

# Sudan

## At the mercy of killers – destruction of villages in Darfur

### Summary

In April 2003, as the world still welcomed the Sudan government's engagement in a peace process with the Sudan People's Liberation Army (SPLA) and hoped for a resolution to the longest-running conflict in Africa, the government embarked on a ruthless counter-insurgency campaign against the civilian population in Darfur. Under the pretext of combating two armed political groups - the Sudan Liberation Army (SLA), formed in February 2003, and the Justice and Equality Movement (JEM) - the government armed and supported militias, the *Janjawid* (armed men on horseback), to attack and burn villages, killing civilians, raping women, and looting property. They operated with impunity and often alongside government forces.

The satellite imagery used in this report highlights the pattern of destruction of villages in Darfur by the *Janjawid* and the government-armed forces, which has led to a human rights and humanitarian disaster in the region. This technology shows vividly the scale and impact of the massive human rights violations against the civilian population of Darfur and the devastation of the region. Amnesty International has interviewed hundreds of victims who fled from the area, whose testimonies of their own experiences of death, destruction, rape and flight illustrate the stark picture of the satellite images.

### Introduction

Of the 6.5 million people living in Darfur, western Sudan, at least 2.2 million have been directly affected by the violence. An estimated 30,000 people have been killed, thousands of women have been raped, at least 130,000 people are now living as refugees on the Chad border or in camps in Chad. Over one million people have become internally displaced, living in camps around the larger population centres, swelling the towns or hiding in the countryside in Darfur<sup>1</sup>. Internally displaced people (IDPs) are among the most vulnerable population in Darfur, they benefit from less assistance and have less protection from the international community than the refugees in Chad. They are still exposed to serious human rights violations by government forces and the *Janjawid* militia.

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<sup>1</sup> According to UN figures 1.2 million people are currently displaced in Darfur.

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## Destruction of villages

The destruction of villages, killing of civilians, raping of women and girls, abductions, looting of livestock and other property has been a recurrent feature of *Janjawid* and government attacks against the civilian population in Darfur. Until May 2004 access for humanitarian organizations was heavily restricted and the estimates of the extent of these attacks were a speculative exercise based on the number of IDPs and refugees and on testimonies gathered from people from Darfur currently in the refugee camps in Chad. The satellite images provide more evidence of the scale of attacks and extent of the destruction of villages in Darfur. By the beginning of the rainy season in May 2004 most of the farming groups in Darfur had left their villages and taken refuge in IDP camps where they are now facing famine, largely dependent on a precarious supply from international humanitarian organizations.

*Fig. 1 Burnt and abandoned village*

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Analysis of satellite imagery commissioned by Amnesty International reveals the extent of the destruction of villages around Mornay in an area west of Darfur. Landsat images were collected on 30 March 2003 and again on 01 May 2004 and compared in order to ascertain the amount of village destruction that took place between these dates in the area of Mornay West Darfur, on the Azum River, a border between the Masalit and Fur areas (See appendix for full report of Landsat data analysis). The analysis of Landsat images shows that at least 44% of the villages in the region have been burnt. Most of the burning appears to have taken place in the Masalit and the Fur areas.

*Fig.2 Area between Zalingei and al-Jeneina. (The spelling of Arabic names in European script varies. The map refers to Murne and Al Kurayniki, in previous Amnesty International documents we have spelt this Mornay and Kereinik)*

The northern area covered by the satellite image appears relatively untouched. This may be because the villages in this area were burnt before March 2003 consequently no change on the ground would have been recorded by the satellite. Another explanation may be that this area is inhabited by a number of smaller ethnic groups, such as the Tama, Irenga, Jebel and Gimmir, and the government troops have not targeted the villages there as heavily<sup>2</sup>.

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<sup>2</sup> While some of these ethnic groups have been victims of attacks by some members of the *Janjawid* (except the Gimmir), it seems they have not been as heavily targeted as the Masalit, Fur and Zaghawa ethnic groups.

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In the area between Zalingei and al-Jeneina alone the Landsat image identified **352 villages/settlements, 155 of which had evidence of change that provides very strong indications of burning, 125 had no significant change and 61 had some change. The remaining 11 had changes that may be related to burning before March 2003, four of these villages showed changes that may have been a result of IDP concentrations.** This evidence is consistent with the many testimonies of victims gathered by Amnesty International and other human rights organisations that the *Janjawid*, armed and backed by the government of Sudan and operating alongside its troops, have been engaged in a widespread and systematic campaign of displacement of certain communities from certain areas.

Landsat data also indicates that the population of a number of villages in the south had grown and this may be due to the fleeing of the people to safer villages. Two major IDP camps which have grown up near population centres are in the region of the satellite photos: Mornay and Kereinik.

### **The human tragedy behind these images**

Each small red star on the satellite image represents a community (village or settlement) where dozens, sometimes hundreds or even thousands, of people once lived. It tells the story of personal loss and suffering at the hands of the *Janjawid* and the government forces. Homes burnt, schools, and community buildings destroyed, cloths, cooking utensils, books and tools to work the soil as well as possessions passed down from one generation to the next looted. These communities that had stood for generations are now deserted and sometimes reduced to ashes. Their inhabitants chased out of their own country or forced into IDP camps, sometimes to live in conditions of near starvation under the control of the people who killed their relatives and neighbours and destroyed all their possessions.

Amnesty International has documented many cases of attacks against civilians, some of which were in the area covered by the Landsat image. In November 2003 the organization took hundreds of testimonies from refugees who had fled to Chad; the gross human rights violations on the rural population were made public in February 2004 in a report entitled *Sudan: Darfur: Too many people killed for no reason* (AFR 54 / 008 / 2004, February 2004). In May 2004 Amnesty International delegates visited a number of camps in Chad where the refugees from Darfur had been settled for safety, further from the danger of *Janjawid* cross-border attacks. Information also comes from scores of other sources, including sources from the region. Notwithstanding numerous requests for visas, the organization has not yet been allowed access to Sudan since its visit to the country in January 2003, which included a visit to Darfur.

Destruction of villages is usually accompanied by looting of livestock and other property and sometimes poisoning of the water supply and the destruction of village landmarks such as large trees. The trees have both practical and symbolic significance, acting as landmarks that are sometimes used for navigation in the region as well as defining features of a community (whereas a house may take days to build, a large tree takes generations to grow). The village of Murli, which is five kilometres from Al-Jeneina, was been attacked twice between July and August 2003, resulting in the mass killing of civilians. One villager told Amnesty International delegates in Chad:

*“It was early in the morning, people were sleeping. About 400 armed people cordoned the village, with military uniforms, the same ones worn by the army, with vehicles and guns. A plane came later, to see if the operation was successful. At least 82 people were killed during the first attack. Some were shot and others, such as children and elderly, were burnt alive in their houses.”*

Another victim who had a wounded foot, said:

*“I stayed in the village after the first attack. Then another group attacked again on market day, at around 2pm, after the 1pm prayer. They had heard that there were people who survived the first attack. They cordoned the market on both sides and shot people. They beat those who tried to flee. They killed 72 persons. I was shot myself and came here to get some medicine. Around Murli, about five other villages were attacked: their names are Kutumanda, Tandi, Kandale, Uchuka and Bertenyu.”*

At least nine women were reportedly shot dead during the attack on Murli by the Janjawid. They include: Alima Adam (25), Kaltuma Sabu (25), Awa Abdallahi (30), Mariam Harun (35), Khadija Abdullahi (30), Fatuma Idris (20), Aisha Mohammed (30), Nafisa Adam (40), and Dolma Ismail (20).

When Murli was attacked, Jamila Mohammed, a woman, reportedly fled on foot with another woman, Aisha Harun. She explains what happened:

*“The attackers pursued us on horseback. They stopped us, beat us with dry bush branches and took our clothes and then released us.”*

A number of women recounted similar stories. In some instances, women found on roads or in the bush while collecting wood, travelling or fleeing attacks were raped. Again in Murli, three girls, aged 10, 15 and 17, who had fled the attack were found by

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the *Janjawid* in the bush and reportedly raped. The girls are said to still be in Sudan where they receive help from traditional healers. Two others, aged 20 and 25, were also reportedly raped by the attackers on the road while they were coming back to the village after fetching water. These reports were given to Amnesty International by two women who came from the same village and knew the girls and are consistent with a number of other testimonies collected. A 28 year old Zaghawa women from Habila region testified:

*“In July 2003, the Arabs raped a 14-year-old girl on the market square and threatened to shoot on the witnesses if they tried to intervene. They also raped other girls in the bush.”*

Between 9 and 13 February 2004 11 villages were reportedly bombed including Habila Kareinik, Kereinik, Magornay, Mornay, Gurnyu, Mejmeri, Effendi, Urbi, Liri, Kastara and Nuri Last. People fled to the four largest villages/towns of Mornay, Habila, Magornay, and Kereinik. Villages in the area were emptied and the area devastated. The *Janjawid* reportedly surrounded the four towns where people had fled and killed many of the displaced.

On 6 March 2004, 15 villagers, all civilians, including a child were reportedly killed by the *Janjawid* in Kereinik which was already swollen with internally displaced people. The *Janjawid* reportedly arrived in three land-cruisers and some 60 men on horseback attacked Kereinik.

On 8 March 2004 three children were among twelve civilians reportedly killed in 'Aish Barra, a village west of al-Jeneina, near the Chad border.<sup>3</sup>

The date of the second Landsat image, 1 May 2004, was nearly one month after a ceasefire was signed in N'Djamena between the government of Sudan and the armed political groups, the SLA and JEM. However attacks on villages and displaced people continued; one of the villages, Tunfuka, south-west of Mornay, was attacked again on 29 June.

### **Impact of the destruction of villages:**

A large number of the estimated 1.2 million people who have been internally displaced by the conflict in Darfur are facing the real threat of starvation as well as

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<sup>3</sup> For further information on attacks against villages see SUDAN: Deliberate and indiscriminate attacks against civilians in Darfur (AFR 54 / 034 / 2004, April 2004)

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continuing violence at the hands of the *Janjawid*. Although most are in IDP camps in West and North Darfur, a significant number of people have been absorbed by the local population and are surviving on support from relatives and casual labour. All remain potential targets of the *Janjawid* militia and of the government troops who have been continuing deliberate and indiscriminate attacks against civilians, despite a ceasefire agreement signed on 8 April 2004.

The government of Sudan continues to maintain that the violence and destruction of property was largely done by “outlaws” and has refused to acknowledge its own role in the human rights and humanitarian disaster in the region. However, by the beginning of 2004 those who had been attacked reported that not only were the *Janjawid* usually accompanied by soldiers but most of the members of the *Janjawid* were wearing government uniforms. The *Janjawid* continue to operate in the region with impunity and the government has done nothing, other than make statements of its intent to disarm or “neutralize” the militia.

The situation in IDP camps is dire and the onset of the rainy season is aggravating the already severe humanitarian disaster. One resident of al-Jeneina told Amnesty International: “The humanitarian organizations are feeding hundreds, but there are thousands who are starving and receiving nothing”. A recent study carried out by Médecins Sans Frontières (MSF) and the epidemiological research centre, Epicentre, in the area of Kabkabia found that in the town of Mornay which currently provides refuge for some 80,000 people, 200 people die every month, from violence, food shortage or disease.<sup>4</sup> According to the report the militias “who carried out the initial attacks now control the camp's periphery, virtually imprisoning people who live in constant fear. ... Between April and May 2004 MSF medical teams treated 132 victims of such violence.” There have been numerous reports of men venturing outside the camps being killed and women and girls raped. The measures taken by the Sudanese government to ensure that people in the IDP camps are provided with protection and humanitarian assistance are non-existent. To date no individual has been arrested or brought to justice for unlawful killing, rape, or other attack on civilians or for the looting of livestock and other property.

*Figure 4. The area of Mornay where a high concentration of burnt villages was found.*

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<sup>4</sup> MSF and Epicentre: Health Assessment in Emergencies: Murnei and Zalingei, West Darfur, Sudan – June 2004).

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Residents in the area (as well as other IDPs around Darfur) said that, before the visit to the Sudan of the United States Secretary of State Colin Powell on 28 June and of UN Secretary-General Kofi Annan the following day, they were threatened to leave the camps and return to their villages. Others said that impoverished displaced people, without the money even to buy sugar for tea, were offered bribes and told to return. According to reports these bribes consisted of small sums of money or sacks of grain. No solid guarantees for the safety of the returnees have been provided. The *Janjawid* are still active and human rights monitors are still not fully deployed on the ground therefore there can be no such guarantees. Under these conditions offering incentives for people to return to their villages is tantamount to encouraging them to return to live in circumstances that place them at serious risk of further human rights abuses.

There were unconfirmed reports of attacks and demolition of shelters by *Janjawid* or government forces. Despite attempts by the local authorities to either encourage or pressure the IDPs to return to their villages most feel that the conditions in the rural areas are still unsafe.

Some IDPs who have escaped from their villages and who fear continued attacks by the *Janjawid* have reportedly taken refuge in the mountains around Mornay. There they are living in very precarious conditions, with very little food. The old and the very young are particularly vulnerable in these conditions. Very little information is available on the exact number and the plight of this population. However their flight is indicative of the levels of fear and insecurity, caused by the government and the *Janjawid*, that pervades the region.

### **Recommendations:**

The international community has been far too slow to react to the unfolding human rights and humanitarian crisis in Darfur. Condemnatory words or pledges for action are not enough. Decisive action is needed now to resolve the human rights and humanitarian crisis in Darfur:

To the government of Sudan

- to immediately disarm and disband the *Janjawid* and ensure that they are no longer in a position to commit human rights abuses;
- to ensure that any member of the *Janjawid* or the armed forces who has been responsible for human rights abuses is arrested, and tried in accordance with international standards of fair trial without the possibility of the death penalty;

- to acknowledge the severity of the humanitarian situation in Darfur and take all necessary measures to allow full and free access to Darfur to ensure that the IDP population is provided with humanitarian relief;
- to ensure the safety of the IDP population is guaranteed by preventing the *Janjawid* from operating inside and on the peripheries of the IDP camps;
- to ensure that IDPs are not forcibly returned to any place where their life, safety and / or health is at risk;
- to accept the full and unhindered deployment of international human rights monitors who should investigate all allegations of human rights abuses by all parties to the conflict in Darfur and report publicly.

To the international community

- urge the government of Sudan to disarm and disband the *Janjawid* and to ensure that any member of the *Janjawid* who has committed human rights abuses is arrested and tried in accordance with international law;
- urge the government of Sudan to allow all humanitarian organisations to have unimpeded access to all areas of Darfur to provide humanitarian aid in the region;
- provide support for the deployment of human rights monitors in sufficient numbers and adequately resourced, and urge the government of Sudan to accept such monitors, ensuring unimpeded access to all areas of Darfur;
- urge the government of Sudan to allow national and international human rights organisations unimpeded access to all areas of Darfur to monitor the human rights situation in Darfur.

To the members of the United Nations Security Council

To adopt a resolution on Sudan that:

- immediately orders the suspension of arms transfers and related materiel used by *Janjawid* and government forces to commit human rights violations in Darfur. The resolution must include a strong monitoring mechanism which could *inter alia* investigate possible violations of the arms embargo and report periodically on its findings;
- deploys human rights monitors in sufficient quantity and adequately resourced, with a clear mandate to investigate ongoing human rights violations in Darfur and monitor the protection of civilians in particular in the IDP camps, and to make its findings and recommendations public;

- creates an international commission of inquiry to examine evidence of war crimes, crimes against humanity and other violations of international humanitarian law as well as allegations of genocide and to make its findings and recommendations public.

To the African Union

- send at its third Ordinary Session a strong message publicly condemning all instances of grave abuses of international human rights and humanitarian law committed in Darfur;
- strongly urges the government of Sudan to comply fully with its obligations under the Constitutive Act, the African Charter and all other relevant regional and international human rights instruments as well as to fully comply with its commitments under the Ceasefire Agreement;
- take all necessary measures to promptly complete the deployment of the full AU Observer Mission monitoring the Ceasefire Agreement;
- to fully support the deployment without delay of a fact-finding mission to Darfur and that their findings and recommendations are made public.



## APPENDIX

### **A pilot study on mapping of burnt villages in western Darfur, Sudan - based upon Landsat data.**

A report conducted for Amnesty International



Technical Report

Erik Prins June 2004



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## Summary

The study was commissioned by Amnesty International (Danish section) to explore the possibilities of using satellite data to document human rights and humanitarian crisis.

The immediate objective of this report was to investigate the possibilities of using Landsat data to map the destruction of villages and water resources in a specific area of Darfur. The Darfur area is roughly the size of France, but the study area will cover the area between al-Jeneina and Zalingei, which is covered by the extent of a Landsat ETM scene 179/051 (approx. 32.000 km<sup>2</sup>).

The study is based upon change detection between 2003 and 2004 where the satellite images have been recorded under the same environmental conditions and found that 44% of the villages in the region covered were burnt. 352 villages were analysed by comparing the albedo from the two images. 155 of these have strong indications of the burning, 125 have no significant change, 61 have some change, and seven of the remaining 11 have some change that can be linked to burning before March 2003.

The result has been compared to various other sources, including sources on the ground that confirms the patterns of burnt villages.

Changes in water resources related to the present situation were not found.

A number of villages in the south increased, this may be related to the establishment of IDP (internal displaced persons) camps. This has not been fully investigated in this study. It is likely that these can be spotted by the change detection, especially if they have been established in places where the background contrast differs from the materials the camps are build from.

It should be noted that the method used here is only one example of the use of satellite data to trace evidence of humanitarian crisis. Other examples could include monitoring of changes in crop pattern as an indication of the presence of people, or locating IDP's by the heat from nightly campfires.

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## Introduction

This report is an investigation into Landsat data to trace evidence of the human rights and humanitarian crisis throughout the Darfur region, Sudan.

Over the past years thousands of civilians in Darfur, western Sudan, mostly from agricultural ethnic groups like the Fur, Masalit and Zaghawa, have been killed or wounded by armed nomadic groups that later organised into the *Janjawid* militia. Their homes have been burnt and herds looted. The Sudan Liberation Army (SLA) and the JEM (Justice and Equality Movement) took up arms against the government in February 2003, because of what they perceived as the lack of government protection for their people and the marginalisation and underdevelopment of the region. Since then, the Sudan government appears to have given free rein to the *Janjawid* to carry out killings, abductions and destruction of homes and property. Over 30,000 people have been killed, thousands of women raped, more than one million people have fled from their burnt villages and most have taken refuge in towns in Darfur, while more than 130,000 have crossed the border into Chad.

The immediate objective of this report is to investigate the possibilities of using Landsat data to map the destruction of villages and water resources in a specific area of Darfur. The Darfur area is roughly the size of France, but the study area will cover the area between al-Jeneina and Zalingei, which is covered by the extent of a Landsat ETM scene 179/051 (32.000 km<sup>2</sup>).

Key indications that can potentially be derived from the Landsat data:

- Burning of villages and crops – villages are clearly visible and fresh fire scars are easy to interpret in the images – burning of single houses.
- Water dams and natural ponds are clearly visible in the images.
- Refugee camps should be possible to observe.
- Change in crop pattern – crops of millet and sorghum can be observed but it requires images taken in the cropping season.

### *Assumption*

It is assumed that villages, open water and fire scars can be identified in the Landsat images. Hellden (1984) and Olsson (1985) have documented that villages in semi-arid Sudan can quite easily be observed from Landsat data, even from the coarse scale MSS sensor with 60 m spatial resolution. Mapping of villages in the semi-arid environment can be done so effectively that population density can be predicted (Stern M 1984).

Open water and fire-scars are both features that can be mapped effectively by remote sensing and the Landsat TM scanner (DeFries *et al* 1998; Barbosa *et al* 1999). It is assumed that burning of villages will cause a drop in the reflection from the village area by 15% in the signal. This reduction in reflection will be recorded by the satellite image.

## Materials and Methods

### General analysis approach

The human rights and humanitarian crisis has lasted for over a year. For this study, two Landsat images were used which recorded the landscape under the same circumstances at the same time of year in order to get the same pattern of reflection.

To improve the spatial resolution the two images have been resolution merged into 15 meters and co-registered to each other so that a direct comparison can be made. A visual interpretation of the image was carried out to analyse the dynamic in the images and get an initial evaluation of the extent to which the above mentioned indicators can be identified in the images and to trace any other possible indication of change relevant to the objective of the study. Images have been radiometric calibrated so they can be directly compared to each other. Information from the TM bands for each year has been compressed to a single reflectance band that will be compared using a change detection analysis of percentage change in 'brightness'.

### Study area

The area of the image covers the open dry Semi-arid area in the north and approaching south Sudano zone characterized by denser shrub and woodland vegetation (fig 1). The conditions were dry when the images were recorded and bush fires are common features of this area.

### Ground truth information

Ground truth information was collected from the press, Amnesty International's own research and various anonymous sources. The information also include a recent Human Rights Watch report (HRW 2004) describing the location of villages in the area as well as describing the modalities of the burning of a large number of specific villages in the area. Information was also gathered from another satellite based mapping project conducted by USAID (2004). Some photos of burnt villages are available, which give an indication of what the villages look like after they have been destroyed by burning (photo 1).

*Burnt village in Western Darfur*

© WFP/Marcus Prior

As it appears from the reporting and photo 1, the burnt area within a village can have quite large variations, which will influence the spectral response recorded by the Landsat TM sensor. Furthermore, old burnings or at least those that have occurred before the wet season will eventually disappear, meaning that uncertainty in their recording will occur. Decisions on which villages have strong indications of being burnt will be evaluated based upon the degree of changes from a change detection analysis between the images compared with the pattern of a number of known burnt villages. A criterion of pixels with more than 15% decrease has been set to indicate that burning has taken place. This measure should ensure that no overestimation will be made.

*Fig 1. Location of the satellite scene in Sudan and in relation to rainfall (from Olsson 1983).*

### **Data characteristics and quality**

*Landsat ETM+*: Landsat Thematic Mapper with six spectral bands (6 in 8 bits), spatial resolution of 30 meters and a thermal channel with a spatial resolution of 120 meters, in addition a thermal band in 60 meter resolution and a 15 meter panchromatic channel within the visible area.

- Path/row 178/51: date 30-03-2003
- Path/row 178/51: date 04-05-2004

Since June 2003 Landsat 7 has not been fully functional therefore gaps are occurring at outer edges and decrease inwards, which may affect up to 20% of the data. For the 2004 scene gaps have been filled with data from the 2003 scene. It is not considered to have a serious affect on the analysis of the data.

The data is projected to UTM projection with WGS84 datum with an approximate accuracy of a 1:200.000 map.

**GIS layers:**

From the African data sampler (WRI 1995) spatial database layers have been used. These layers are in a scale of 1:1.000.000 and include: roads, villages and national borders. Further, an updated location layer was received from the United Nation cartographic department.

**Pre-processing procedures**

In order to increase the spatial resolution, the 2003 and 2004 Landsat ETM+ was resolution merged into 15 metre resolution bands by the use of the multiplication method (ERDAS, 1997).

During the gap-filling of the 2003 into the 2004 data the images were registered to each other so direct overlap occurs with sub-pixel accuracy. For a direct comparison on the two scenes the 2003 image was spectrally calibrated to the 2004 scene.

**Radiometric Calibration**

Radio metric calibration has been preformed using the following approach suggested by Hellden (1984):

$$\begin{aligned} B_{his} &= B_i - B_{min} \\ B_{new} &= B_{his} * (255/B_{max}) \end{aligned}$$

Where

$B_{hist}$  = new pixel value after histogram subtraction

$B_i$  = pixel value in raw data

$B_{min}$  = value of the darkest pixel in the scene

$B_{max}$  = value of the brightest pixel in the scene after the histogram subtraction

$B_{new}$  = the resulting scaled pixel value (0-255).

**Map reference**

Universal Transverse Mercator (UTM) that links up directly with almost all GPS receivers.

Transverse Mercator, with the following map details:

Spheroid: WGS84

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Datum: WGS84  
Scale 1.0  
Central longitude. 21 00 00  
Central latitude. 00 00 00  
X-shift 0  
Y-shift 0

### **Change detection**

The 2003 and the 2004 images have been compared for spectral differences by three different methods. A Principal Component Analysis (PCA) has been applied to each of the two images. The PCA will transform the image data into a new set of bands where the first PC will represent 'brightness' reflection or albedo of all the original Landsat bands (Schowengerdt, 1983). Secondly by the Tasseled Cap transformation (Crist and Kauth 1986), which also produces a layer that represents the variation in soil colour. Thirdly, an albedo (albedo may refer to the ratio of the amount of electromagnetic radiation reflected by a body to the amount incident upon it) layer was produced for each of the two images. It was decided to use the albedo layers for change detection since it is the most objective method and has been documented (Otterman and Fraser 1976) for monitoring changes caused by antropogenic activity in semi arid regions.

A change detection of the two albedo layers has been performed by producing an image difference file. This image is the direct result of subtraction of the before image from the after image. The change detection calculates change in brightness values over time, the image difference file reflects change in percentages represented by a greyscale image.

## **Results**

### **Image interpretation**

In terms of seasonality the images are from the late dry seasons. The spectral property of the land cover is quite similar in the two images, the dry woody vegetation is greenish in the Landsat band 4,5,3 combination that can be viewed in fig 2.

*Fig 2. View of the Landsat 2004 scene (185x173 km) band 4, 5, and 3. The scene has been superimposed over a map of the area, indicating national border, roads and*

*place names. Note the vegetation transition and the widespread bush fire scars (dark areas).*

The landscape is characterized by an absence of dry land crops and widespread fire scars (especially in the hills and in the Sudano zone). In the main river valleys and wadis evergreen trees can be seen.

Water reserves such as natural ponds can be observed in the images but are largely dried out in both images and are not considered to be a suitable indicator for destruction of infrastructure.

Villages are clearly visible in the semi-arid zone by their spectral properties of grass ruffs. Villages in the Sudano zone are not so clearly visible but can be identified by the surrounding cleared areas and dirt tracks leading to the villages. Villages are difficult to locate along the major rivers and wadis amongst evergreen woody vegetation.

## **Change detection**

*Fig3. Result of the change in detection of albedo. Gray (like the frame of the image) denotes no change; dark denotes a decrease in albedo and bright an increased albedo. Note; the dominating bush fires are white from 2003 and black from 2004.*

A visual inspection of the three enhancements (albedo, PCA and Tassel cap) showed similar results. However, albedo layers have been used in this study as they did not have to be rescaled as input to the change detection analysis. The result of change detection layer seems to be an appropriate tool to evaluate specific changes. As a first evaluation all major towns were viewed and as expected they were stable with only small and local change. The change detection layer further revealed where the gap filling had occurred in the 2004 data.

## **Indication of village burning**

Indication of village burning is wide-spread over the scene and seems to be concentrated in certain areas. Figure 5 is an example of how the indication of burnt villages appears in the Landsat data. Image 1 is the 2003 situation where two villages can be observed (A and B, olivine green colour), a dirt road is running close to the villages and the areas surrounding the villages are quite bare. The pattern of farm fields can be seen 1-2 ha each. In image 2 the villages are significantly darker in contrast. This can be compared with the bush fire scar occurring just below A in image 1. In the change detection analysis image 3, A and B have decreased their reflectance, on spots more than 20% relative reflectance (darker). Further, it can be noted that the bush fire scar from image 1 has more or less disappeared in image 2 and thus increased its brightness in the change detection analysis (brighter). Furthermore, some noise striping can be noted as a consequence of the malfunction of Landsat 7.

Another example of indication of burnt villages is an area with three villages (figure 4) where one of the villages shows signs of being burnt (1) and the two others remain relatively stable.

*Fig 4. Example of three villages where one shows signs of recently being burnt (1). Tracks, dirt road, farm fields and a pond are also visible in the image.*

*Fig 5. Example of two villages showing signs of being burnt (A and B), image 1 is from 2003 2 from 2004 and 3 the change detection.*

A few villages had a dark contrast in 2003, which was increased in 2004. This indicates that burning had occurred before April 2003 and was confirmed from other recordings from the area.

### **Distribution of villages**

In the process of interpreting the images the condition of single villages and settlements was digitized (figure 6). In all 352 villages/settlements that were digitized, 155 revealed strong indication of burning, 125 showed no significant change and 61 had some change. Of the remaining 11, seven had a darker contrast in 2003, which can be linked to burning before March 2003. Changes in four of the villages remain unexplained – and may be due either to past burning or the establishment of IDP camps.

Figure 6 reveals that only a part of the scene has been interpreted. Not all observations have been verified against the change detection analysis. The interpretation in this study focussed along the main roads – some interpretation remains outstanding in the eastern and southern part of the image.

*Figure 6. Distribution of digitized villages and settlements. Green triangles denote no significant change; red dots denote significant change and yellow/black denote some change. Most villages and settlements that could be observed in the images have been digitized.*

Following interpretation, the consultant compared the satellite images with a detailed description of burnt villages in the study area produced by Human Rights Watch (HRW) in 2004. The HRW report described more than twenty villages, which were burnt in the Mornay area, which can be observed clearly in the satellite images (figure 7).

*Figure 7. The area of Mornay (referred to as Murnei in the satellite image) where a high concentration of burnt villages has been reported.*

## **Verification of the results**

The results have been verified from various sources, which are all in support of our findings.

USAID (2004) published on 24 June 2004 a satellite-derived map of burnt villages in Darfur. The general pattern of burnt villages is very similar although the methodology is different from methodology used in this study. USAID have used Quick Bird 2 data with 0.7 m resolution from where details of houses can be interpreted.

The recent HRW (2004) has given detailed information on areas and specific villages that have been burnt in the area covered. The HRW report highlighted more than twenty villages/settlements that had been burnt around the Mornay area. Our study found that nearly all satellite villages close to Mornay had strong indications of being burnt. In Sildi, south-east of al-Jeneina, thirty villages were attacked and burned in

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February 2004. This is another area where the image analysis has revealed that most villages show strong indications of being burnt. The names of two burned villages from the HRW report could be located in the satellite images with strong indications of being burnt.

Amnesty International has received information from undisclosed sources on a number of villages that have been burnt between Zalingei and Mornay. Indications uncovered from the satellite study confirm this.

### **Conclusion and discussion**

There is strong indication of widespread burning of villages in the area between Zalingei and Mornay. Landsat images indicate that 44% of the villages in the region were burnt between March 2003 and May 2004. There are some cases where it cannot be established if the changes are related to fire or some other reason. This uncertainty can be attributed to a number of factors, including limited disturbance/burning; the location of villages in larger bush fire areas; the occurrence of burning prior to March 2003; villages with diffuse shape e.g. along some of the large wadi banks; villages occurring in the malfunctioning area of the Landsat TM scanner and changes in spectral properties due to atmospheric conditions.

In terms of analysis, a visual inspection of the whole scene is necessary in order to register/digitize villages and to interpret the state by comparing two images and a change detection analysis. A potential short cut can be to create for example a 300 meter buffer around each village and then use a statistical measure from the change detection analyses. However no digital registration of the villages is available and potential artefacts (e.g. bush-fire scars) can produce errors. The criterion that more than 15 % decrease should occur within a village to determine a strong indication of burning appears to result in an underestimation of the area of actual burning and a statistical test should be performed in order to improve the method.

In spite of limitations, it is the consultants' impression that this type of analysis can be used to indicate the pattern and extent of village burning. Available verification sources support the result of this study, including a detailed verified mapping from USAID (2004).

Changes in water resources related to the present situation were not found. A number of villages in the south had some enlargement that could be related to establishment of IDP camps.

In this study the selection of images has been directed toward monitoring of burnt villages. Monitoring of IDP camps was not fully investigated due to lack of detailed information. It is likely that these can be spotted by the change detection, especially if they have been established in places where the background contrast differs from the materials the camps are build of.

It should be noted that the method used in the present study is only one example of the use of satellite data to trace evidence of a human rights and humanitarian crisis. Other examples could include monitoring of changes in crop pattern as an indication of presence of people, or locating IDP's by the heat from their nightly campfires

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