Land Use Change in Oil Field 5a – Satellite-Based Evidence of Traditional Farming and Patterns of Change (1994–2004)

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PRINS Engineering

Prins background on Sudan and Human Conflicts

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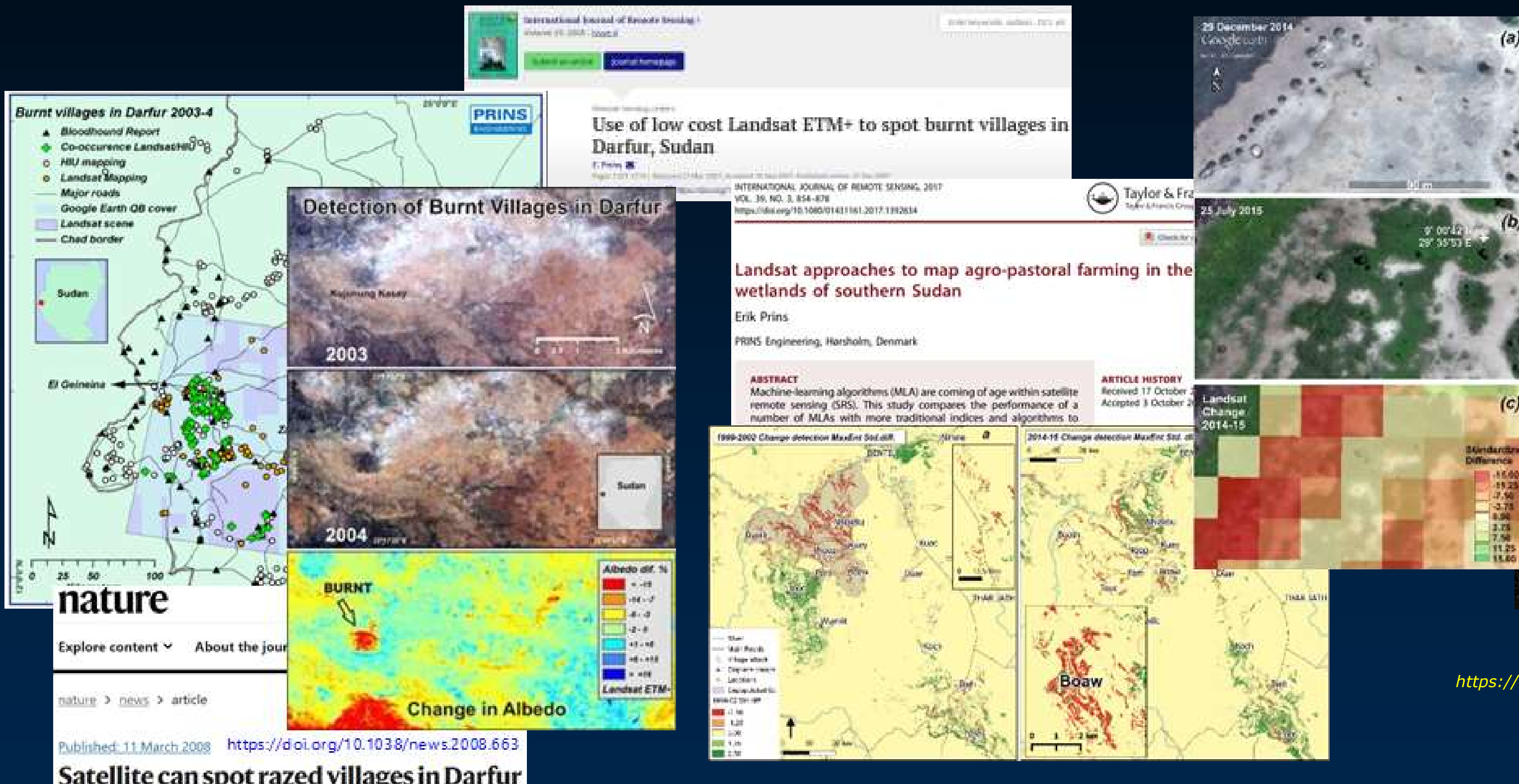
Over the past two decades, I have pioneered the use of multi-spectral satellite imagery to detect large-scale human rights violations—both in Darfur and Southern Sudan.



Closed ESA / European Space Policy Institute meetings 2022-23

https://connectivity.esa.int/news/civil-security-space-industry-day

https://www.espi.or.at/2nd-esa-security-conference/

https://www.amnesty.org/en/documents/afr54/072/2004/en/

https://landsat.gsfc.nasa.gov/article/using-landsat-to-detect-human-rights-violations/

Satellite data is a powerful tool. It captures changes invisible to the naked eye, with precise timestamps, vast coverage, and a deep historical archive.

- Landsat Data Detect and Ground Information Confirm -

Introduction

Your Honour, Ladies and Gentlemen,

- I am here to present objective evidence captured from space—evidence that aligns closely with eyewitness accounts on the ground.
- Using satellite technology, we have documented significant changes in land use in Southern Sudan between 1999 and 2003. These changes match reports of mass displacement and village destruction.
- The satellite data provides a historical record that can be verified by very high-resolution imagery—and it reveals more - patterns not visible to the human eye.
- My work has undergone peer review in respected scientific journals and has been validated by international experts.
- As the saying goes, "A picture is worth a thousand words." In this case, it bears witness to the truth.

Introduction

Structure of presentation:

- To aid understanding, I will begin with an introduction to traditional land use in the region, and how this is visible in satellite imagery from oil block 5a.

- Then I will walk you through the work that began in 2006 and evolved over three stages:
  - The **ECOS 2009** Report (European Coalition on Oil in Sudan)
  - The **Stockholm 2013** presentation, which expanded the methodology
  - The IJRS 2017 peer-reviewed scientific publication

- To support general understanding, I have included updates, explanatory materials, and illustrative images. The technology has advanced over the past 20 years, and these additions reflect some of those improvements. Some supporting materials can be accessed at www.prinsengineering.com/Attacks_5a.doc

- Reports, data and explaining text can be found at: https://www.prinsengineering.com/sudan_5a_pro.htm

Concession 5A – People and Land Use

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“Let’s begin with how this landscape works - how people live, use the land, and leave visible signs of that use. These patterns are so strong that they are clearly detectable even from space - and that’s key for what follows.”

People are living in mud huts with thatched roofs – Tukuls

Cattles are the turning point in the way of life – in South Sudan double amount of cattle to humans. This agro-pastoral way of life **is a kind of range land farming system** with a homestead where crops are grown.

In dry season (~November – May) land becomes parched and cattle's are driven far to seek ‘green grasses’ – can move > 50 km a day.

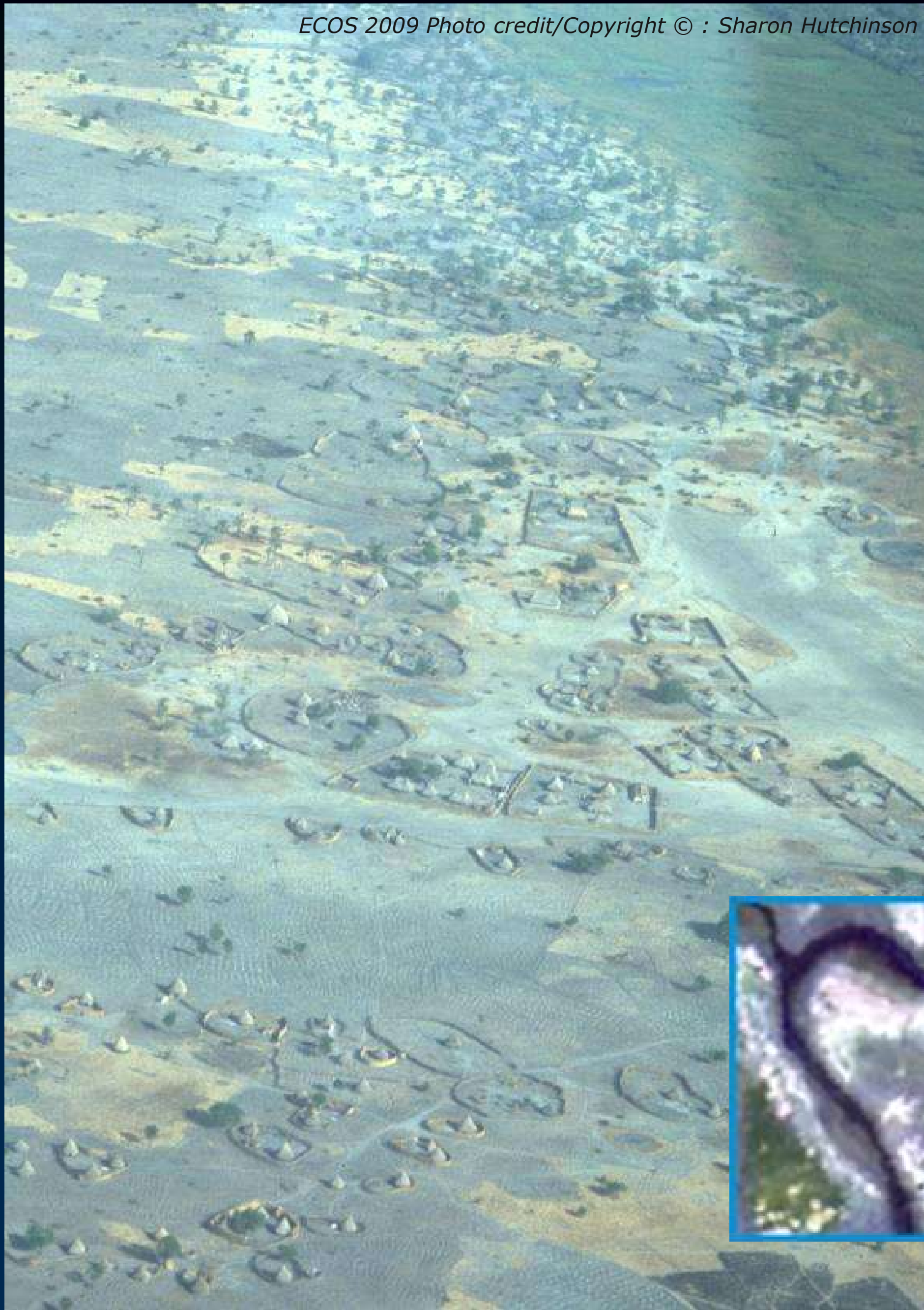
In the wet period mobility is hampered; people and cattle are typically concentrated on homesteads placed on higher grounds.

Cattle’s can leave a strong land degradation footprint that is a well known satellite application for monitor and manage rang-lands.

photo credit: @ Nakachew Minuye and Nuer study

photo credit: @ Peter Lawson

The Study area – Geography - Homesteads / Land Use



Understanding the Setting is Key

The area is generally flat and frequently flooded during rainy season where mobility is low.

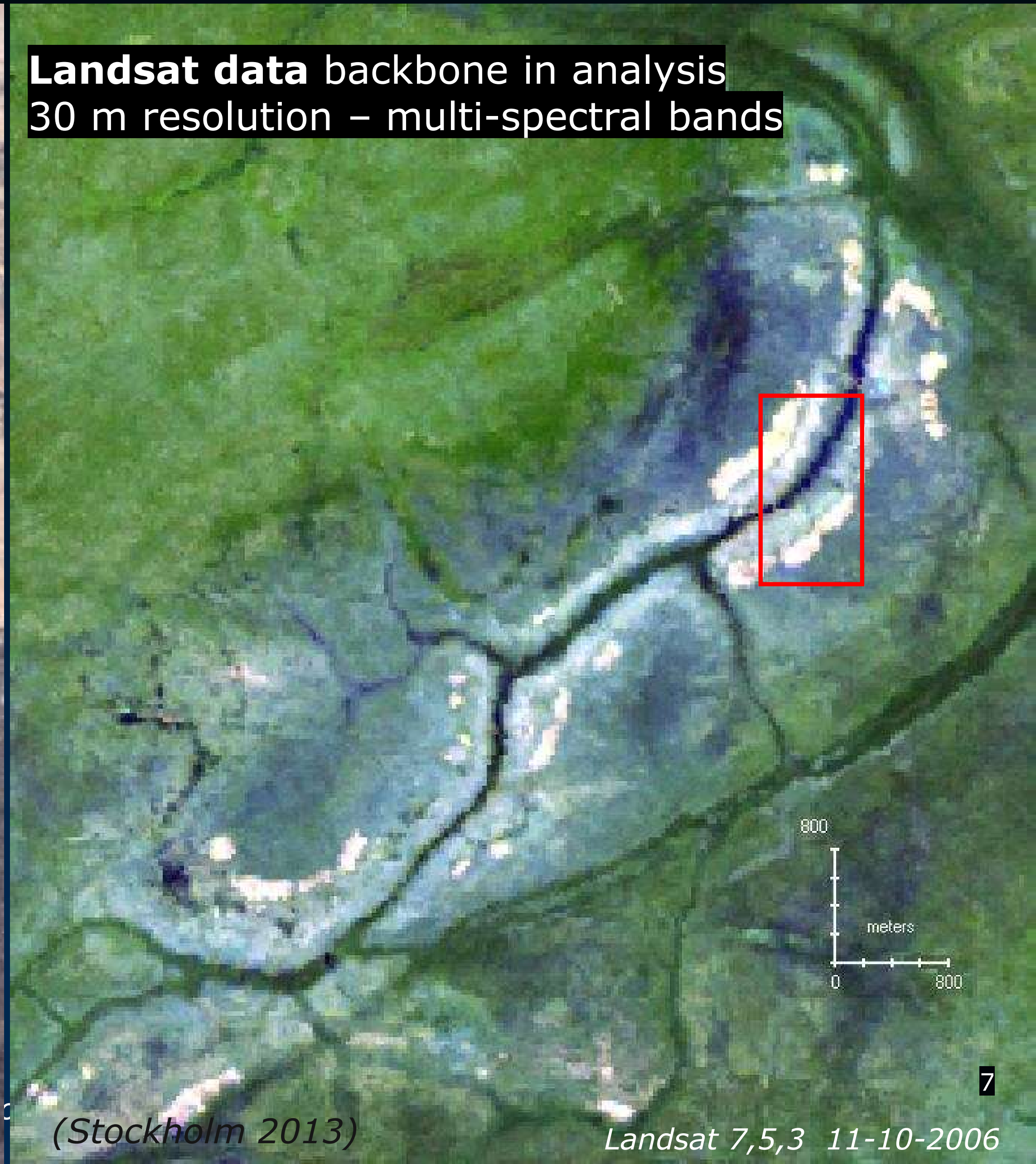
Traditional settlements are typically located on elevated sand bars along streams

In the beginning of the dry season after harvest – the land use leave a strong footprint from degradation by human and cattle's that are contrasting the surrounding lush vegetation.

This footprint is clearly visible from the sky and can be used to determined if there have been recent land use

The Study area – Traditional Land Use from Space

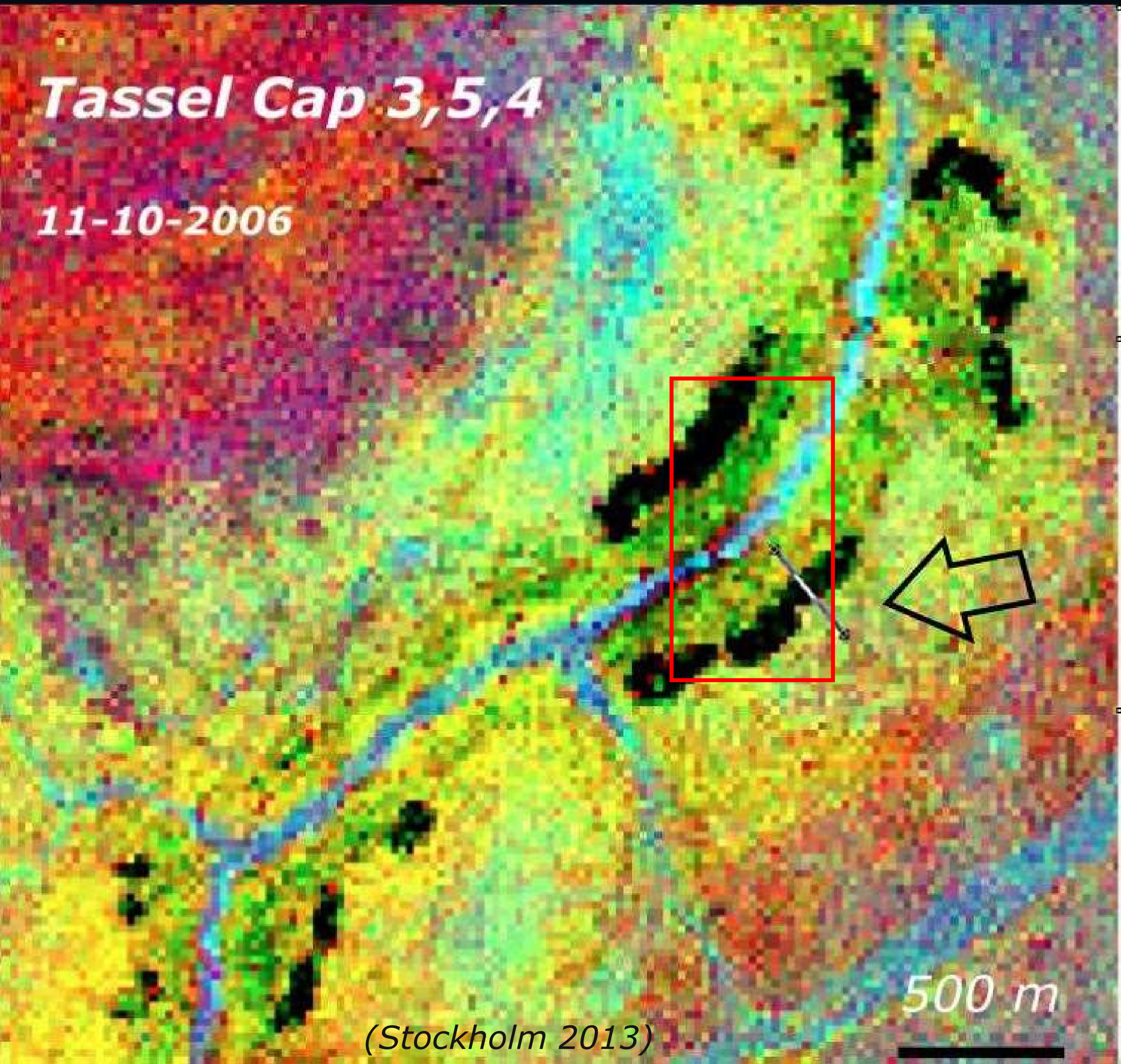
Source: ***Google Earth*** *- Quick Bird 2 26-1-2006*

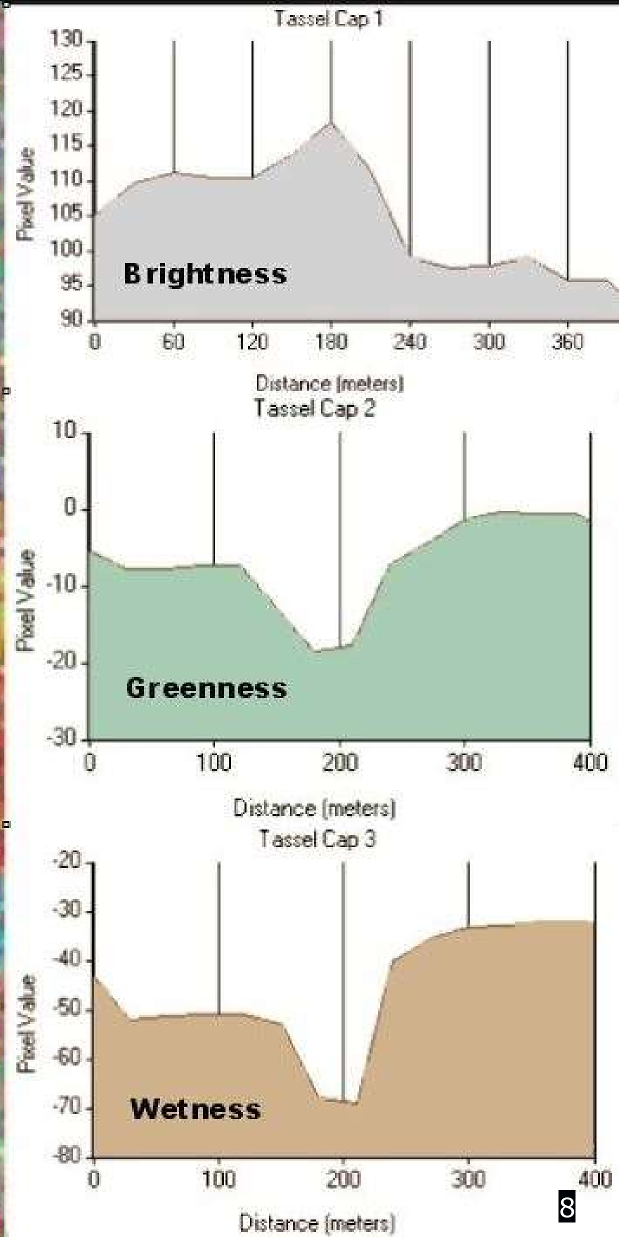


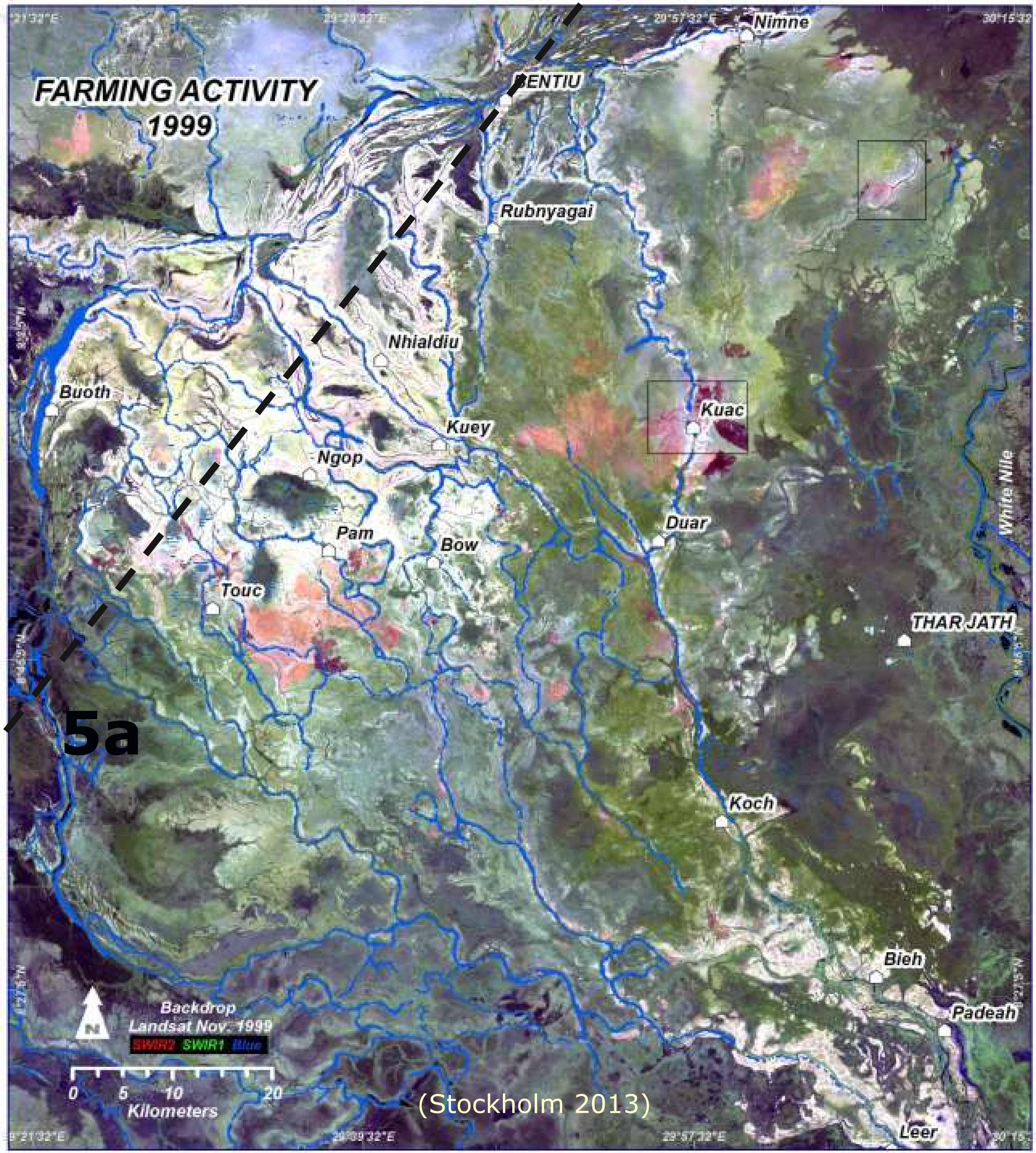
(Stockholm 2013)

Landsat 7,5,3 11-10-2006

Landsat data is powerful – it picks up information <u>that is not visible for human eye</u> but can be transferred into well documented indices







Landsat data

27-November 1999

https://www.prinsengineering.com/sudan_5azzz_lay.htm

Mapping of Land-Use in 5a – Stage 1

The ECOS 2009 report covered 1987-2006 – with **focus on land use changes -** during the establishment of the oil industry in 1999-2003

Much of the work was compleated in 2006 and had **simple objectives**; to show the development of oil industry and change in traditional land use patterns:

Landsat data was the backbone in this work:

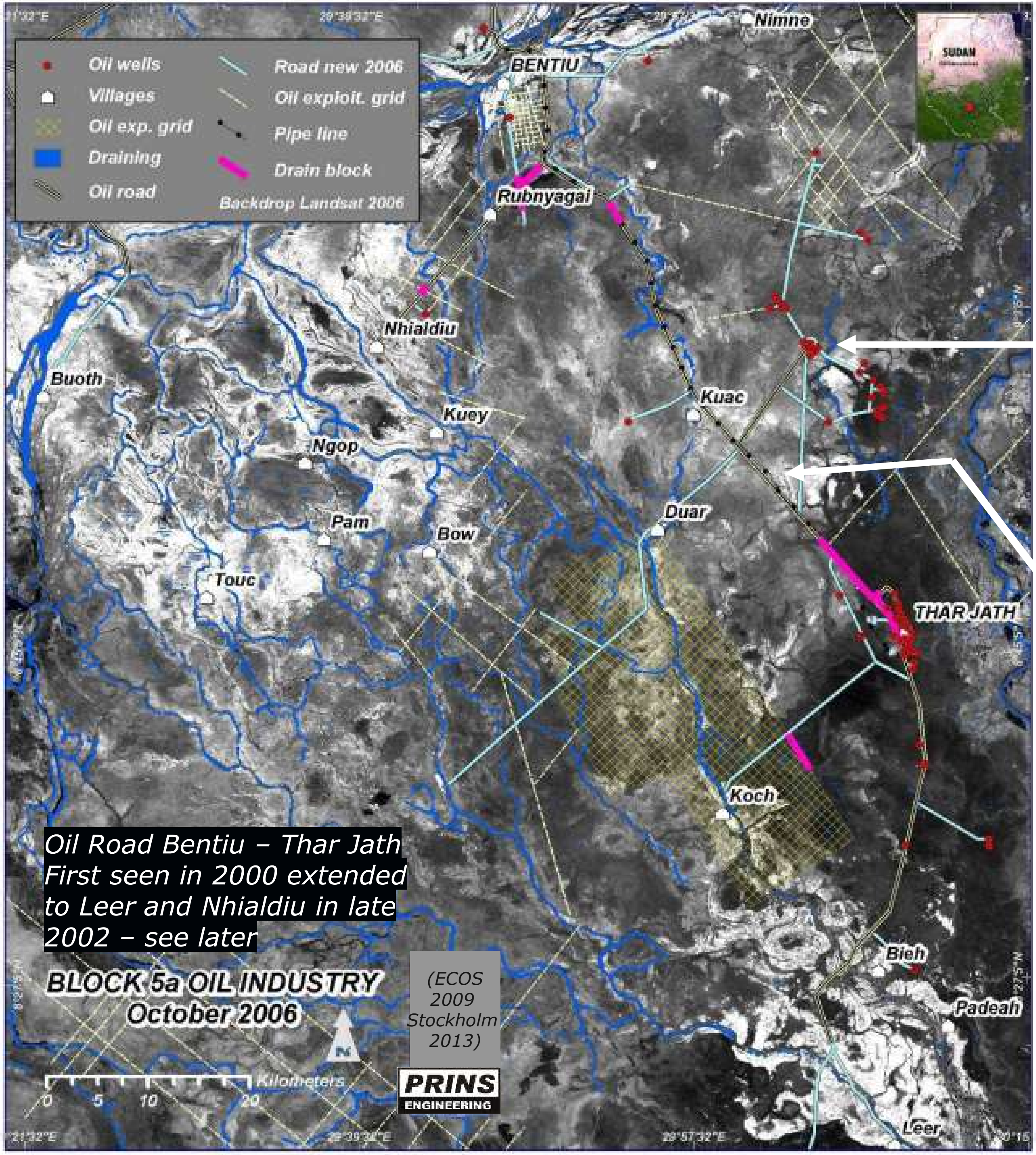
- Oil Industry – mapping of the development of physical infastructure.

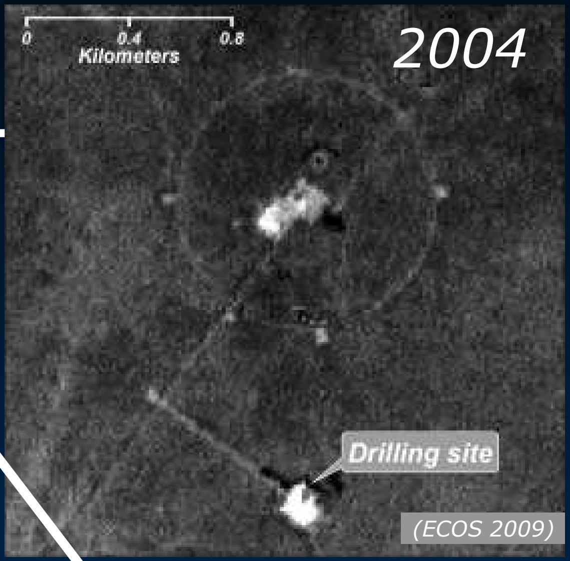
- Traditional land use - digital classification and change senarios.

The overall objective was to produce a large scale change assessment. At that time, massive ground reports on displacement or village attacks was found useful to explained / confirmed changes in satellite detected traditional land use patterns.

Oil Industry

Digitalization of Oil Industry 1999-2006 from Landsat





Mapping of Traditional Land Use by Landsat data

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Approach to Mapping Traditional Land Use

- Focused on early dry-season imagery (~November), when lush vegetation starts to dry out. This period shows highest contrast in land use and is also used globally in rangeland monitoring (e.g., Sahel, Australia – IJRS 2017).
- During this period, homesteads typically show strong degradation footprints from harvested fields and livestock, making land use highly detectable.
- Minimal interference from seasonal migrations and bushfires during this window.
- In this analysis, October–April (6 months) Landsat data was considered.
- While bushfire scars can affect readings, high-intensity land use typically dominates the signal.

Priority Early Dry Season & Fire Analysis

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Data Selection & Fire Sensitivity

- Between 1999–2003, 42 Landsat scenes (16 from Landsat 7 and 26 from Landsat 5) were screened – with less than 10% cloud cover.
- Two images, from **27 Nov 1999** and **3 Nov 2002**, provided optimal contrast with minimal cloud cover and fire interference for detecting land use change..
- **Normalized Burn Ratio (NBR)** and **ΔNBR** can be used to confirm fire scars. Moderate-to-low burn severity was observed, validating image suitability.
- Example: Satellite-derived **ΔNBR** for Nov 1999 confirmed low interference from bushfires.

Data Source: USGS Earth Explorer & ClimateEngine.org

Global Fire Guidelines: UN-SPIDER Burn Severity

Priority Early Dry Season with Limited Bush-fires and High Land Use Contrast

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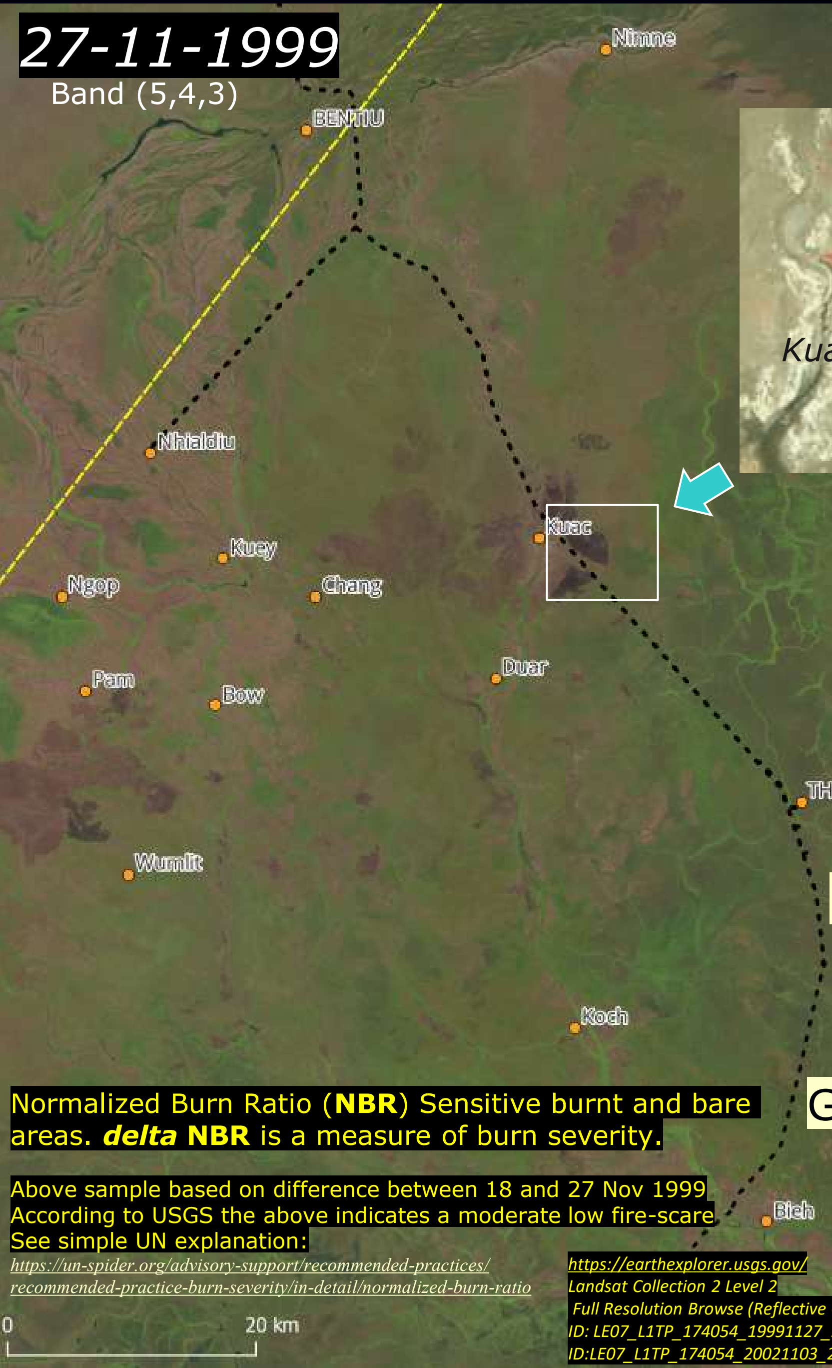
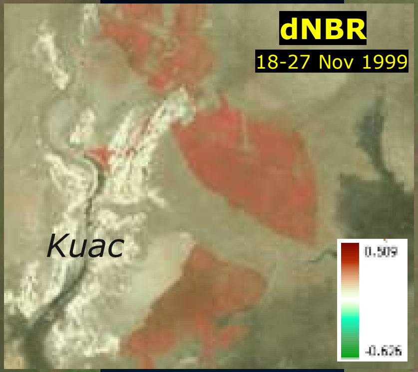
27-11-1999

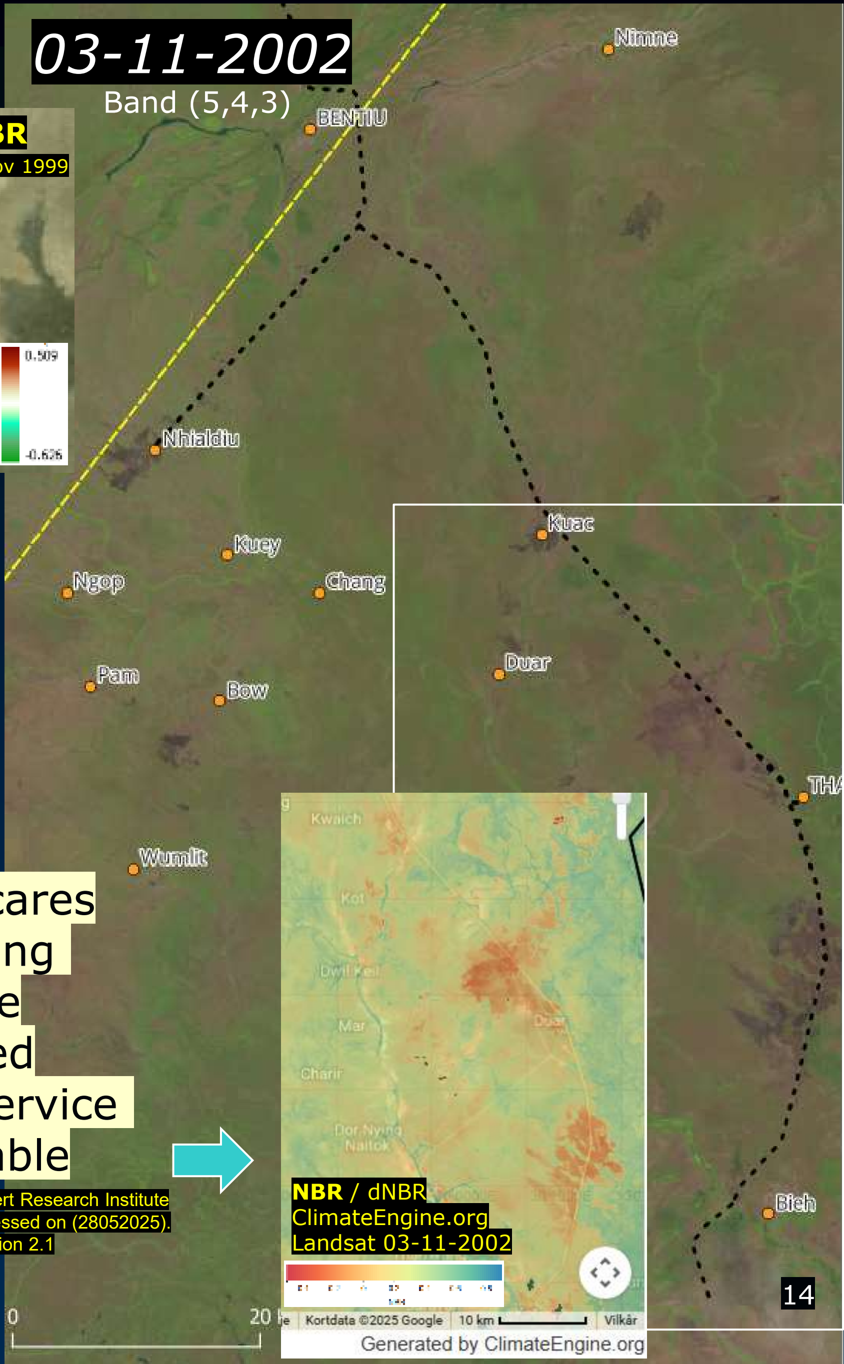
Band (5,4,3)





03-11-2002

Band (5,4,3)



Bush fire scares show strong response in infrared

Global webservice now available

Climate Engine. (2025). Desert Research Institute and University of Idaho. Accessed on (28052025). http://climateengine.org, version 2.1

NBR / dNBR
ClimateEngine.org
Landsat 03-11-2002

Normalized Burn Ratio (**NBR**) Sensitive burnt and bare areas. ***delta* NBR** is a measure of burn severity.

Above sample based on difference between 18 and 27 Nov 1999
According to USGS the above indicates a moderate low fire-scare
See simple UN explanation:
https://un-spider.org/advisory-support/recommended-practices/recommended-practice-burn-severity/in-detail/normalized-burn-ratio

https://earthexplorer.usgs.gov/
Landsat Collection 2 Level 2
Full Resolution Browse (Reflective Color) band 5,4,3
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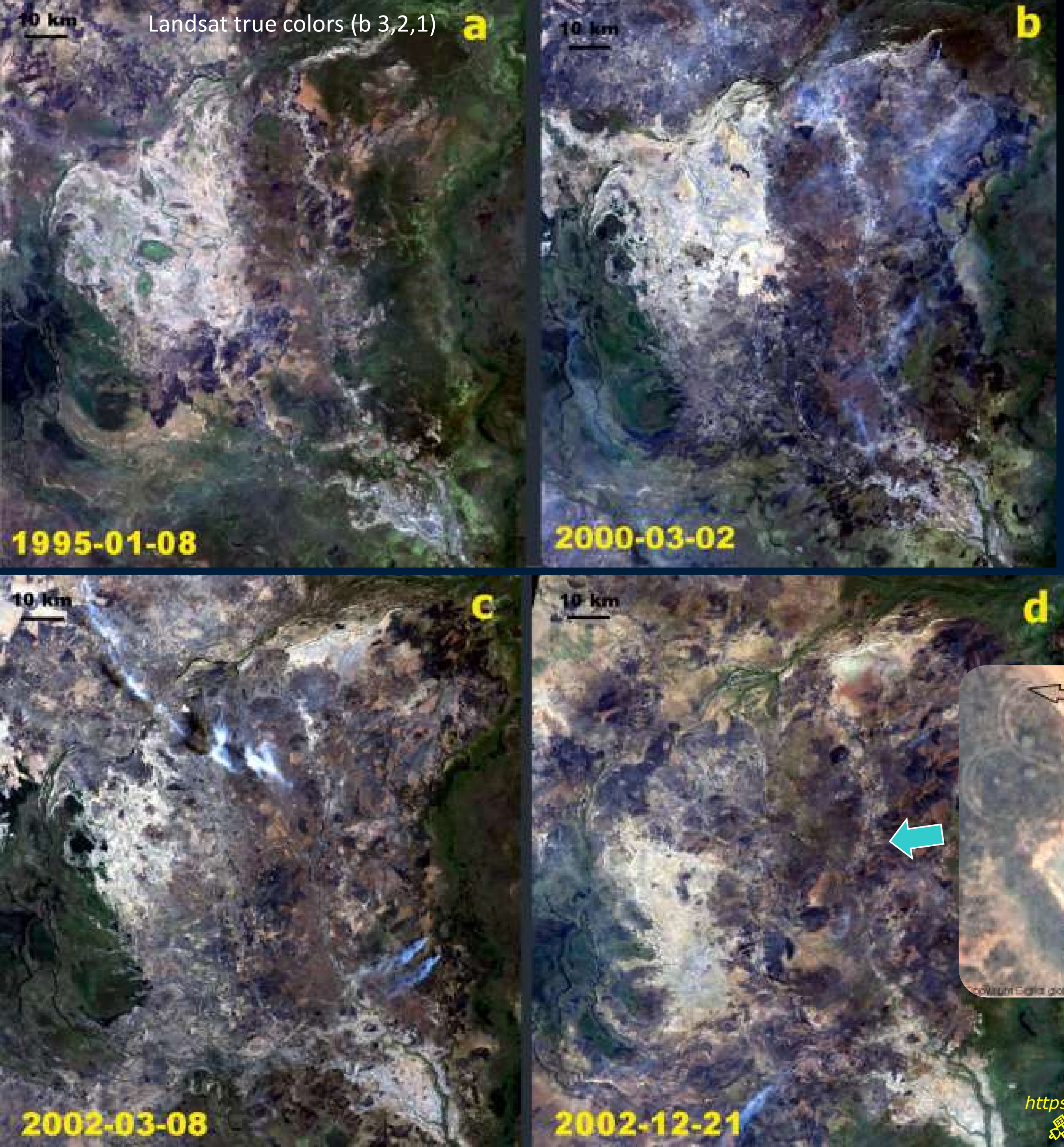

Fire Scars vs Land Use Signal

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Active Land Use Can Override Fire Scars

Even during fire-prone periods, satellite imagery can reliably detect ongoing human land use.

Conclusion:
Intensive land use leaves stronger spectral signals than fire alone, making it detectable even when fires are present.

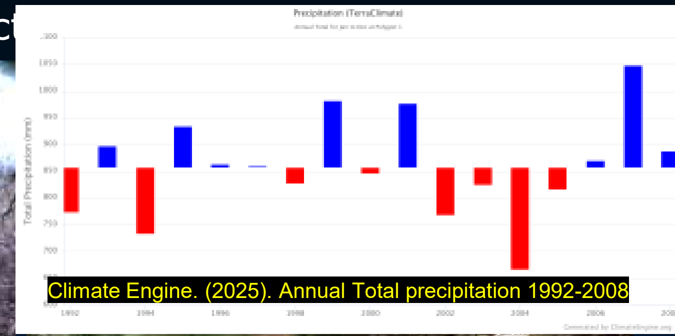
Example: Oil road south of Kuac - 21 march 2023 – Quick bird 0.6 m data

https://www.prinsengineering.com/sudan_5azzz_lay.htm

Landsat 5 & 7 | Access via earthexplorer.usgs.gov

‘Off-Season’ images and Climate

The effect of climate had most impact on flooding (some effect in 2001) the effect of anomaly in precipitation was hard to detect in mages – though variation in wetness can be expected to have smaller effect



In the end of dry season (e.g. may) cattle's are driven around to streams making homestead monitoring confusing as limited people are left

In wet season moisture conditions can be uneven making assessment difficult

Approaching dry season (e.g., Sep) wetness can still be high making challenges to access the total extent of the farming system (e.g. cattle Impact).

Landsat 5 & 7 | Access via earthexplorer.usgs.gov

Change Detection shown by True Color

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Visual Pattern of Conflict through Satellite Data (True Color Band 3-2-1)

- Visual maps remain intuitive and compelling even to non-experts, with Landsat's **true-color composites** offering direct interpretability.
- Satellite imagery from 1996–2002 shows notable land use change over time.
- Fires detected within **village cores** (unusual in traditional fire regimes) suggest intentional burning during conflict.
- Progression across time illustrates the abandonment and relocation pattern.

🛰 Landsat 5 & 7 | Access via earthexplorer.usgs.gov

Road site 1996-2002 – Landsat true colors (band 3,2,1)

27-nov 1999 and 3-nov 2002 (ECOS 2009) 12-dec 1996 https://earthexplorer.usgs.gov/ Landsat 5 Collection 2 Level 1 and 2

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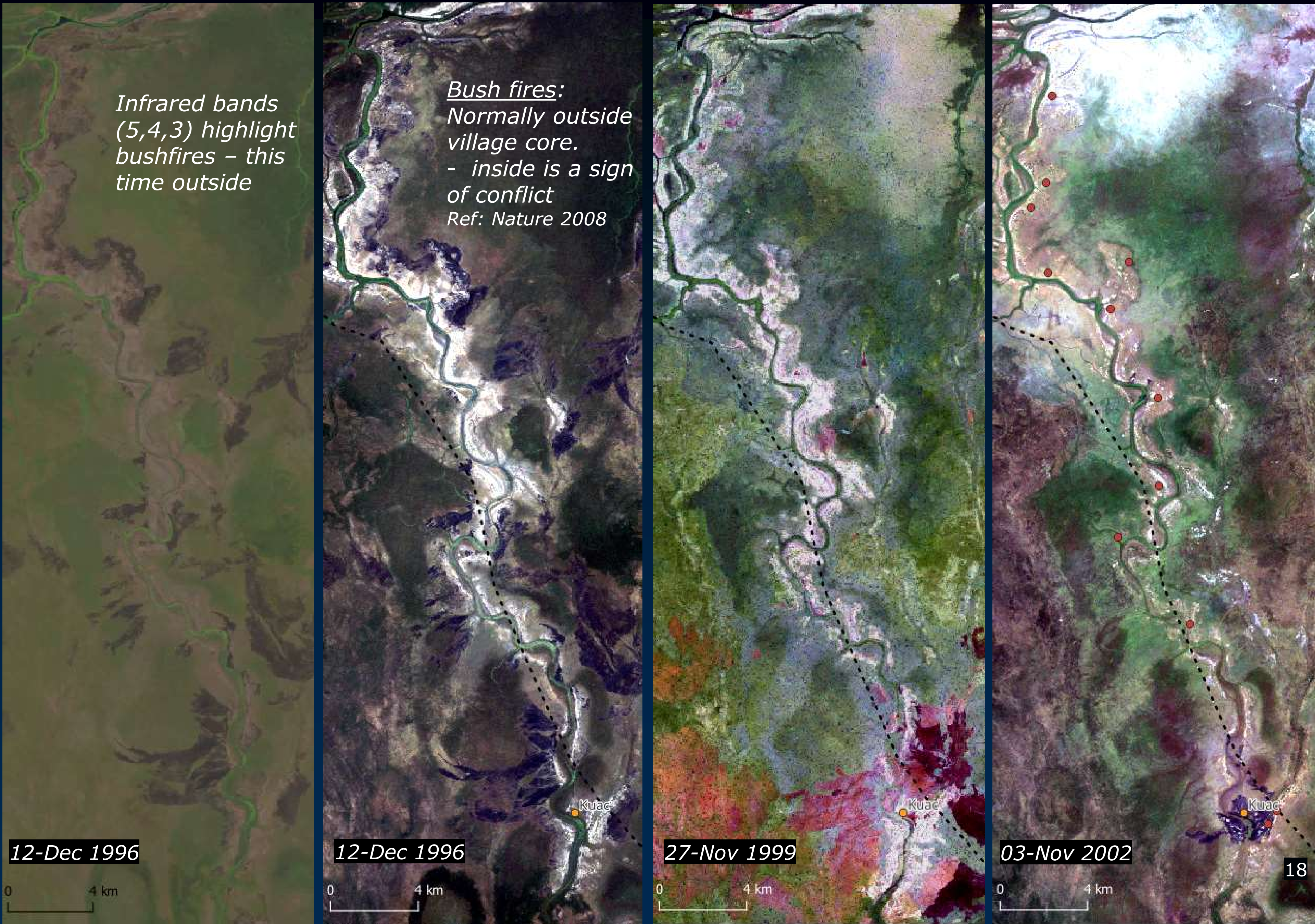

Road site 1999-2002 - true colors (band 3,2,1)

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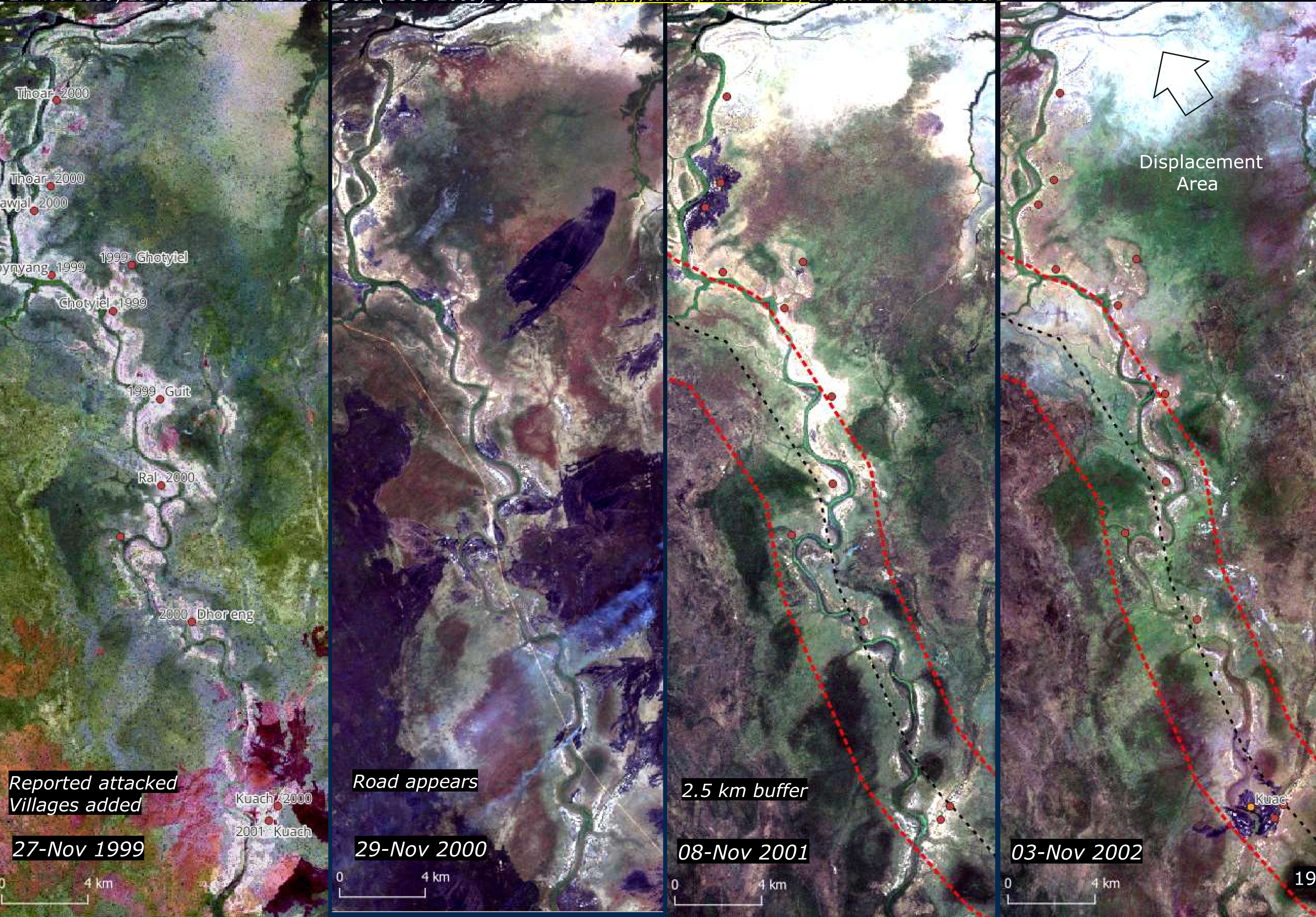
27-nov 1999, 29-nov 2000 and 3-nov 2002 (ECOS 2009) 8-nov 2001 *https://earthexplorer.usgs.gov/ Landsat 7 Collection 2 Level 2*



Road site 1999-2002 - true colors (band 3,2,1)

27-nov 1999 and 3-nov 2002 (ECOS 2009) 16-nov 1998 and 23-oct 2004 https://earthexplorer.usgs.gov/ Landsat 7 Collection 2 Level 2

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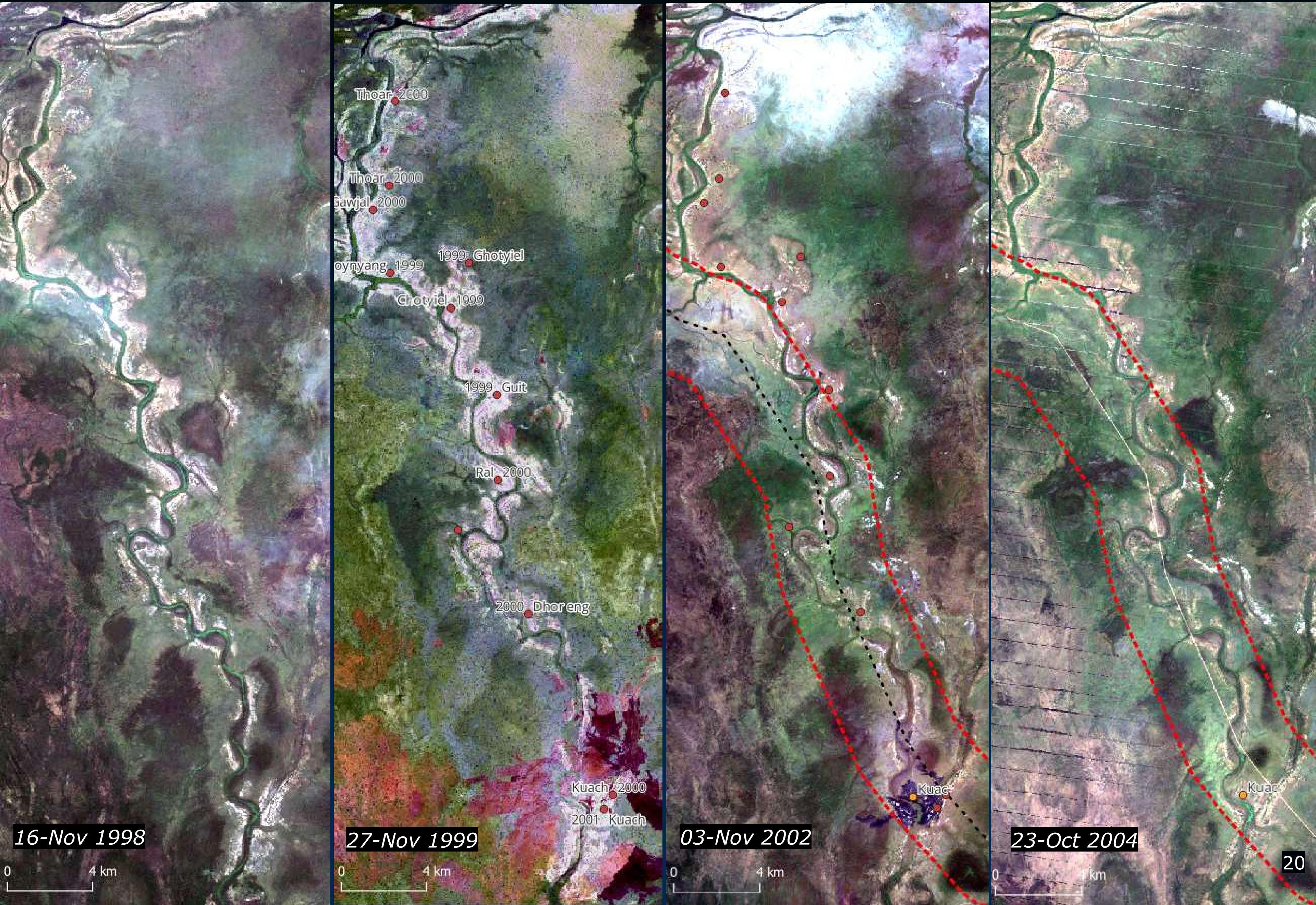
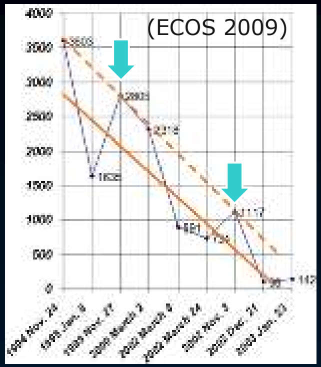
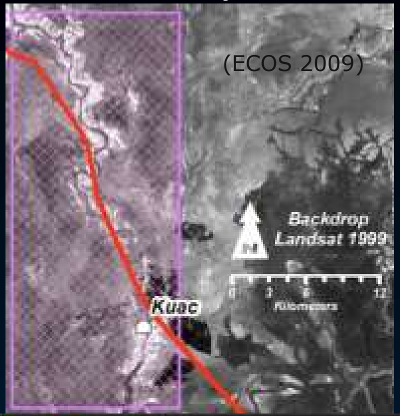
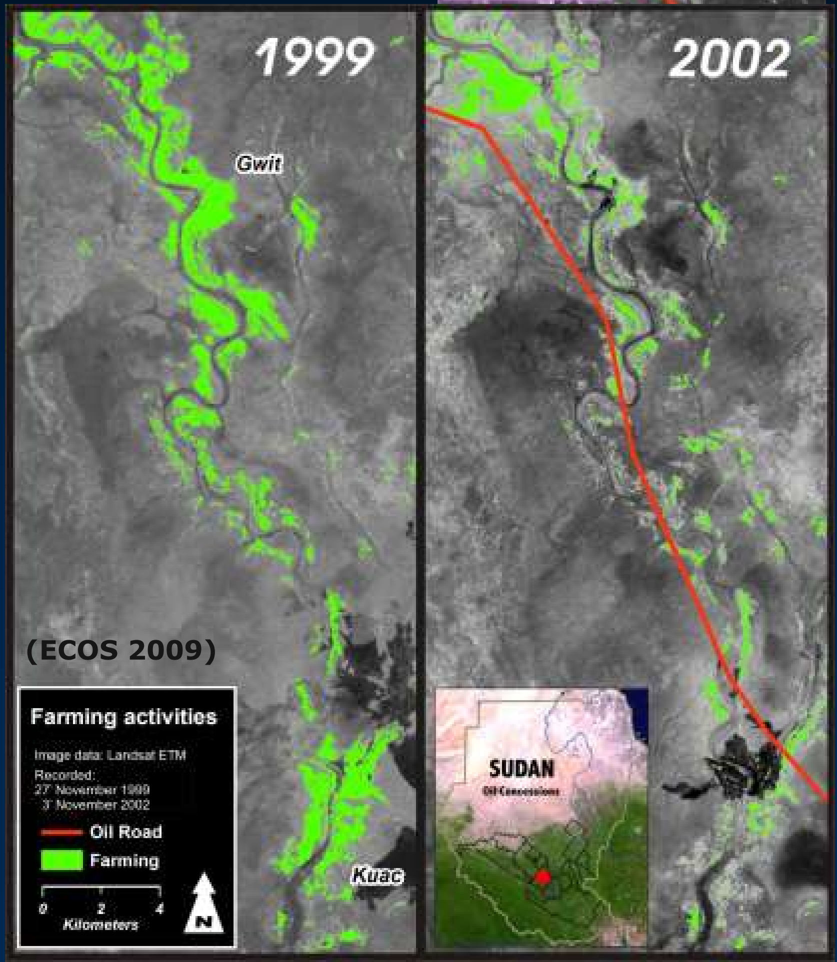


Road site 1999-2002 – Land use Classification (ECOS 2009)







Mapping of the traditional land use by Landsat data

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Approach to map the tradition land use footprint in the ECOS rapport

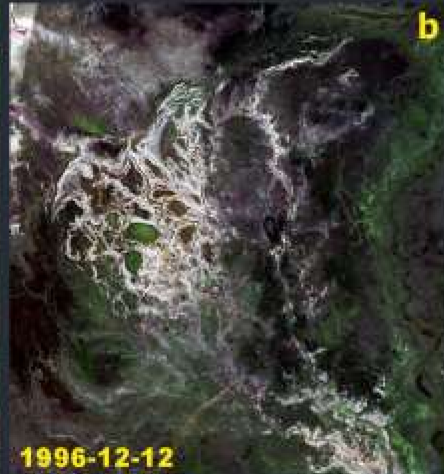
In the **ECOS 2009** work the d**igital classification of images** based upon automatic / unsupervised classification that have show to work better than supervised classification for range-lands (Tueller 1989 – see also *IJRS 2017*).

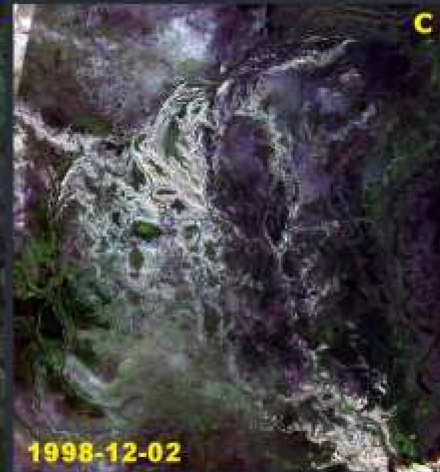
Unsupervised classification has a wide range of applications. For example, I used it for the Danish Kyoto reporting (ESA consortium) - maps were delivered with ISO 91130 / INSPIRE certificates. https://www.prinsengineering.com/kyoto_dk2.htm

<u>In simple practice, this means :</u> Cut out the same area, run the classification specifying 60 classes and take out the 1-2 classes that show the land-use foot-print.

This produces a land use scenario for each image that can be compared with others

More on this later



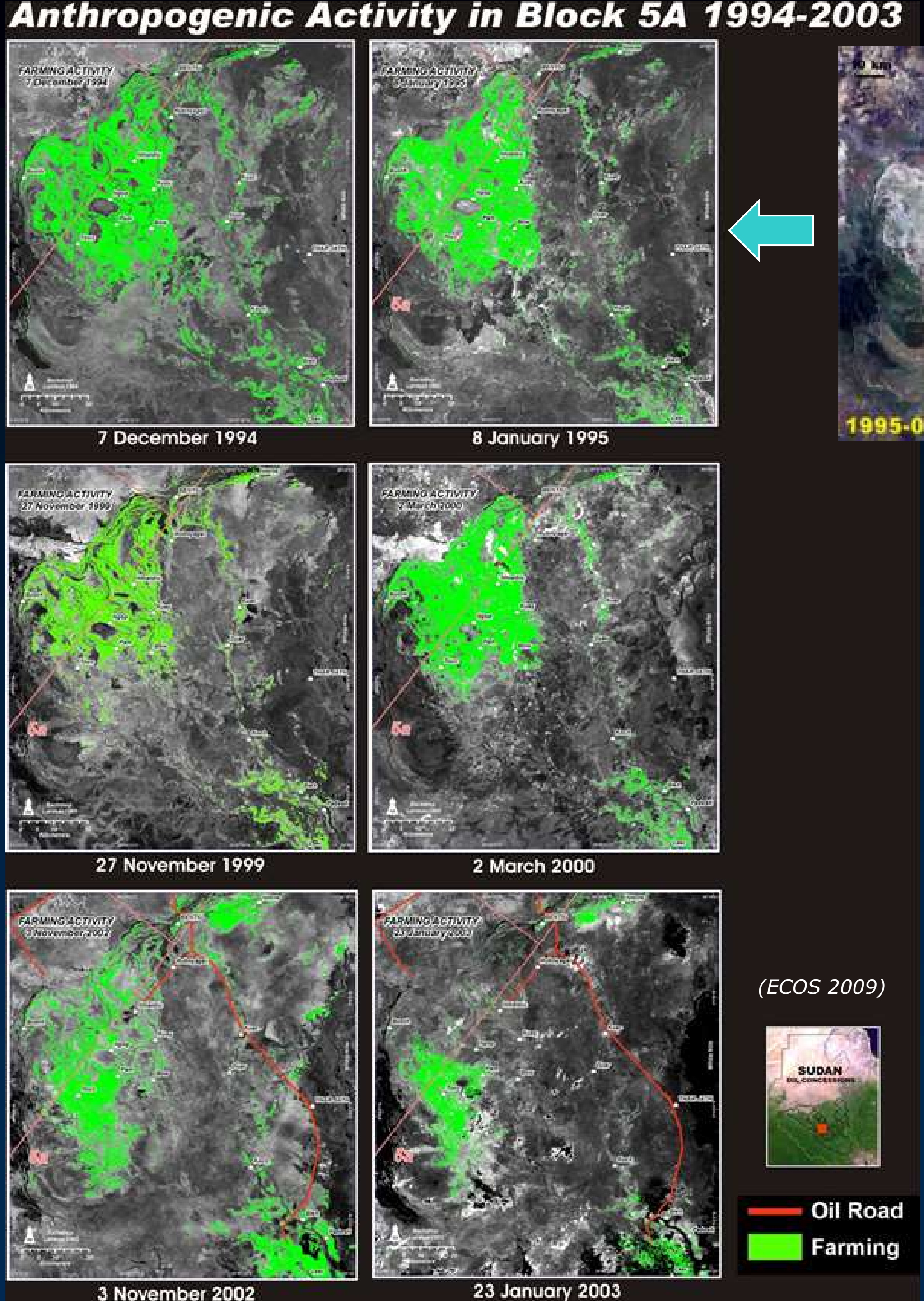


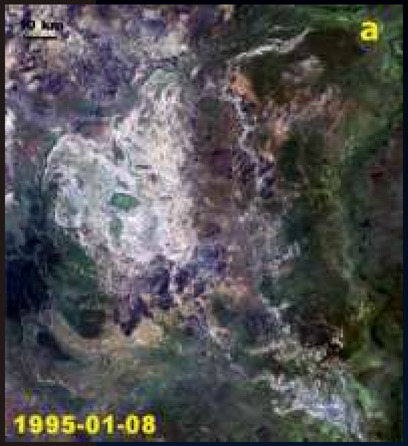
https://www.prinsengineering.com/sudan_5azzz_lay.htm

Landsat in natural colors (321)

Landsat 5 & 7 | Access via earthexplorer.usgs.gov

A time series of Landsat images covering oil block 5a during 1994 to 2004. The images are set in visible light colors. The bright areas are the human footprint from cropping and grazing activity. On the right (h) is a close-up that show the homestead that are spread along streams





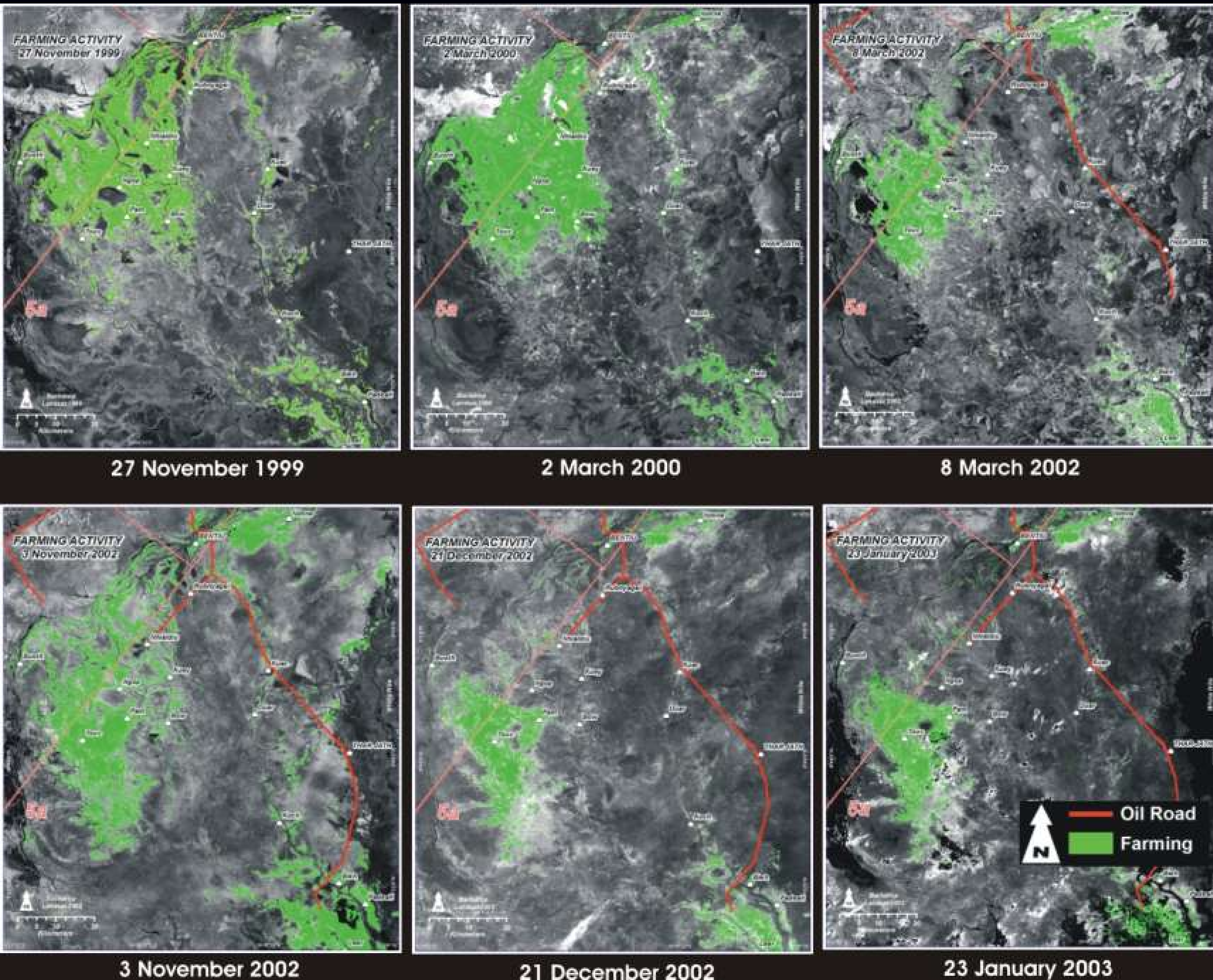
Land Use mapping (ECOS 2009)

Unsupervised – classification

Land use showed massive changes at large scale during 1999-2002

The Landsat data covering this time period consistently showed this land use change pattern

Example of Land use Classification 1999-2003 (ECOS 2009)



(ECOS 2009)

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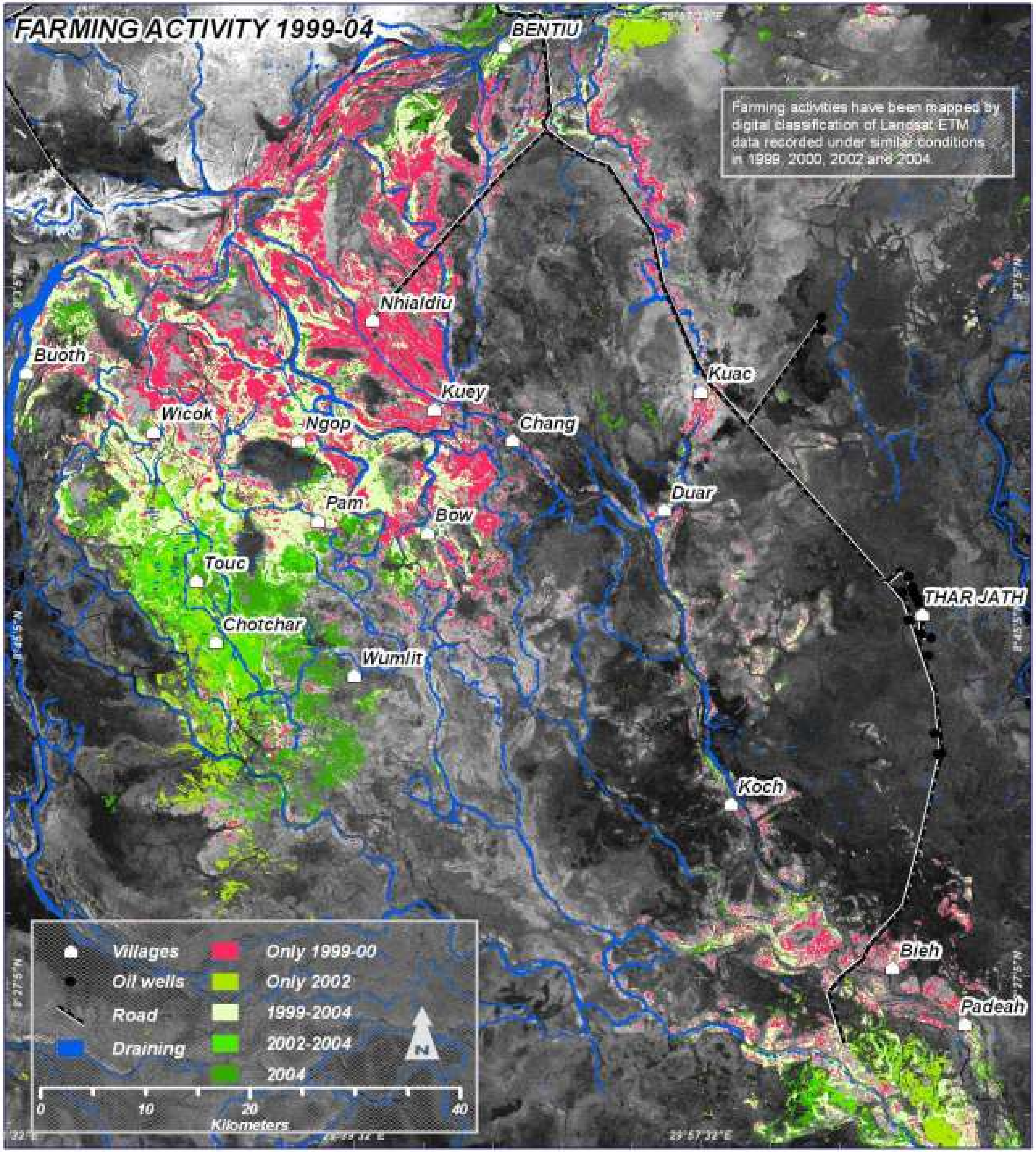

Change Scenario 1999-2004

(ECOS 2009; Stockholm 2013)

Ground Verification and Reports - Major events

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13-01-2001	Pultutu	Rebel attack on garrison of Pultutu.	SPLA	HRW 2003:390
13-01-2002 to 25-01-2002	Oil installations and convoys	The rebel armies of SPLA/SPDF declared oil installations military targets. Convoys set under bloody attacks.	SPLA/SPDF	deGuzman 2002:18
14-01-2002	Oil installations and convoys	Ambush on the road between the villages of Nhialdiu and Bentiu. Large convoy attacked of about 7 000 men including regular army soldiers, "tribal militias", two helicopter gunships and an Antonov bomber.	SPLM/A – GoS	HRW 2003:390; IRIN WebPaper
Beginning of 01-2002	Area around Nimne	Villages of Nimne attacked by air forces, including Antonovs, gunship and rocket. Thereafter horsemen were set in to raid the village.	GoS	Christian Aid 2002:6
23-01-2002	Oil installations and convoys	Ambush of government convoy between the River Thar Jath garrison at Pultutni and Mirmir. 60 soldiers killed, 2 soldiers captured and various amounts of weapons.	SPDF	HRW 2003:391
24-01-2002	Koch	Village of Koch attacked and bombed, using Antonovs.	GoS	HRW 2003:392
25-01-2002	Koch, Ler and Mayandit	Villages of Koch, Ler and Mayandit attacked by air force, using helicopter gunship.	GoS	HRW 2003:392
25-01-2002	Oil installations and convoys	Ambush of government convoy 40 km south of Bentiu. 102 enemy soldiers killed and 4 captured.	SPDF	HRW 2003:391
25-01-2002	Oil installations and convoys	Convoy with two hundred conscripts ambushed. The Sudanese army sent the reinforcement for the Pultutni garrison and for the protection of Lundin's rig at River Thar Jath. The killing of 198 government soldiers was reported.	SPLA	HRW 2003:391-2
26-01-2002	Ler	Government soldiers ambushed on their return to the Ler barracks from Pavak airstrip. 15 government soldiers killed and 2 soldiers from the rebel army SPDF.	SPDF	HRW 2003:392

Table with ~90 references and GIS layer with ~60 records can be downloaded: www.prinsengineering.com/Attacks_5a.doc and attack.zip

Forces	Villages	source	[illegible]
GOS	0	ECOS	[illegible]
GoS	0	Christian Aid	[illegible]
GoS	0	Christian Aid	[illegible]
GoS	0	Christian Aid	[illegible]
Matiep	1	NULL	[illegible]
Matiep	1	NULL	[illegible]
GoS	0	Christian Aid	[illegible]
GoS	0	HRW 2003	[illegible]
GoS	0	Christian Aid	[illegible]
Matiep	4	MSF 2002	HRW
Matiep	6	HRW 2003	[illegible]
GoS	1	NULL	[illegible]

(Focus area from Stockholm 2013)

Extensive Reporting from various sources was used to identify attacked villages and areas.

Linked to maps e.g. UN-OCHA Settlement databases

See: https://data.humdata.org/

Focus Areas:

Villages located **along the northern end of the new all weather road** (Oil road) attacked and many destroyed during 1999 and 2000 (Christian Aid 2001, HRW 2003, ECOS 2002). **Many stayed there until 2001** (Christian Aid 2002).

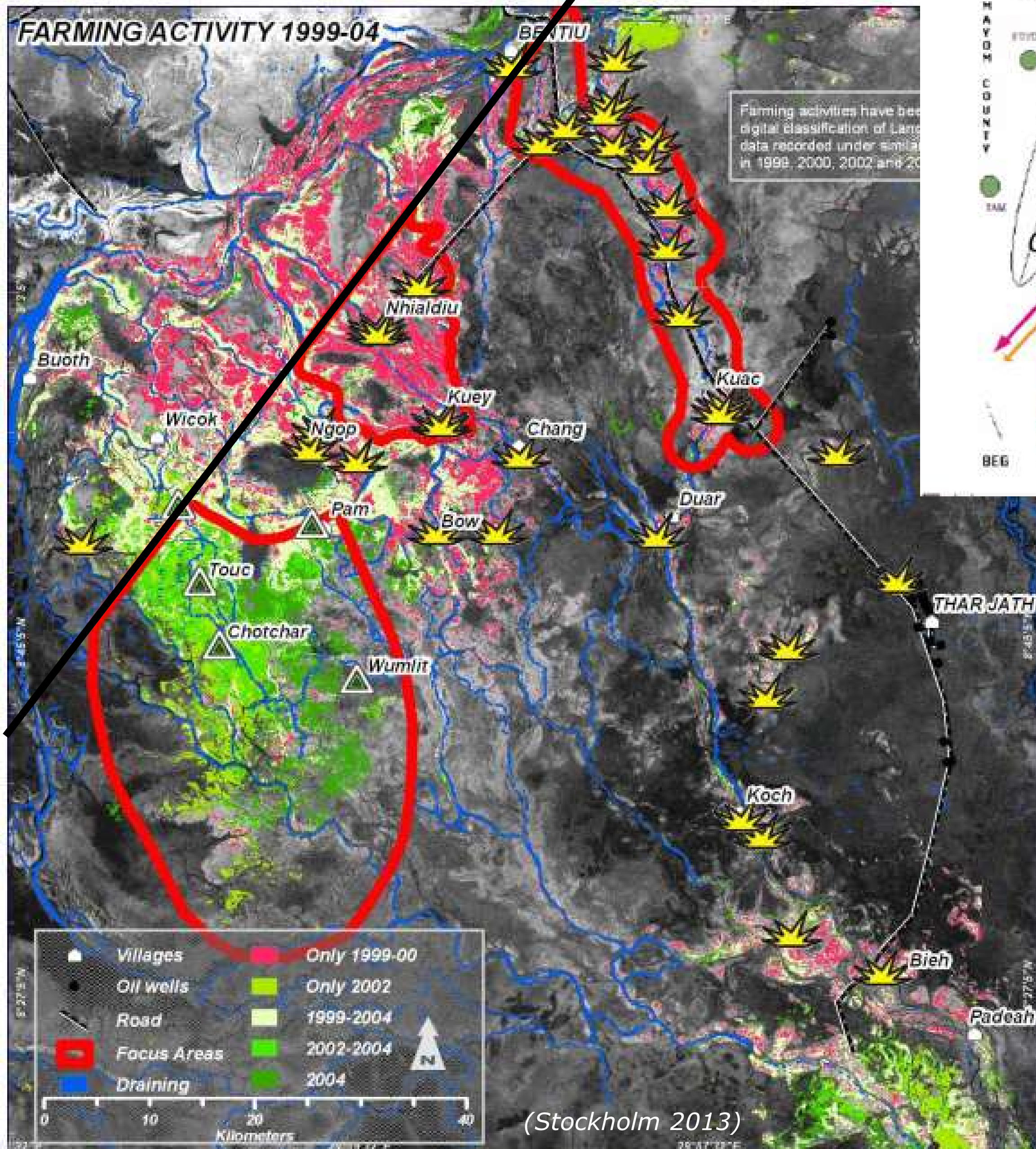
Road buffer 2.5 km as said as a risk zone (HRW 2003)

All villages in the **Nhialdiu area** attacked and destroyed during major attack and was depopulated in February 2002. (Christian Aid 2001, ECOS 2002, HRW 2003; UN reporter 2002)

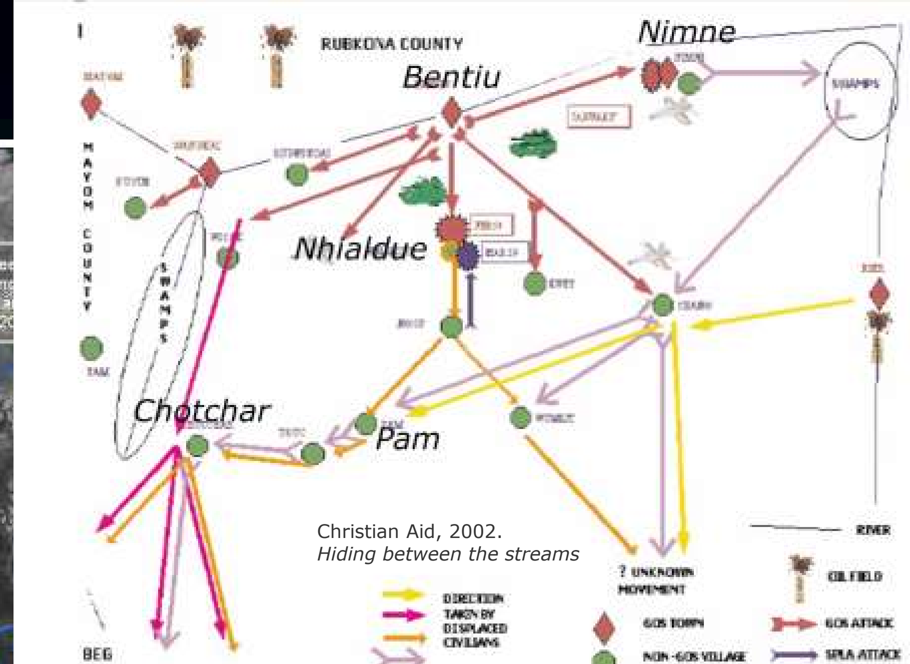
Everything burnt and deserted down to river Chaar in feb 2002 (HRW 2002)

In 2002 most **displaced people ended up in Wicok, Touc, Pam, Wumlit, Chotchar and south of**. (Christian Aid 2001; 2002, ECOS 2002, HRW 2003, UN reporter 2002). 50-60.000 displaced on top of 18-20.000 already living there (Christian Aid 2002).

Satellite Analysis Detects Ground Reports Confirms

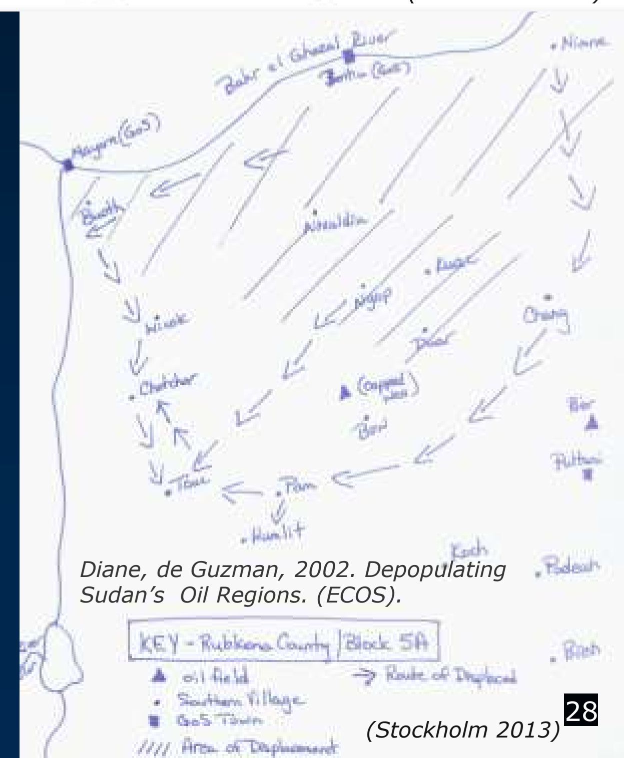


(Stockholm 2013)



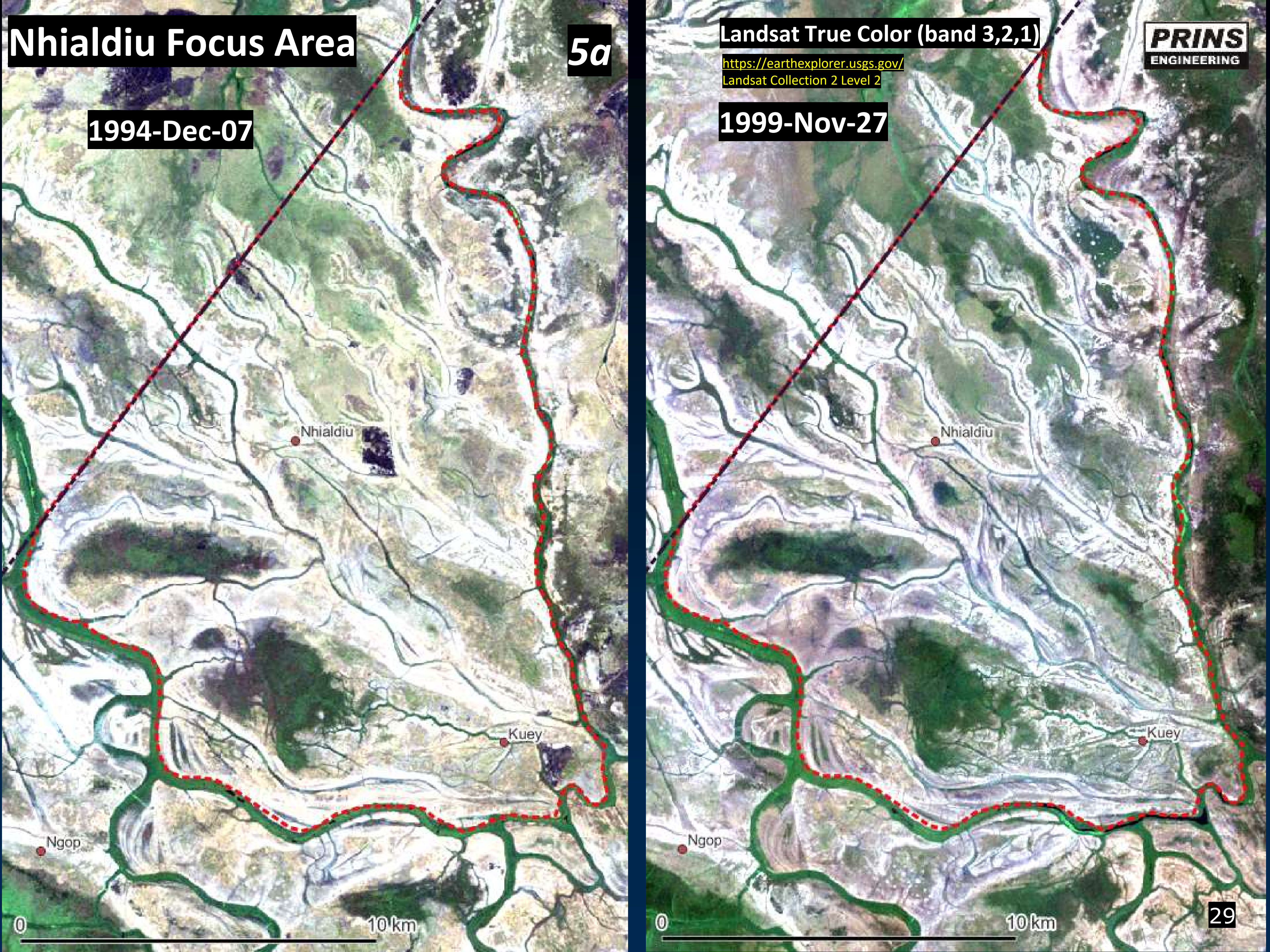
Christian Aid, 2002.
Hiding between the streams

(Stockholm 2013)



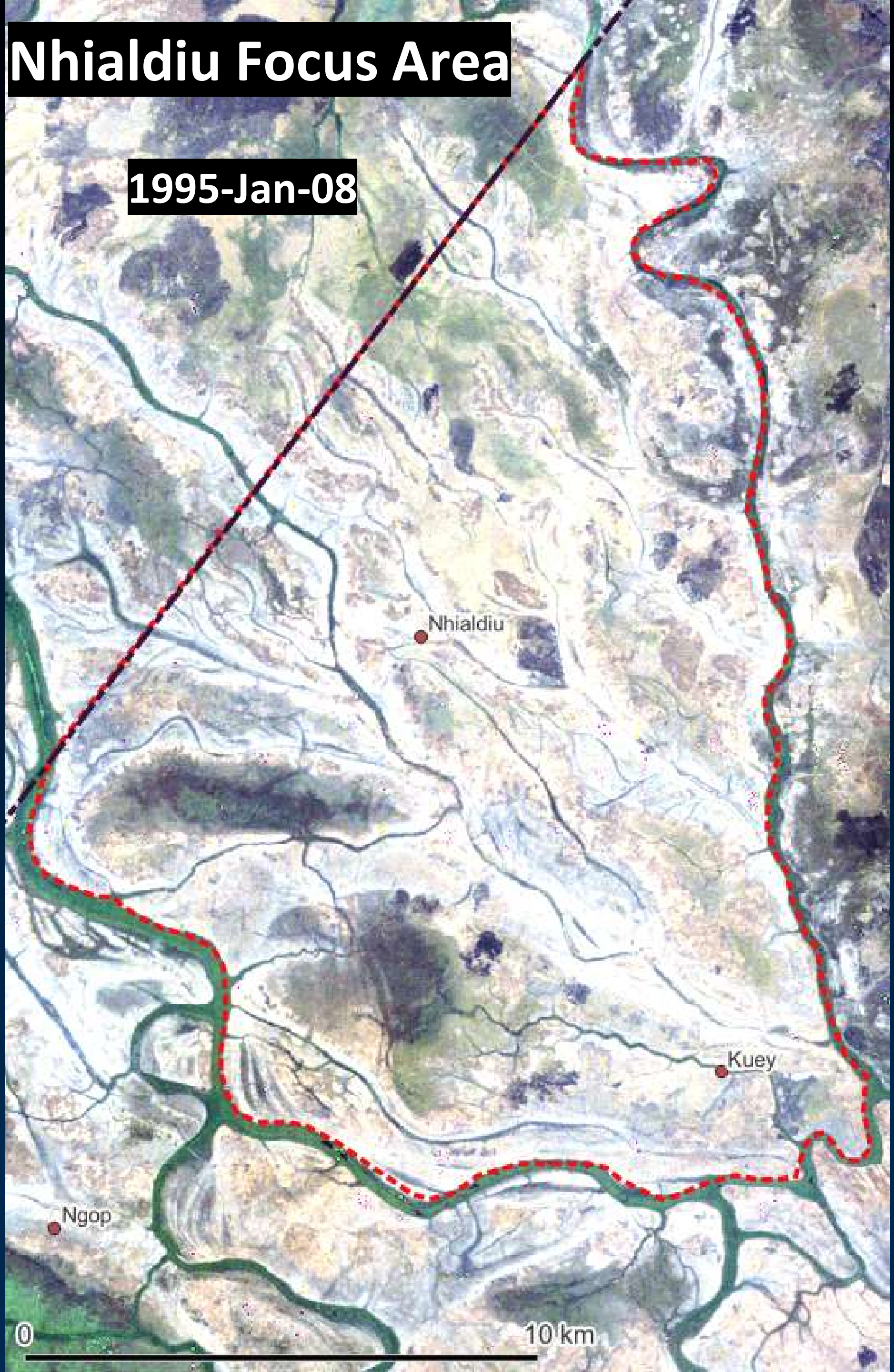
Diane, de Guzman, 2002. Depopulating Sudan's Oil Regions. (ECOS).

(Stockholm 2013)

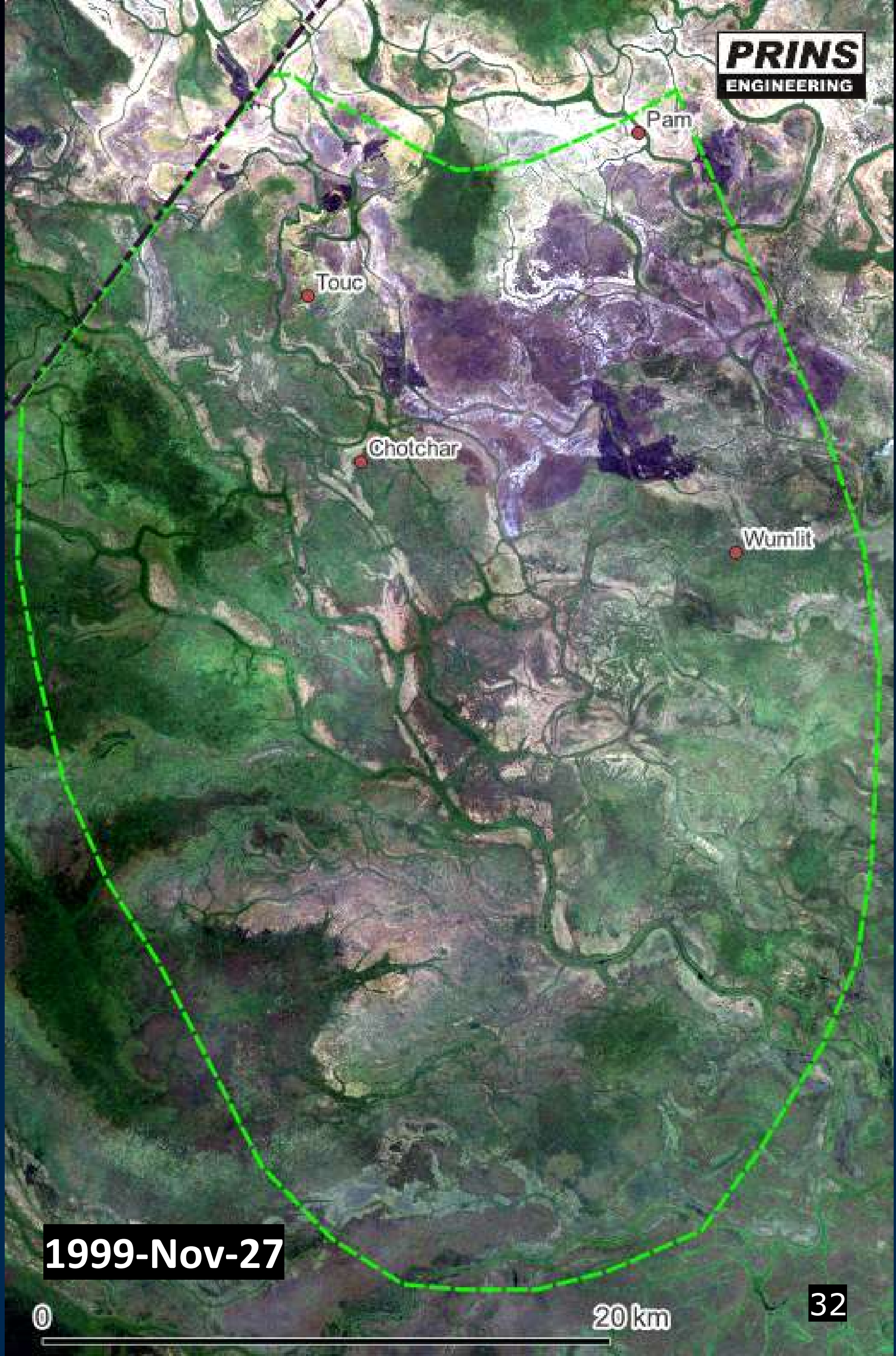

Nhialdiu Focus Area
5a
1994-Dec-07
Nhialdiu
Kuey
Ngop
0
10 km
Landsat True Color (band 3,2,1)
https://earthexplorer.usgs.gov/
Landsat Collection 2 Level 2
PRINS
ENGINEERING
1999-Nov-27
Nhialdiu
Kuey
Ngop
0
10 km

Nhialdiu Focus Area

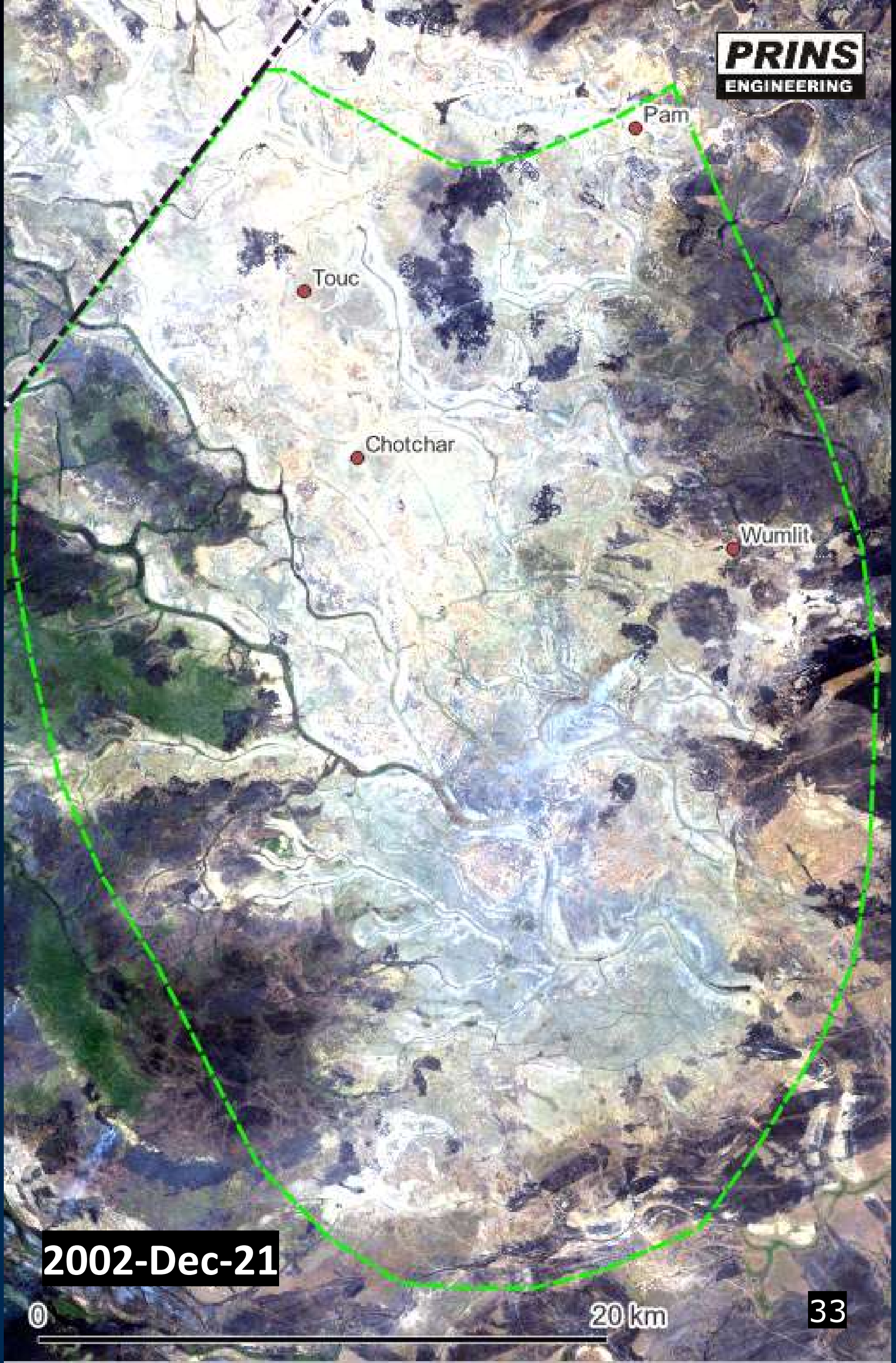
Nhialdiu Focus Area

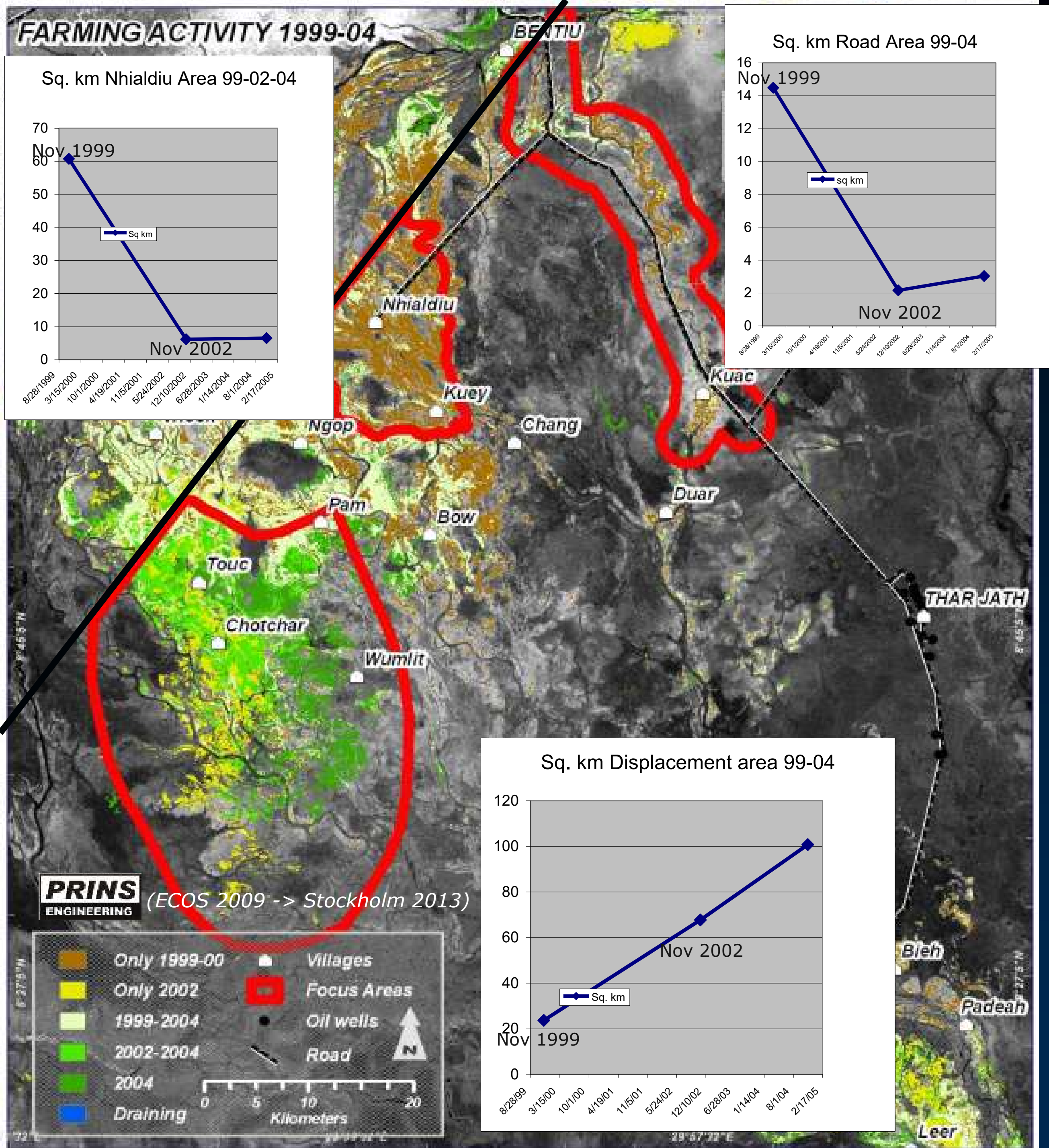


Displacement South



Displacement South





Classified Change Detection (1999–2004)

- Land use classification from Nov 1999 to Nov 2002 revealed dramatic loss of human activity, coinciding with peak displacement events.
- Graphs show displacement zones growing significantly in square kilometers over time.
- Temporal evolution corresponds with documented attacks.
- Classification accuracy was later validated by higher resolution data and refined algorithms (see IJRS 2017).
- This provided statistical evidence of displacement patterns, extending beyond visual interpretation alone.

📓 **Key Takeaway**:
Satellite data does not just visualize land use change—it quantitatively supports displacement narratives with credible, replicable evidence.

Novel web-service allow swift extended Landsat detection from Focus Areas @climateEngine.org

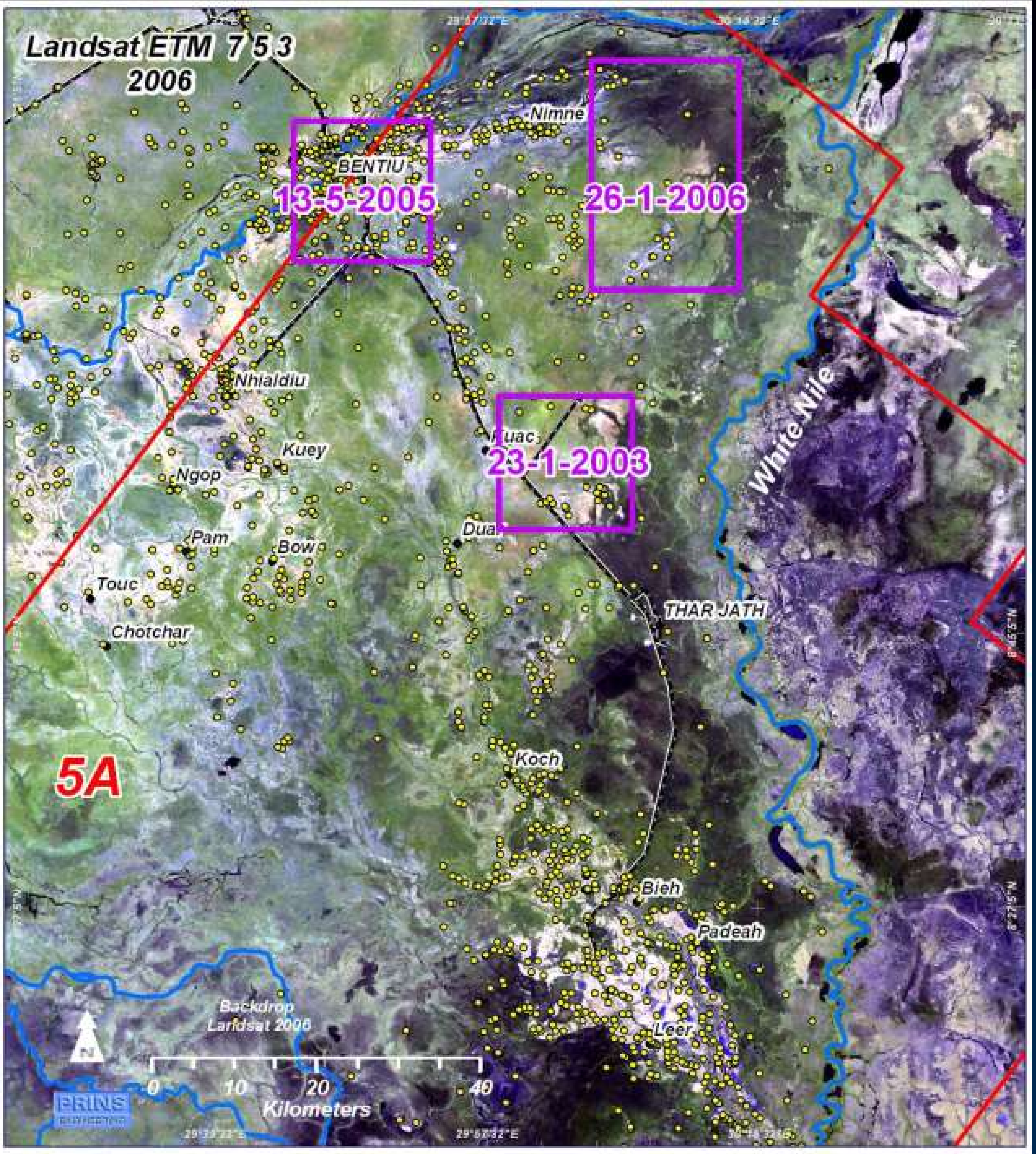
Extending methods of Land-Use assessment in 5a – Stage 2

After the completion of the ECOS 5a report, Very High Resolution (VHR) images became freely available on Google Earth, which allowed testing of supervised classification algorithms with the Landsat data.

Furthermore, improved calibration of Landsat data was developed – so digital values across years should show the same objects – the basics of a monitoring system – as the technology have evolved - this calibration of Landsat can now be directly downloaded.

The supervised approach includes in this case: interpretation of land use from VHR images, select training areas for classification as well as verification based upon VHR.

The **results were presented at Swedish Space days 2013 as invited keynote speaker**.



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VHR Quick Bird 2 data

Interpretation

Test of Methods

Verification of Methods

Yellow dots show settlement from UN-OCHA geo-databases

(Stockholm 2013)

Extending Methods and Documentation

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Source: ***Google Earth*** *- Quick Bird 2 26-1-2006*

Types of classifications

One with only crops and degraded areas

To types of unsupervised classification (ISODATA)

Accuracy Assessment from Test Sites – Stage 2

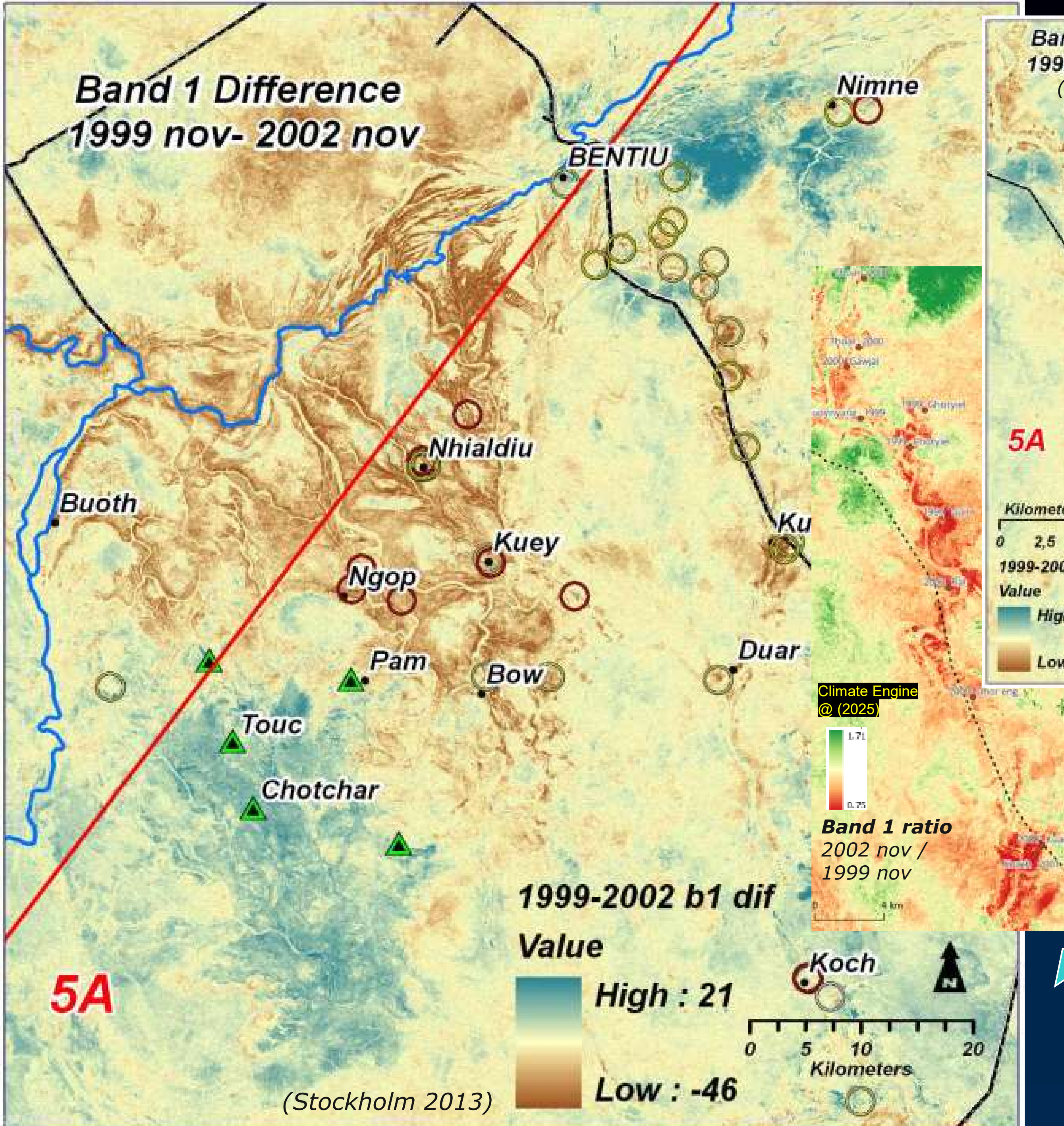
Selected classification solutions tested with VHR data as reference

(Stockholm 2013)

Classification	MMU	Acceptable	High	Very high	Overall	Kappa
Bare class accuracy		**>70**	**>80**	**> 90**	*Percent*	
2006						
ISODATA 1 bare class	1 ha		**x**		99.88	0.86
ISODATA 2 bare class	1 ha		**x**		99.54	0.81
CTA Clay index	1 ha	**x**			99.89	0.76
CTA B1 (blue light)	0.5 ha		**x**		99.9	0.82
CTA Band 7,5,1	0.5 ha			**x**	99.98	0.96
CTA TC BI, GI, WI	2 pixel			**x**	99.99	0.99
2003						
ISODATA 2 bare class	1 ha	79.5			99.76	0.79

Categorical accuracy levels taken from Fagan and De Fries (2009) who used it to describe overall accuracy for classification types

ISODATA (unsupervised) preforms well and CTA better. Majority of errors in 2003 can be linked to off-set in time and season (> 1 yr.) between VHR reference and satellite data



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Improved Calibration

Example: Difference in Blue light (B1)

Calibration: Mean difference from 2002 image

Date	Mean diff.
11/21/1994	0.01
11/27/1999	0.017
11/08/2004	0.001
10/11/2006	0.025

Similar change Pattern as ECOS 2009 report

Reported Attacked Villages (rings) and Displacement areas (triangles)

Calibrated data can now quickly be collected from the web e.g., Climate Engine

Climate Engine. (2025). Desert Research Institute and University of Idaho. Accessed on (28052025). http://climateengine.org, version 2.1

Development of monitoring system for Land-Use in 5a – Stage 3 – Scientific Documentation

PRINS ENGINEERING

INTERNATIONAL JOURNAL OF REMOTE SENSING, 2017
VOL. 39, NO. 3, 854–878
https://doi.org/10.1080/01431161.2017.1392634

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Landsat approaches to map agro-pastoral farming in the wetlands of southern Sudan

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ABSTRACT
Machine-learning algorithms (MLA) are coming of age within satellite remote sensing (SRS). This study compares the performance of a number of MLAs with more traditional indices and algorithms to map annual agro-pastoralist farming activity in southern Sudan.

ARTICLE HISTORY
Received 17 October 2016
Accepted 3 October 2017

(IJRS 2017)

In 2014 a new humanitarian crises unfolded in 5a, which lead to a huge amount VHR image became available on Google Earth. This allowed an evaluation of the Landsat data applications and development of a monitoring system for this land use system.

34 classification methods were evaluated e.g. some of the latest machine-learning algorithms and indices for range-land monitoring. Results were consistent with the Stockholm 2013 presentation – though much more comprehensive and detailed.

Scientific Result Summery

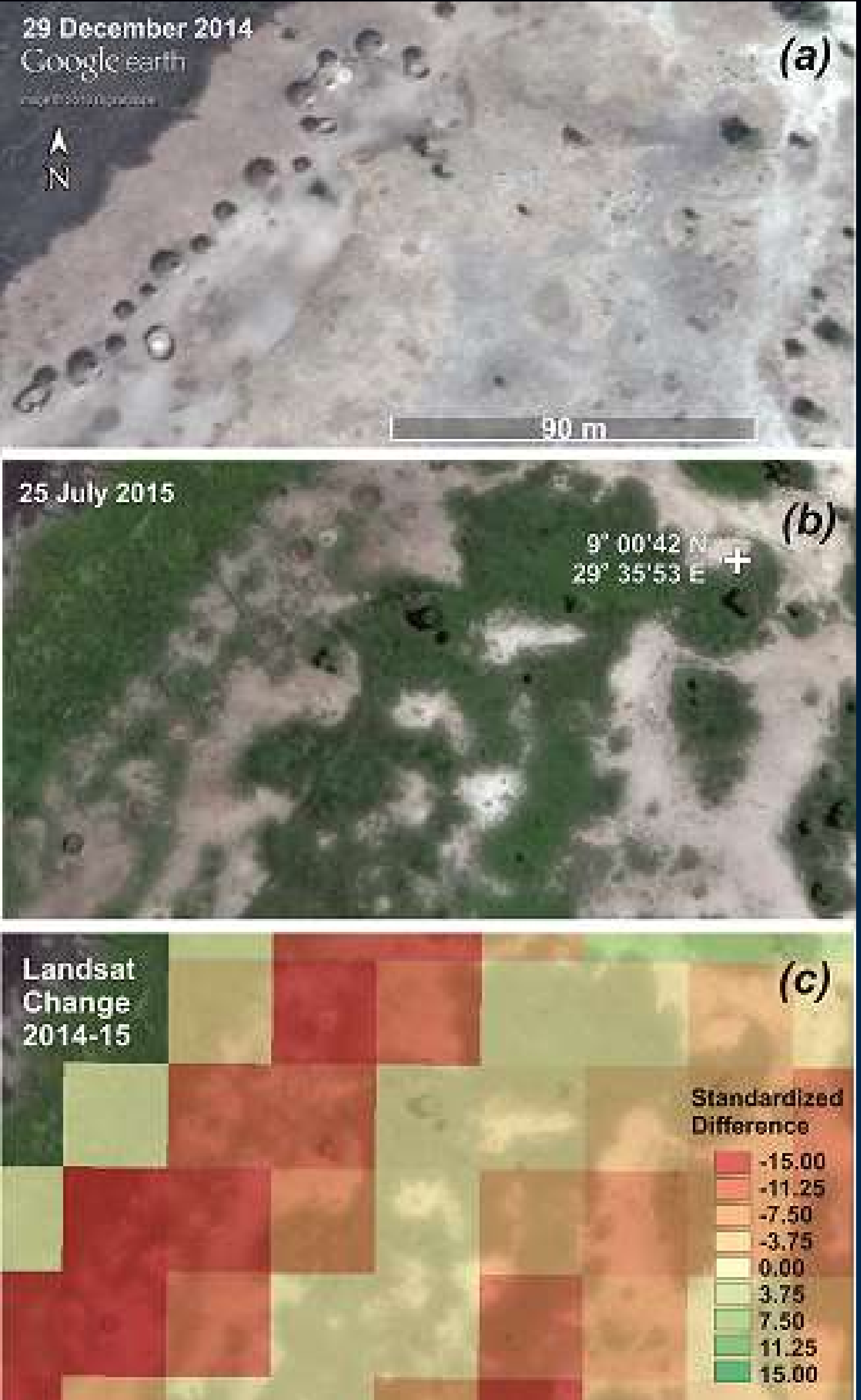
A new algorithm for remote sensing (MaxEnt) outperformed all other methods with overall mapping accuracy > 98.5% (Kappa 0.88-0.92 – very high). **The unsupervised classifier used in ECOS report were in the best third with overall mapping accuracy > 97.2%** (Kappa 0.81-0.86 - high). **However, many algorithms preformed well to show land use change pattern**

The training, analysis and verification was **based upon a conservative interpretation of VHR images -** as assessing land use below 10% of a pixel was considered too contain uncertainty.

Scientific Peer-reviewed: Result Interpretation and Conclusion (*text from IJRS 2017*):

'The result of this research showed that agro-pastoral farming activity in the wetlands of southern Sudan could be mapped with high mapping agreement by the use of Landsat data*… In this case, it clearly shows displacement areas on a map that collaborate and detail resent and historical ground reports of mass displacement'*

'In this case, there were some limitations particularly for accounting for ***'lighter' grazing pressure that is difficult to interpret from VHR imagery. However, it appears to be captured better by Landsat data****, especially when continuous data are put together in change detection scenarios that eventually can be corroborated by ground reporting'*



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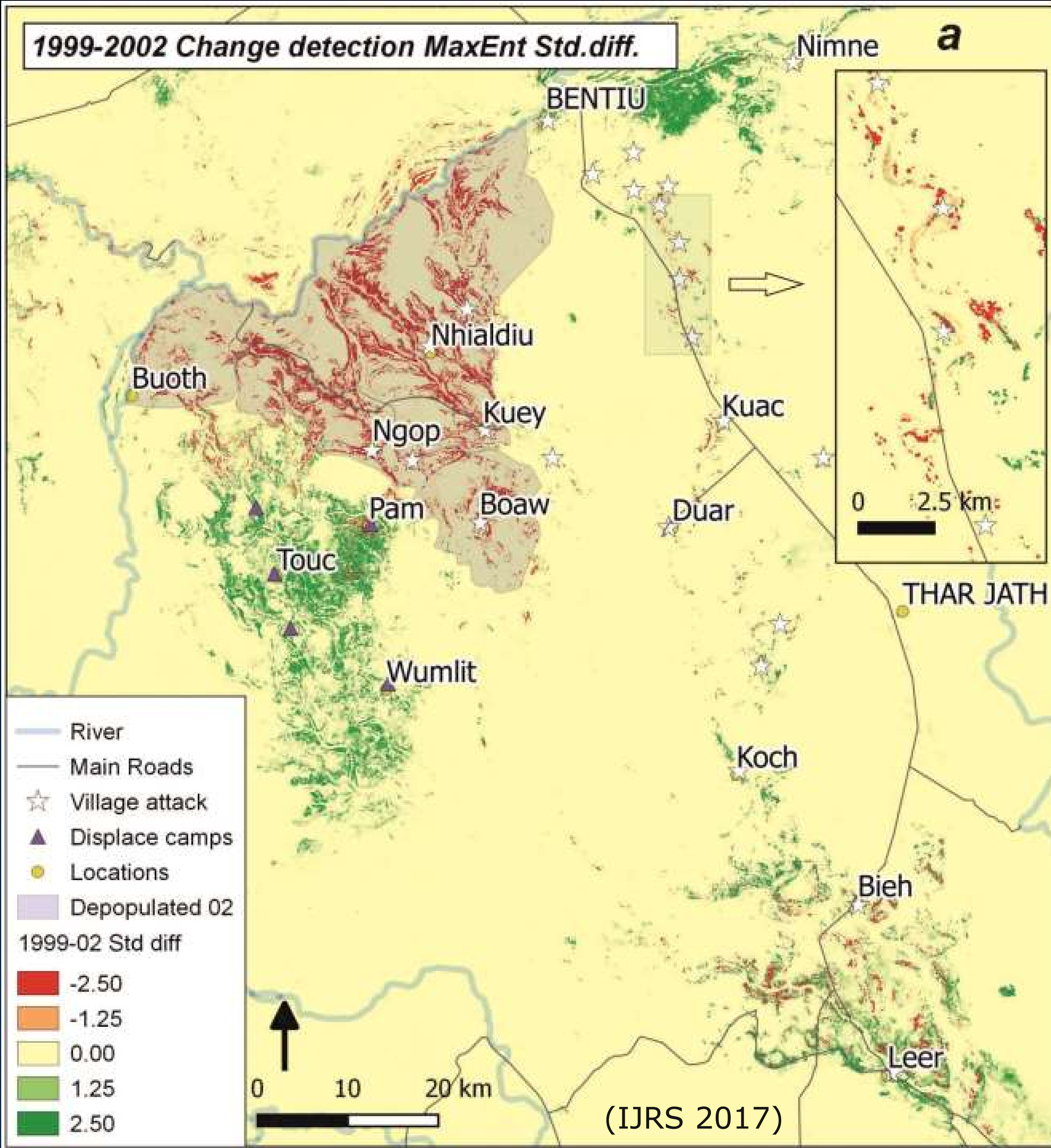
Example of detail:

A farming area in late 2014 (a) shows to be abandoned 7 months later (b).

Already, in the mid-rainy season, the vegetation cover had almost recovered and the change was eventually picked up (c) by the Landsat 2014–15 difference image (z-scores).

(IJRS 2017)



(IJRS 2017)

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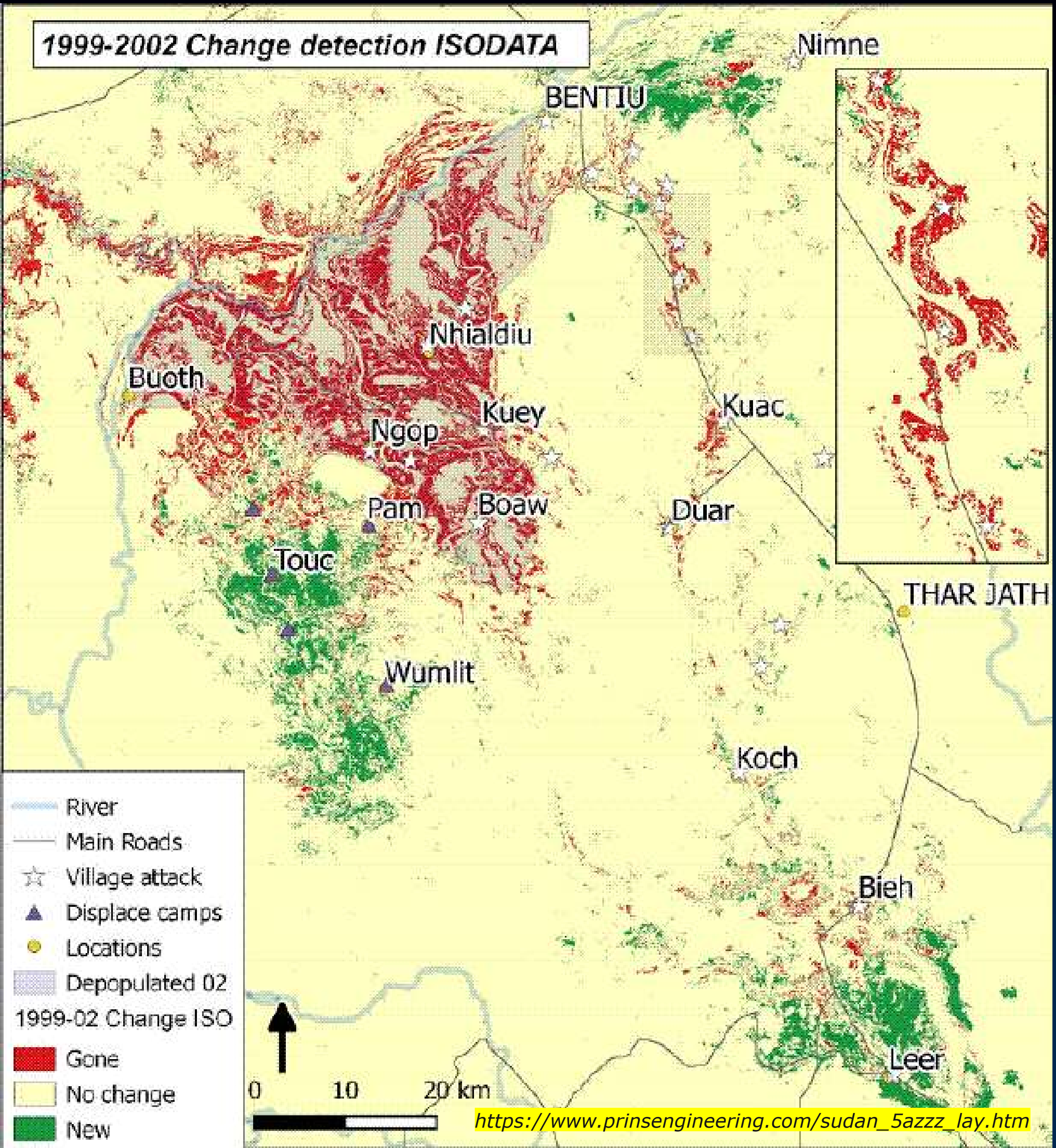
Regional scale

From IJRS 2017:

"Change detection (z-scores) of MaxEnt derived farming activity on a large scale, its detail and collaborate reports of massive displacement of people from two different periods and events [1999–2002 (a) and 2014–2014 (b)]."



https://www.prinsengineering.com/sudan_5azzz_lay.htm

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On the unsupervised ISO Classifier

Text from IJRS 2017:

*'In this case, Landsat analysis traced farming activity beyond what could be clearly interpreted from VHR imagery. Like this, **the ISODATA classification was performing well** but had relative high commission errors that appeared to be farming activity below the threshold used in this work'.*

In other words:

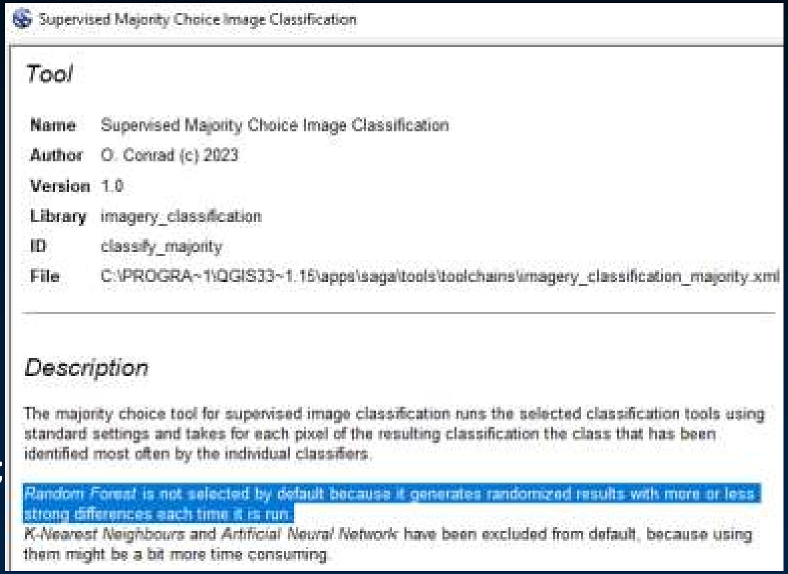
The classifier used in ECOS 2009 showed strong to capture connected area that are hard to interpret using only very high resolution images

Conclusion on Technical Findinges and Comments

The above shown summery is a fraction of tested images and analysis – however, it can be concluded that the change in land use pattern in the 1999-2002 period is consistent across stages and processing approaches.

There is many algorithms that works (IJRS 2009); each may have straight and weaknesses and an average of several classifications can be chosen. Although some are considered less stable than others- for example, Random Forest that have been popular for some years – but the technological push have led to other algorithms or methods may be preferred at this time.

Multispectral satellite data captures what VHR images can't; like light grazing, soil exposure, or resource stress. These are now standard in monitoring ecosystems, and crucial for the future.

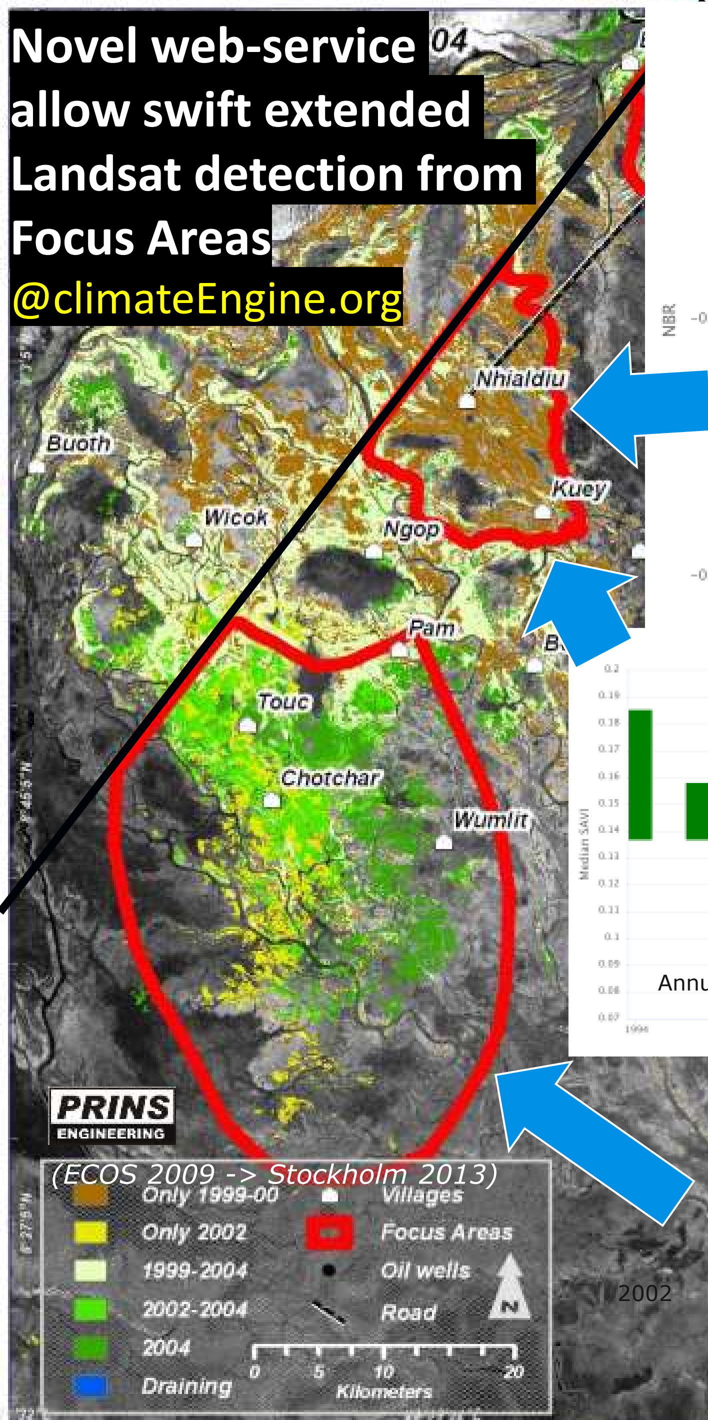


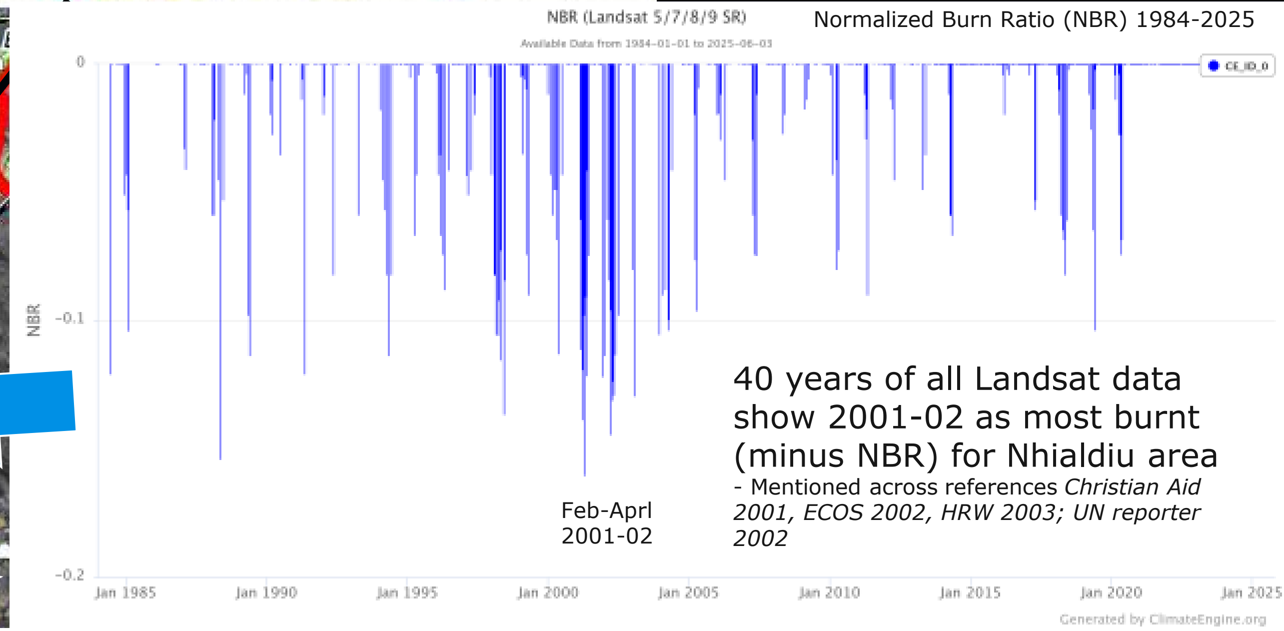
https://saga-gis.sourceforge.io/saga_tool_doc/9.4.1/tc_imagery_classification_classify_majority.html

The next slide shows a validation of the same displacement pattern, now derived independently by ClimateEngine.org—an internationally recognized, cloud-based satellite analysis service. What's remarkable here is not just the agreement—but the fact that it confirms results developed two decades ago, using far more limited tools. It shows that our early analysis was not only valid—it anticipated what would later become mainstream.

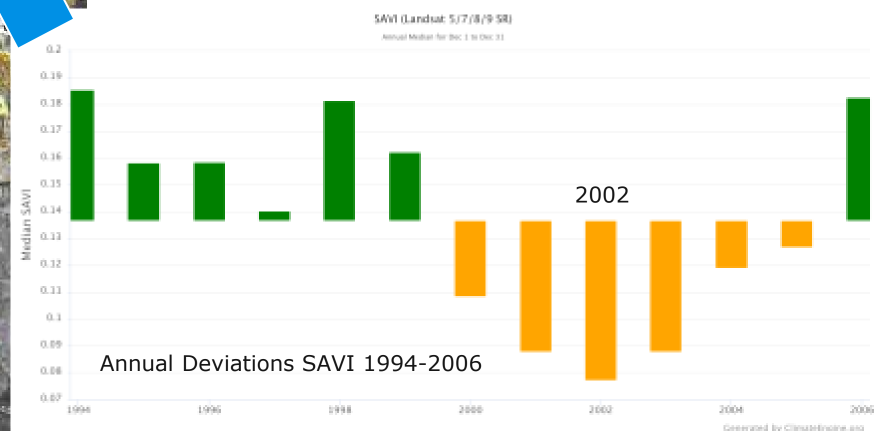
In other words: What we once had to custom-calibrate and verify manually is now auto-processed—and it tells the same story

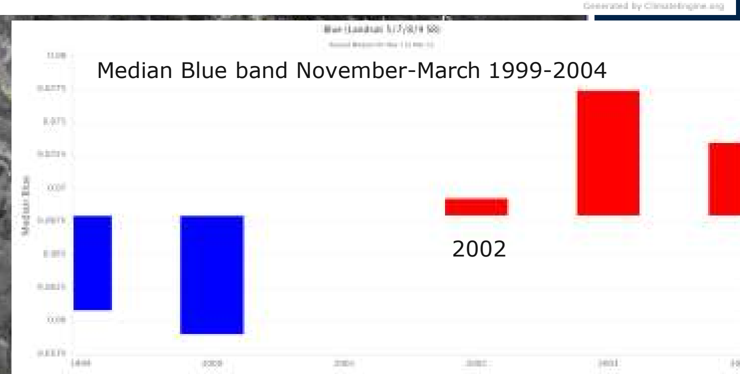
Novel web-service allow swift extended Landsat detection from Focus Areas @climateEngine.org





40 years of all Landsat data show 2001-02 as most burnt (minus NBR) for Nhialdiu area
- Mentioned across references *Christian Aid 2001, ECOS 2002, HRW 2003; UN reporter 2002*





2002

Indicators that showed useful in IJRS 2009 as land use indicators - could be confirmed using @climateEngine.org

e.g., anomaly for Band 1 and SAVI in December values for Dec 1994-2006

Climate Engine. (2025). Desert Research Institute and University of Idaho. Accessed on (28052025). http://climateengine.org, version 2.1

Conclusion

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The satellite-based findings presented here are supported by three layers of robustness:

1. Scientific Merit: The methodology has passed peer review in an international journal (IJRS 2017), confirming both rigor and reproducibility.

2. Ground Truth Alignment: Field reports and eyewitness testimony independently confirm the patterns observed—displacements, village abandonment, and destruction. These are not abstract maps; they are visual evidence that aligns with human experience.

3.Technological Validation: Today, platforms like ClimateEngine.org—built years after this work began—support the results using pre-calibrated, cloud-based data. The same land use changes appear, detected by different tools and methodologies.

Expert Opinion on this Presentation

Lund University has been a leading institution in satellite analysis of Sudan for decades.

A pioneer in this field, **Professor Lennart Olsson of Lund University** completed his PhD in 1986 on remote sensing in Sudan. I cited his work twice in the ECOS 2009 report, and after reviewing the above presentation, he concluded:

"I find the compilation of imagery and interpretations of them by E. Prins both highly plausible and convincing."

After this introduction:

Remote sensing from sun-synchronous orbiting satellites (e.g. Landsat) has been used extensively since the mid-1970s to monitor changes of land surface and land cover, including natural and anthropogenic processes such as land use, infrastructure, and fire (both natural and human induced). The sun-synchronous orbit makes the satellite pass over the same area at the same time of the day, therefore making images directly comparable over long time periods (decades). Furthermore, advanced continuous calibration of sensor parameters and precision geo-referencing make time series of such imagery ideal for change detection. More recently, machine learning algorithms have greatly advanced our ability for systematic and unbiased analysis of these large datasets of images. When performing a search for scientific peer-reviewed articles on the database Scopus (key words: satellite AND remote AND sensing AND land AND cover AND change) I found almost 8000 relevant articles. In terms of geography, vast expanses of comparatively flat land (such as the Sahel and Sudano-Sahel region) make this kind of change detection particularly accurate and unbiased.

Remote sensing has provided substantial evidence of human rights abuses around the world, not least in Sudan and South Sudan. By monitoring settlement patterns and comparing with reports from ground observations, satellite imagery has become a crucial tool in understanding and addressing the humanitarian crises (see some representative articles below). – artichels will be added to my webpage

Thank you for your Attention

More info and data can be found on:

www.prinsengineering.com