# Monitoring Land Degradation and Erosion Control Measures : Analysis of Multitemporal Satellite Data of the West African Sahel

***Kirsch-Jung, Karl P.*** and ***Kusserow, Hannelore***

Gesellschaft fuer Technische Zusammenarbeit - Freie Universitaet Berlin
E-mail: karl-peter.kirsch-jung@gtz.de
E-mail: h.kusserow@nexgo.de

**Abstract**: Long-term analysis of ecological changes are possible on the basis of data from the earth observation systems Landsat (since 1972) and SPOT (since 1986). This potential is used to monitor desertification processes as well as to investigate the success of erosion control measures.

Standard methods of remote sensing and the merge of multispectral bands of SPOT XS/XI with the panchromatic SPOT-PAN to increase the spatial resolution from 20m to 10m, as well as visual interpretation techniques allowed the identification of the erosion control measures.

The results of the analysis of the multitemporal satellite data are presented in thematic maps showing the functionally classified changes in soil cover over time and allow to identify areas where soil and water conservation measures have effectively been established.

By the help of SPOT based satellite data it could be demonstrated that the impact of erosion control measures leads to a remarkable increase in agriculture and woody vegetation, whereas only a small increase in vegetation outside of the erosion control measures indicate the problem of revegetation mainly due to the existence of sealed and crusted soils. Additional analysis based on Landsat data demonstrate the development of the region since 1975. The woody vegetation density on the lateritic plateaus in 1975 was in spite of the drought of the early seventies even better than in 1988/1989. Due to the establishment of soil and water conservation measures since the beginning of the nineties sealed surfaces could be revegetated and their extension documented and quantified.

Based on time series of earth observation satellites the evolution of desertification processes as well as the success of combatting these processes are well documentable.

**Keywords**: desertification, soil and water conservation, satellite imagery interpretation, erosion control measures-Niger

## 1 Introduction

Long-term analysis of ecological changes of more than 25 years are possible on the basis of data from the earth observation systems Landsat which is working since 1972 and SPOT, working since 1986. This is of particular interest in the West African Sahel region, where the droughts of the seventies and eighties increased desertification processes. Land degradation is widespread and do occur as water erosion, wind erosion, physical degradation (surface crusting) and chemical degradation (soil mining). Resulting changes in soil cover since the drought years of the seventies until today have been monitored by interpreting time series of Landsat and SPOT data of the Sahel of Niger.

At the same time technical and financial co-operation programmes are underway to combat desertification. The technical measures for soil and water conservation comprise stone rows, small stone walls and banquettes (used for the top and the slopes of the plateaus and in the valleys), various types of planting holes (e.g. “tassa”, “demi-lune”) and small dams. The biological rehabilitation of the degraded surfaces includes the planting of trees and shrubs as well as grasses and herbs. Soil and water conservation activities co-financed by the German Federal Ministry for Economic Co-operation and Development have been evaluated after ten years of applying techniques for rehabilitating degraded soils (KIRSCH-JUNG 2000). Since 1989, a total of 277.000 ha of agricultural and sylvo-pastoral land have been treated by two projects, jointly implemented by the “Gesellschaft fuer Technische Zusammenarbeit” (GTZ) and the “Kreditanstalt fuer den Wiederaufbau” (KfW).

The objectives in this multitemporal study were (1) to document and quantify the success of soil and water conservation measures and (2) to indicate and quantify areas which are still exposed to desertification and need to be treated in future. The results of one reseach site situated approximately 25 km east of Tahoua in the southwestern part of Niger Republic are presented here.

## 2 Methods

Standard methods of remote sensing in combination with visual interpretation techniques were used to monitor the changes of the research area. The earth’s surface monitoring was carried out on the basis of satellite data (SPOT-XS and SPOT-PAN) from 1989 (first phase of the projects) and ten years later (KUSSEROW 2001). By using a special computer-based transformation, the multispectral bands of SPOT XS are merged with the panchromatic SPOT-PAN. This results in an increase in spatial resolution from 20 m to 10 m and allows the identification of the anti-erosive measures which are also marked by a denser woody vegetation cover. The results of the visual based interpretations of the images of 1989 and 1999 were transferred into an Arcinfo in order to quantify land cover changes between the two years.

Two ground checks were conducted in September 1999 and February 2000 to verify the satellite image interpretation in the field.

## 3 Results

The sections of the satellite images (Fig.1 and Fig.2) show the lateritic plateaus with woody vegetation cover and in the southern parts agricultural activity (mainly millet fields).

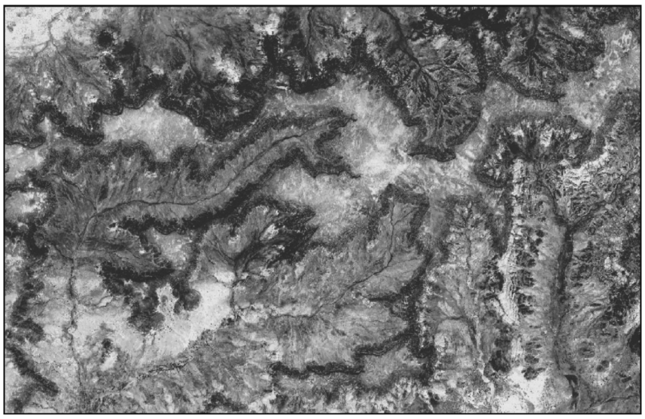

**Fig. 1** Part of a satellite scene (merge of SPOT XS, dated 1 September 1989 with SPOT PAN from the 31 January 1989)

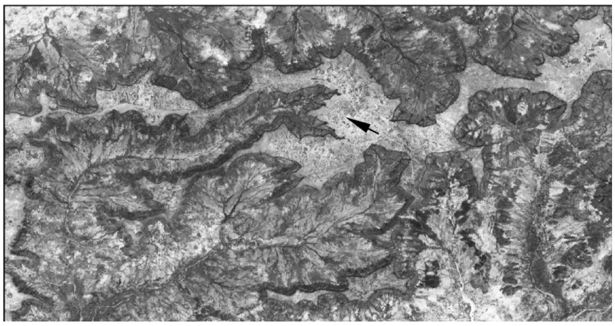

**Fig. 2** Part of a satellite scene (merge of SPOT XI and SPOT PAN dated 2 October 1999; scale)

The research area covers approximately 18 km in east-west direction. Vegetation is presented in red, lateritic plateaus in green, rivers in blue and sandy areas in yellow. The slopes can be recognised by their dark brown colour. In 1989 (Fig.1) agricultural activity is not very well established in the valleys. In the middle of the main plateau the initial stages of the soil and water conservation measures (banquettes) are recognisable as a line-shaped structure. The image from 1999 (Fig.2) demonstrates the changes. The main plateau is now covered by clearly visible conservation measures (banquettes). The pale colours on the plateau indicate dry herbs. A further impact during the past ten years observable in the valleys is a significant increase in agriculture. Dense vegetation cover underlines the impact of the project in some parts (e.g. left corner) of the slopes. First signs of the sustainability of the anti-erosive measures could be observed in the right edge of the image. There has been an increase of herbaceous vegetation cover but not all project areas seem to be revegetated.

The final map (Fig. 3) is the result of the Arcinfo based intersection in order to quantify land cover changes between 1989 and 1999. It shows surfaces covered by soil and water conservation measures, increases in vegetation and agriculture as well as areas which are still exposed to desertification (decrease in vegetation and agriculture). For the region under study (12,194 hectares) the anti-erosive measures cover 3,024 ha (24.8%; plateau: 16.1%, slopes: 6.9%, valley: 1.8%). Since 1989, cultivated areas in the valleys increased by 7.4% (902 hectares) on sandy soils and by 4.4% (540 hectares) on lateritic soils. There was an increase in vegetation over 1.3% (162 hectares) of the area. This small increase of the vegetation (mainly pioneers like members of the family Combretaceen) outside of the conservation measures indicate the problem of revegetation, mainly due to the existing of sealed and crusted soils.

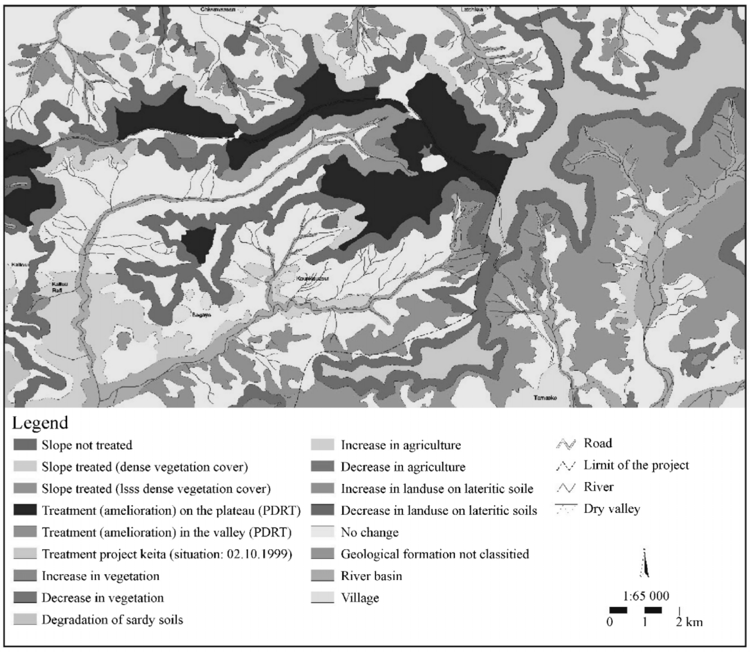


**Fig. 3** Map of the natural resources management practices, increase in vegetation and agriculture and identification of areas exposed to desertification

A decrease in agriculture and vegetation is with less than 2% neclectable. 59.3% (7,227 hectares) of the area presents no change, no differentiation is made between agriculture and vegetation. The total balance presents the success of the project. The area treated by the project together with the increase in vegetation and agriculture amounts to 37.8%. The decrease in vegetation, agriculture and in sandy soils is documented for 2.6% of the region under study.

## 4 Discussion

The key results of the time-series monitoring based on satellite data for selected areas are:

(1) the Spot based monitoring dealing with the impact of erosion control measures demonstrate clearly that the anti-erosion works themselves (stone bunds, trenches and semi-circles) are not always easy to identify on satellite imagery, but it is possible to monitor erosion control measures by vegetation density. The age of the measures is hereby of no significance.

(2) The surfaces of the plateaus which were degraded in 1989 and which have not been treated remain degraded also in 1999. The relatively higher rainfall (in the 1990s) leads to an improvement in the state of vegetation only on sandy soils (valley bottoms and sandy layers on plateaus), but not on laterite soils which are often characterised by crusted surfaces. Despite the increase in rainfall no regeneration of lateritic plateau surfaces is discernible.

(3) The extent of erosions control measures can be quantified and it is possible to identify the impact in surrounding areas not necessarily supported and monitored by projects but in which population took up measures on their own. Regions still under threat from desertification are also well recognisable. This information is of great importance for further project planning.

New results (KUSSEROW 2002) from investigating Landsat MSS (15 October 1975), TM (18 October 1988) and ETM (3 October 2000) demonstrate for a bigger section (30 km×30 km) of the research site mentioned above, that in 1975 the woody vegetation density on the lateritic plateaus was even better than in 1988. A comparison of the seventies and eighties with 2000, also conducted for other regions in Niger confirm the findings. In addition, it could be stated that the ecosystem’s ability to recover was better between the seventies and the late eighties (including two serious drought periods), than between 1989 and 2000, although the nineties were characterised by relatively higher rainfall. That can be put down to the facts of increase in population and soil crusting/soil sealing processes.

In total vegetation decrease could be stated with only 6% between 1975 and 2000 for the region under study. The other research regions tested in the western and eastern parts of Niger present between 27% and 39% loss in vegetation cover. The project’s input reduces the loss in vegetation and leads to an increase in agriculture up to 24% (17.263 ha).

In addition to that the comparison with satellite data of the early 1970s (example Mali, Niger KUSSEROW 2000) demonstrate, that areas formerly covered by dense vegetation are now characterised by crusted soil types (HAHN & KUSSEROW 1998). Investigations of different areas by the support of multitemporal and multiseasonal satellite data demonstrate that the phenomenon of soil sealing and soil crusting in some areas is even well developed before the 1970s drought. Other regions show an remarkable increase of crusted areas after the 1980s drought. Of interest is that, even under the relatively higher annual precipitation rates during the 1990s, the process of land degradation is still ongoing.

Summing up: Time series of earth observation satellite data provide information on land surface changes. Based on these data, the process and the extension of land degradation is well documentable. It could be also proved that erosion control measures are an effective instrument in combating desertification.

## References

HAHN, A., H. KUSSEROW. 1998. Spatial and temporal distribution of algae in soil crusts in the Sahel of W Africa: Preliminary results. Willdenowia, vol. **28**: p.227-238.

KIRSCH-JUNG, K.-P. 2000. Impact Monitoring and Evaluation at project level: experiences and lessons learnt from GTZ-projects with special focus on the UNCCD. Paper presented at the side event “Process Monitoring, Impact Indicators and Evaluation for Action Programmes to Combat Desertification”, UNCCD COP 4, Bonn.

KUSSEROW, H. 2000. Suivi des ressources naturelles. Etude d’indicateurs de la désertification à partir de l’imagerie satellitale. Observatoire du Sahara et du Sahel, Rosseels, Belgium, p.33.

KUSSEROW, H. 2001. Lutte contre la désertification au Niger: utilisation des images pour le suivi d'impact. Cas de PASP et PDRT. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), TZ Verlagsgesellschaft Roßdorf, p.50.

KUSSEROW, H. 2002. Etude du devéloppement à long terme de la zone pastorale et des zones avoisinantes au Niger entre 1970 et 2000. Rapport final, GTZ, p.49. Annex I: p.43., Annex II: p.63.