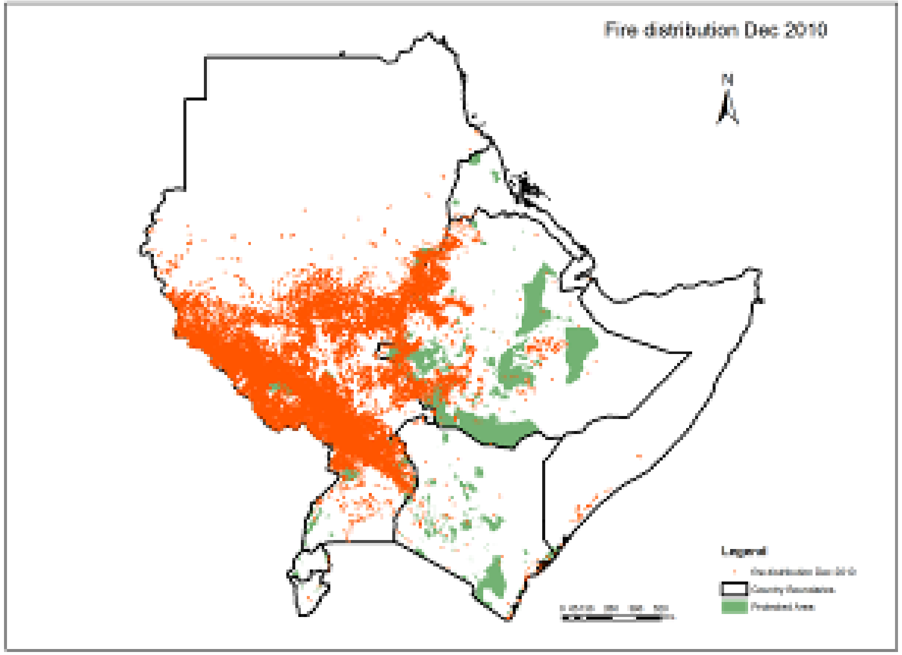
Precipitation anomaly



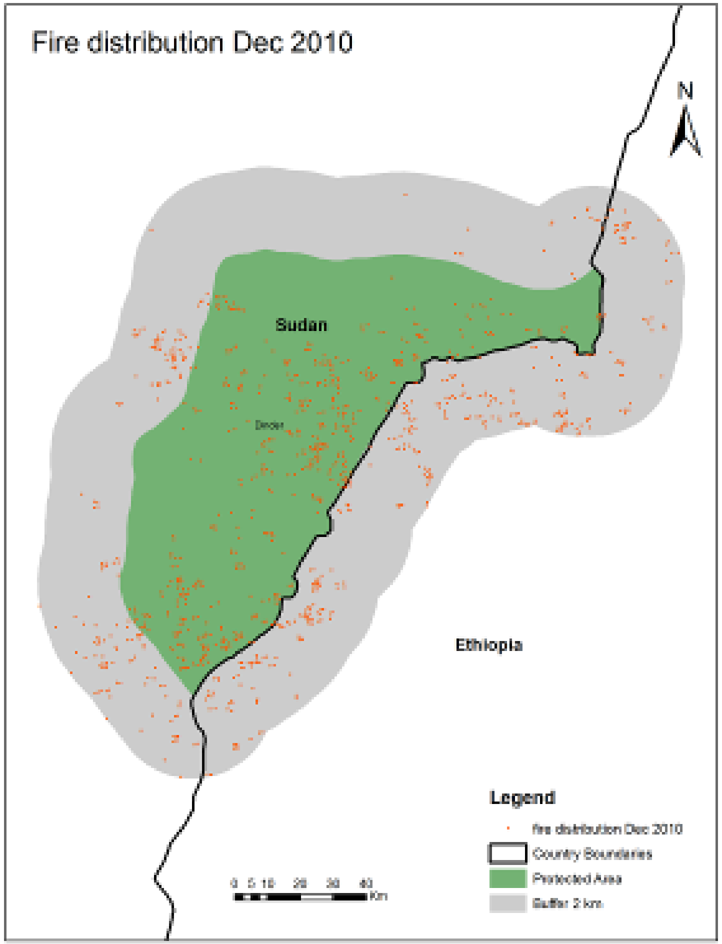


Estation Products Use

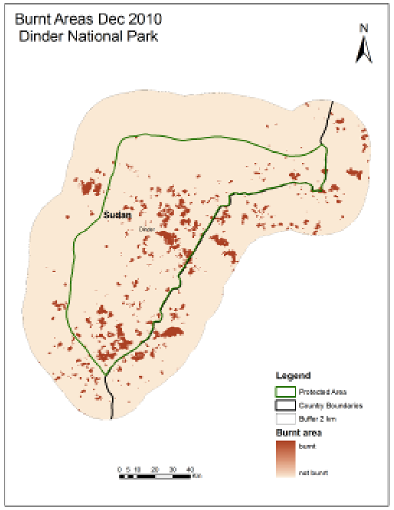
Fire density



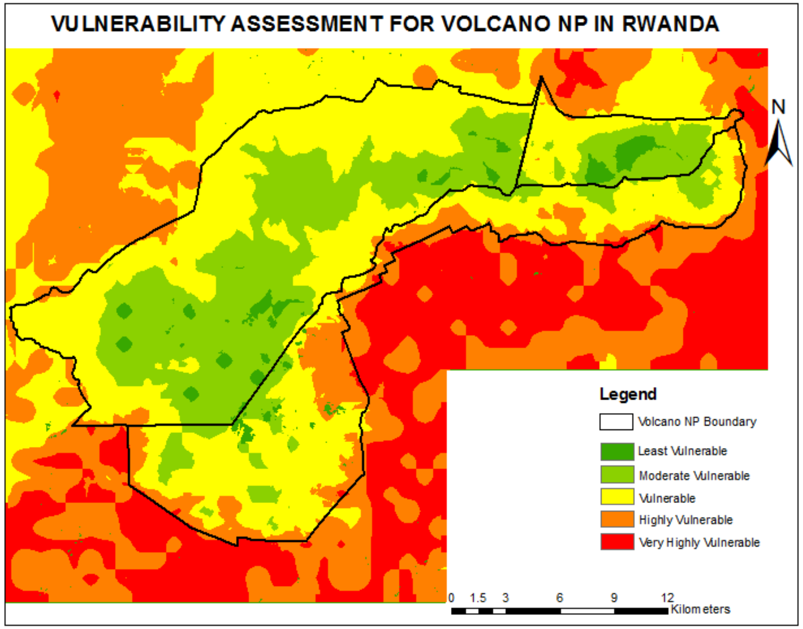
Fire distribution



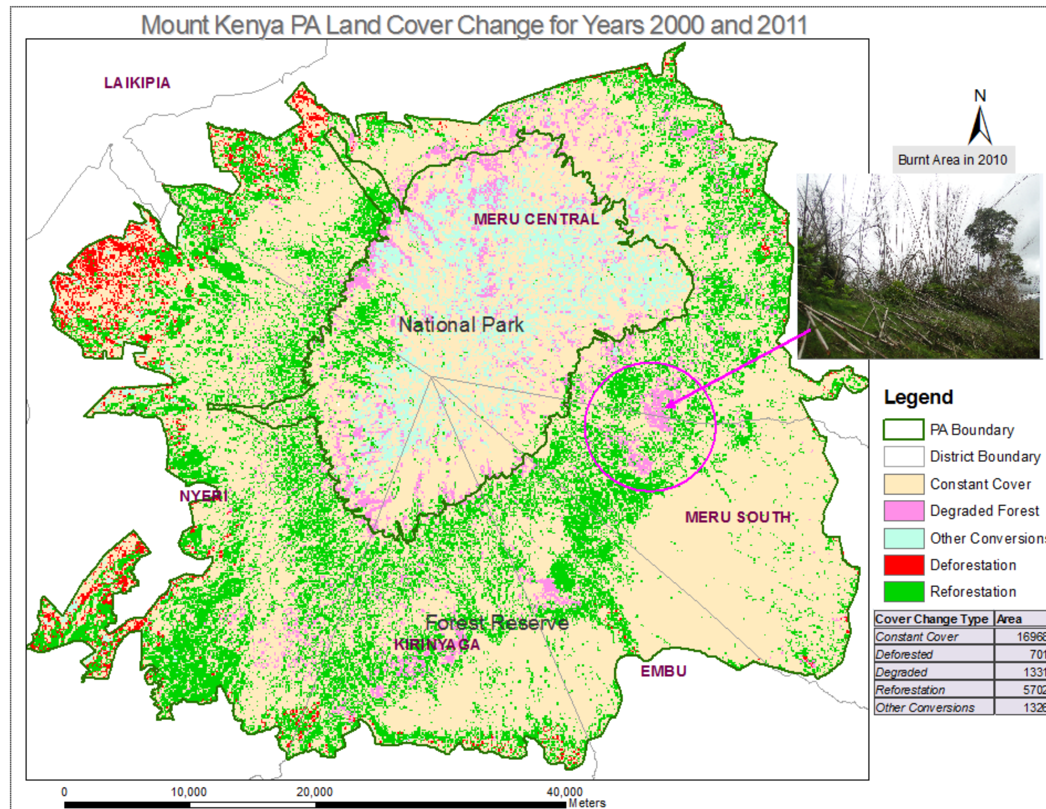
Burnt areas



Other Products Use

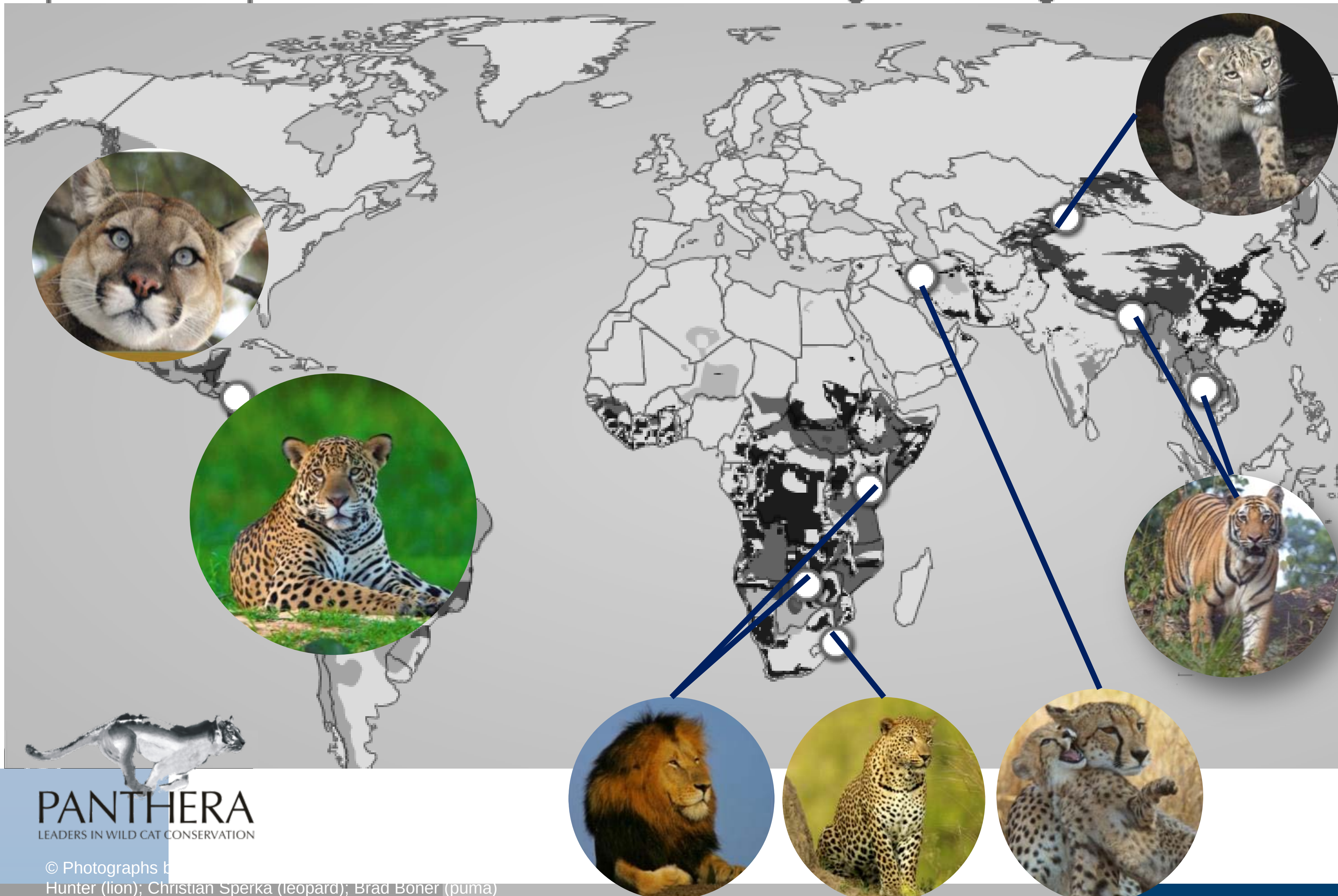


The Protected Area Vulnerability model used a combination of three indicators; Population, Accessibility and Agricultural



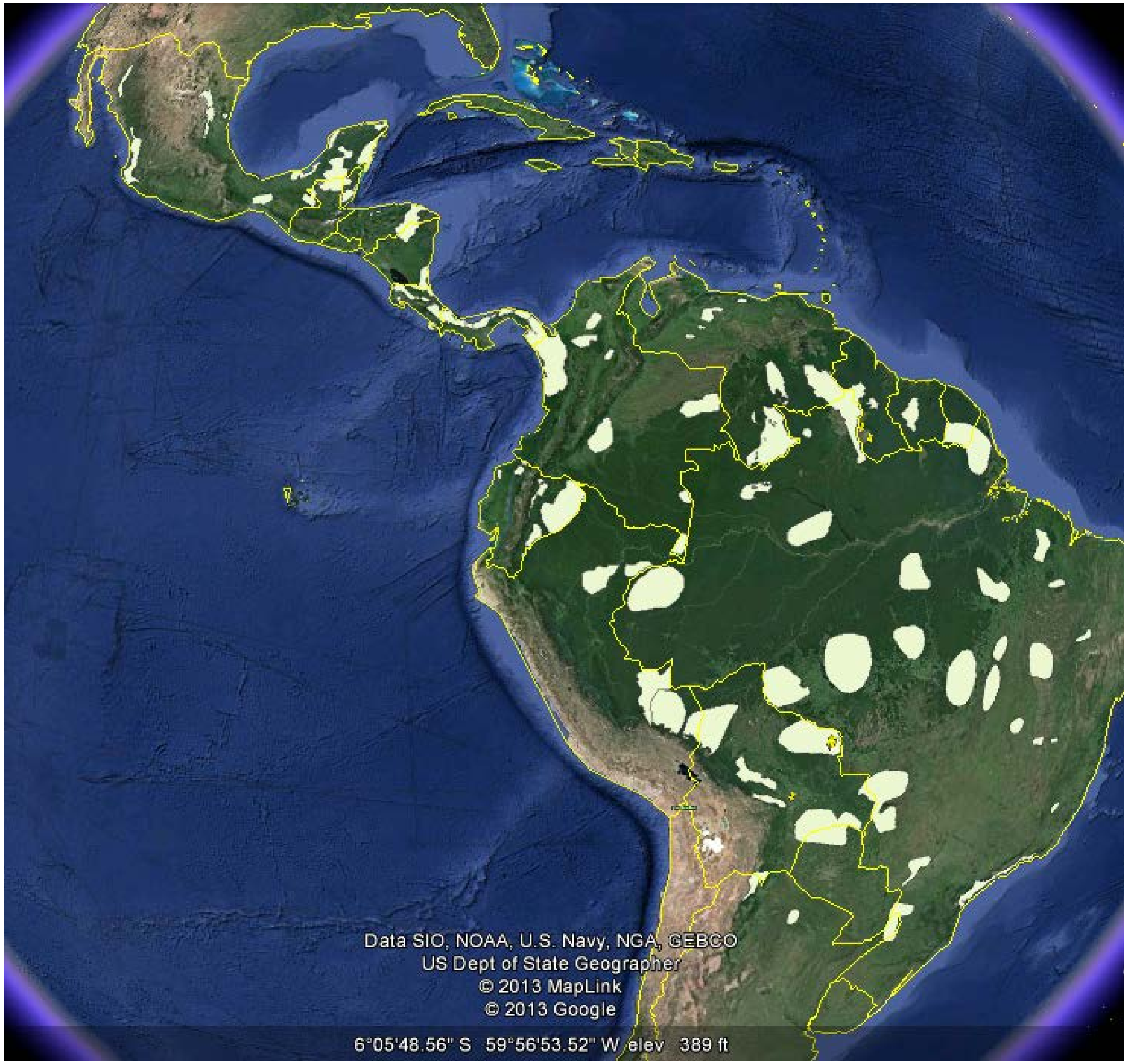
Panthera is working in more than 50 countries around the globe.

Explore The Map Below To Learn More About Our Range-Wide Programs.



PANTHERA
LEADERS IN WILD CAT CONSERVATION

© Photographs b
Hunter (lion); Christian Sperka (leopard); Brad Boner (puma)

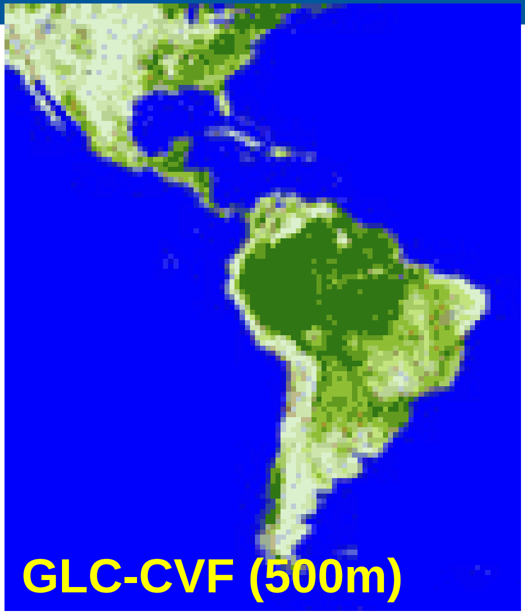


PANTHERA
LEADERS IN WILD CAT CONSERVATION

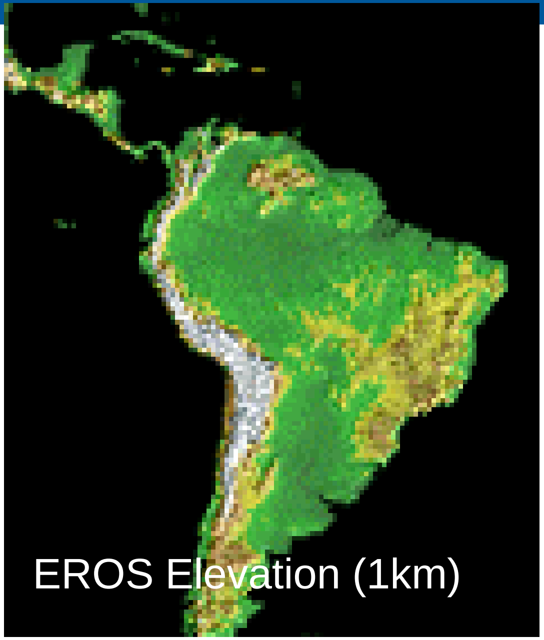
Google earth

Jaguar Movements

GLC2000 (1km)



GLC-CVF (500m)

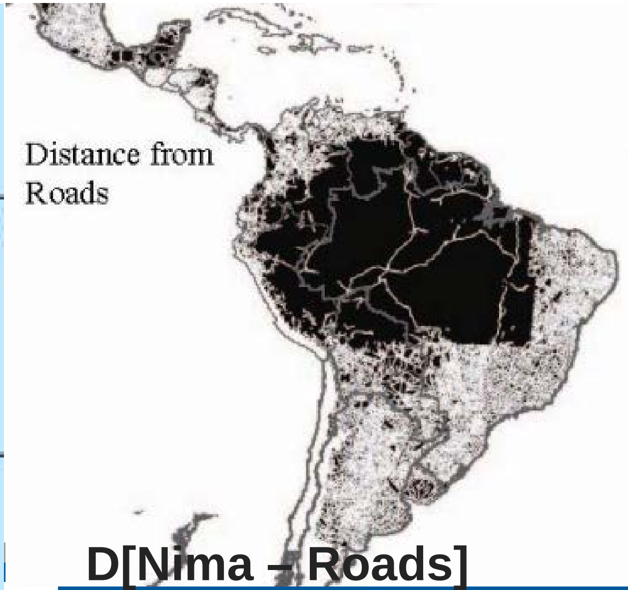


EROS Elevation (1km)

Zeller & Rabinozwitz 2011

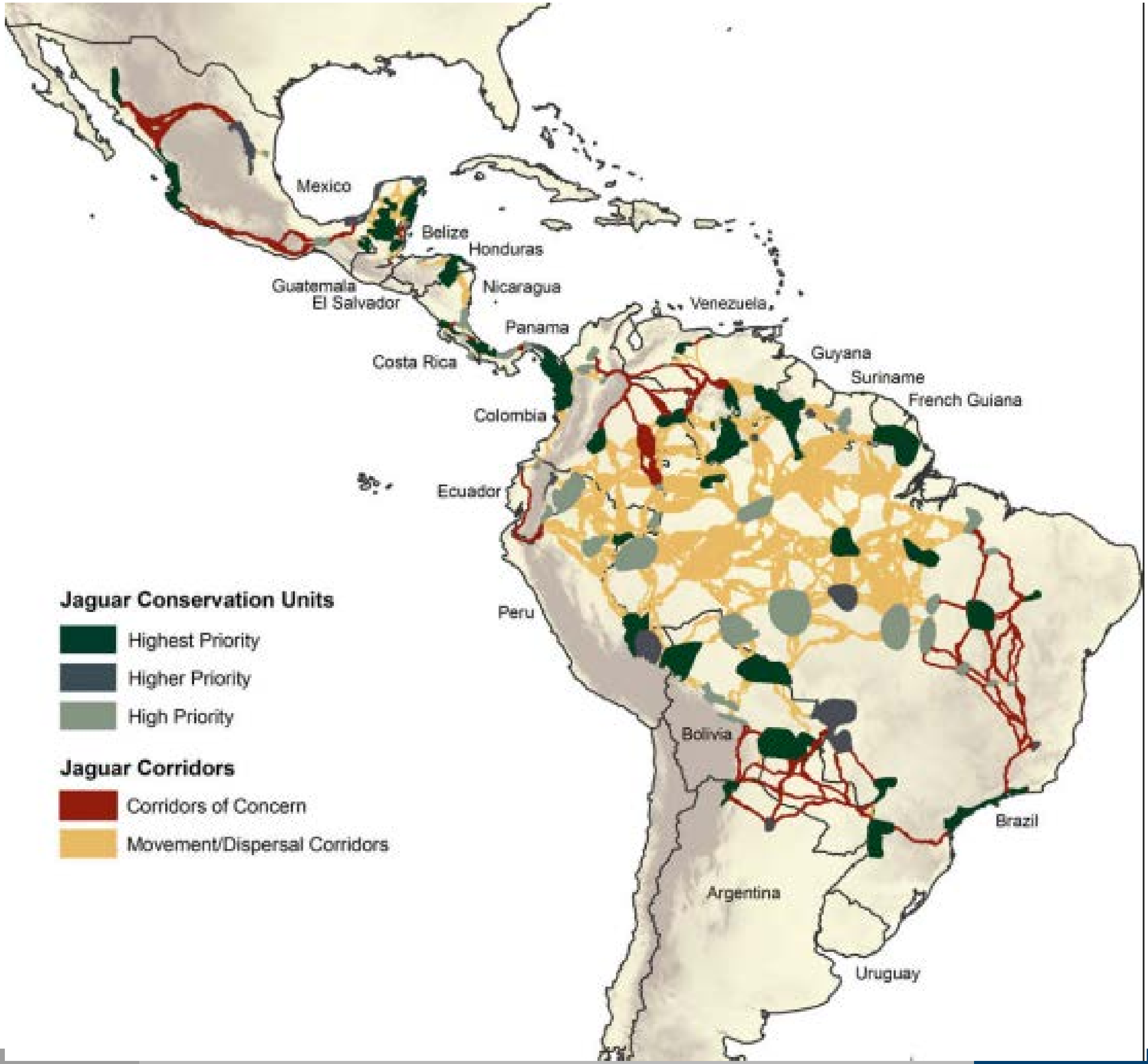
Jaguar persecution

Ciesin - Population



D[Nima – Roads]

D[Nima – Settlements]


Mexico
Belize
Honduras
Guatemala
El Salvador
Nicaragua
Venezuela
Panama
Costa Rica
Guyana
Suriname
French Guiana
Colombia
Ecuador
Peru
Bolivia
Brazil
Argentina
Uruguay
Jaguar Conservation Units
Highest Priority
Higher Priority
High Priority
Jaguar Corridors
Corridors of Concern
Movement/Dispersal Corridors

PANTHERA
LEADERS IN WILD CAT CONSERVATION
Mexico
Belize
Honduras
Guatemala
El Salvador
Nicaragua
Panama
Costa Rica
Venezuela
Guyana
Suriname
French Guiana
Colombia
Ecuador
Peru
Brazil
Bolivia
Paraguay
Chile
Argentina
JAGUAR CORRIDORS
JAGUAR CONSERVATION UNITS
0 500 1,000 2,000 Kilometers

Thanks for your attention !

Indikatoren

- Biodiversität ist ein **komplexer Begriff mit mehreren Hierarchieebenen**, der unter unterschiedlichen Aspekten gesehen und analysiert werden kann.
- Mit Fernerkundung können i. d. R. nur **Indikatoren** für Biodiversität abgebildet bzw. abgeleitet werden (kein kompletter Überblick).
- **Biotoptyp, Landnutzungsart oder deren Zusammensetzung als geeignetes Habitat für bestimmte Arten**
- **Bewertungen**, z. B.: **Naturnähe** bzw. **Hemerobie** von Biotoptypen oder Landnutzungsarten; Störungen bzw. Entwicklungstrends von Einzelflächen oder Gebieten (multitemporaler Fernerkundungseinsatz);
- „**Günstiger Erhaltungszustand**" von Lebensraumtypen (LRT) im Rahmen des EU Programms „Natura 2000" – für einzelne LRT zu definieren.
- **Nicht für alle Ebenen und Aspekte** der Biodiversität sind Beiträge der Fernerkundung nutzbar.

Modelling the relationship between species distribution patterns and remotely sensed data

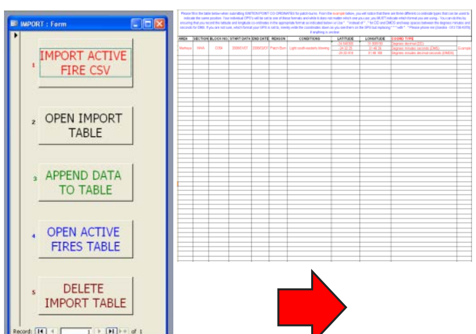
- It has been suggested that **species richness can be estimated by deriving models of its relationship with remotely sensed data**.
- However, verifications of this hypothesis have been carried out using sometimes questionable statistics, and provide conflicting results.
- Example: Lewis (1994) attempted to **relate classifications using Landsat MSS imagery to vegetation composition** on Barrow Island, Australia. For 38 sites of approximately 15 ha each, encompassing all habitat types found on the island (mainly dominated by spinifex grasses), the percentage of ground cover for all 300 plant species found in the area as well as for the physical components—plant litter, bare ground and stone, was calculated. Based on this, a cluster analysis was performed in order to cluster these sites into seven groups. Based on spectral reflectance, these sites were again clustered into six groups. These two classification schemes were found to significantly correspond ($p<0.005$).

SANParks Fire Monitoring System

FIRMS daily fire alerts sent to fire@sanparks .org

FIRMS email includes date, time and co-ordinates of fire as well as basic map indicating location

FIRMS active fire alerts are imported into the **SANParks Active Fire Database** along with *in situ* lat/long reports from rangers (used for ground-truthing).



MODIS satellite image subsets are downloaded twice daily i.e. Terra (AM) and Aqua (PM) .

Kruger_NP Subset - Terra 1km Bands 7-2-1 image for 2008/335 (11/30/08)

Vectors selected: none

Change vector options: none submit

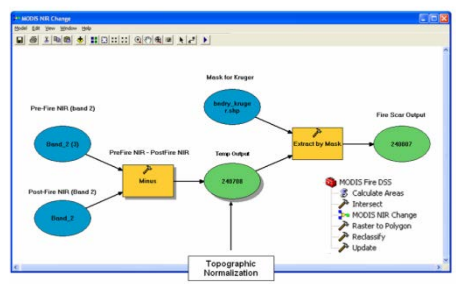
View alternate pixel size: 2km | 500m | 250m |

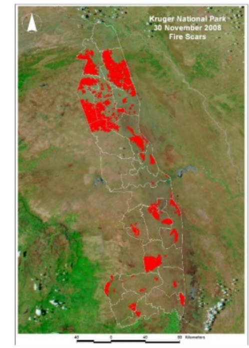
View alternate band combination: True Color | NDVI |

View Aqua image | See all images available for this area this day |

http://rapidfire.sci.gsfc.nasa.gov/subsets/?subset=Kruger_NP

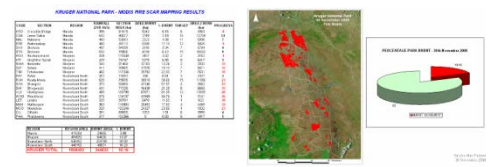
Change Detection Model identifies changed pixel from image to image, using bands most susceptible to change by fires.



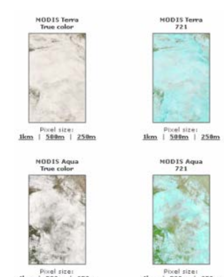


The FIRMS and ranger report co-ordinates are used to verify fire scars mapped using model

Model output is used to generate **Fire Mapping Report.**



Problems include, Cloud-cover; No fire co-ordinates reported by rangers; Format of co-ordinates inconsistent or not recorded correctly.



Degree Minutes Seconds
DD.MM.SS

Degrees Minutes Seconds Decimal Seconds
DD.MM.SS.sss

Degrees Minutes Decimal Minutes
DD.MM.mmm

Degree Decimal
DD.ddddddd

http://www.sanparks.org/parks/kruger/conservation/scientific/key_issues/