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THE USE OF SPOT IMAGES FOR THE ASSESSMENT AND MAPPING OF GEOMORPHOLOGY AND LAND DEGRADATION BY SAVANISATION IN A WET-AND-DRY TROPICAL FORESTED ENVIRONMENT (LUBUMBASHI, SHABA, ZAIRE) (****)

Abstract: DE DAPPER M., GOOSSENS R. & ONGENA T., *The use of Spot images for the assessment and mapping of geomorphology and land degradation by savanisation in a wet-and-dry tropical forested environment (Lubumbashi, Shaba, Zaire).*

Digital SPOT image processing, combined with conventional panchromatic B&W airphoto interpretation and field observations, is used to survey and map geomorphological phenomena and land degradation by savanisation in the Lubumbashi area (Shaba, Zaire), a typical wet-and-dry tropical forested environment. The digital treatment includes LAI and biomass calculations, box classification, mask techniques and image stretching.

KEY WORDS: Aerial photo interpretation, Spot, Soil drainage detection, Land degradation, S. Zaire.

Riassunto: DE DAPPER M., GOOSSENS R. & ONGENA T., *L'uso delle immagini Spot per la cartografia geomorfologica e la valutazione della degradazione del suolo indotta da savanizzazione in un ambiente di foresta tropicale a stagione umida e secca (Lubumbashi, Shaba, Zaire).*

L'elaborazione digitale delle immagini SPOT, combinata con l'interpretazione di foto aeree convenzionali pancromatiche B&N, e con osservazioni di campagna, sono state utilizzate per rilevare e cartografare i fenomeni geomorfologici e la degradazione del suolo indotta da savanizzazione nella zona di Lubumbashi (Shara, Zaire), un tipico ambiente di foresta tropicale caratterizzato da un'alternanza di periodi aridi e piovosi. L'elaborazione digitale comprende calcoli di biomassa e di indice di superficie foliare (LAI), classificazione «a scatola», e tecniche di miglioramento del contrasto e di mascheramento delle immagini.

TERMINI CHIAVE: Fotointerpretazione, SPOT, Difesa del suolo, Degradazione del territorio, Sud Zaire.

INTRODUCTION AND MATERIALS

The aim of this paper is to explore the possibilities of SPOT-imagery to detect geomorphological phenomena and land degradation by savanisation in a typical wet-and-dry tropical forested environment. To achieve that goal, investigations are done on a digital SPOT-image covering about 3,600 km² in the Lubumbashi area of southern Shaba (Zaire) and dated 04 June 1986 (124-373). The satellite data are compared with field observations and with interpretations of conventional panchromatic B&W aerial pictures on scale 1/40,000 and dated 13 and 19 May 1954 (E'ville 2629-2636 and 2528-2536).

Lubumbashi is the capital of Shaba province and a booming town; its population quadrupled from 133,017 inhabitants in 1954 to 553,510 inhabitants in 1984 (WILMET & SOYER, 1982; SOYER & WILMET, 1983; LOOTENS DE MUYNCK, 1985). MALAISSE & *alii* (1980) estimated the annual deforestation caused by the Lubumbashi population's need for charcoal at 140 km² in 1980. According to SOYER & ALEXANDRE (1987) a subcircular area of 1,700 km² around Lubumbashi was already affected by deforestation in 1985.

To avoid the expansion of the human influence during the time gap between the taking up of the aerial pictures and the satellite image as much as possible, a remote test area covering 250 km² is chosen. It is part of the basin of the Upper Kifumanzi and located at some 40 km to the NNE of Lubumbashi, quite far from the railway and the road to Kolwezi and from the road to Kasenga.

ENVIRONMENTAL SETTINGS

The Kifumanzi River is an affluent of subsequently the

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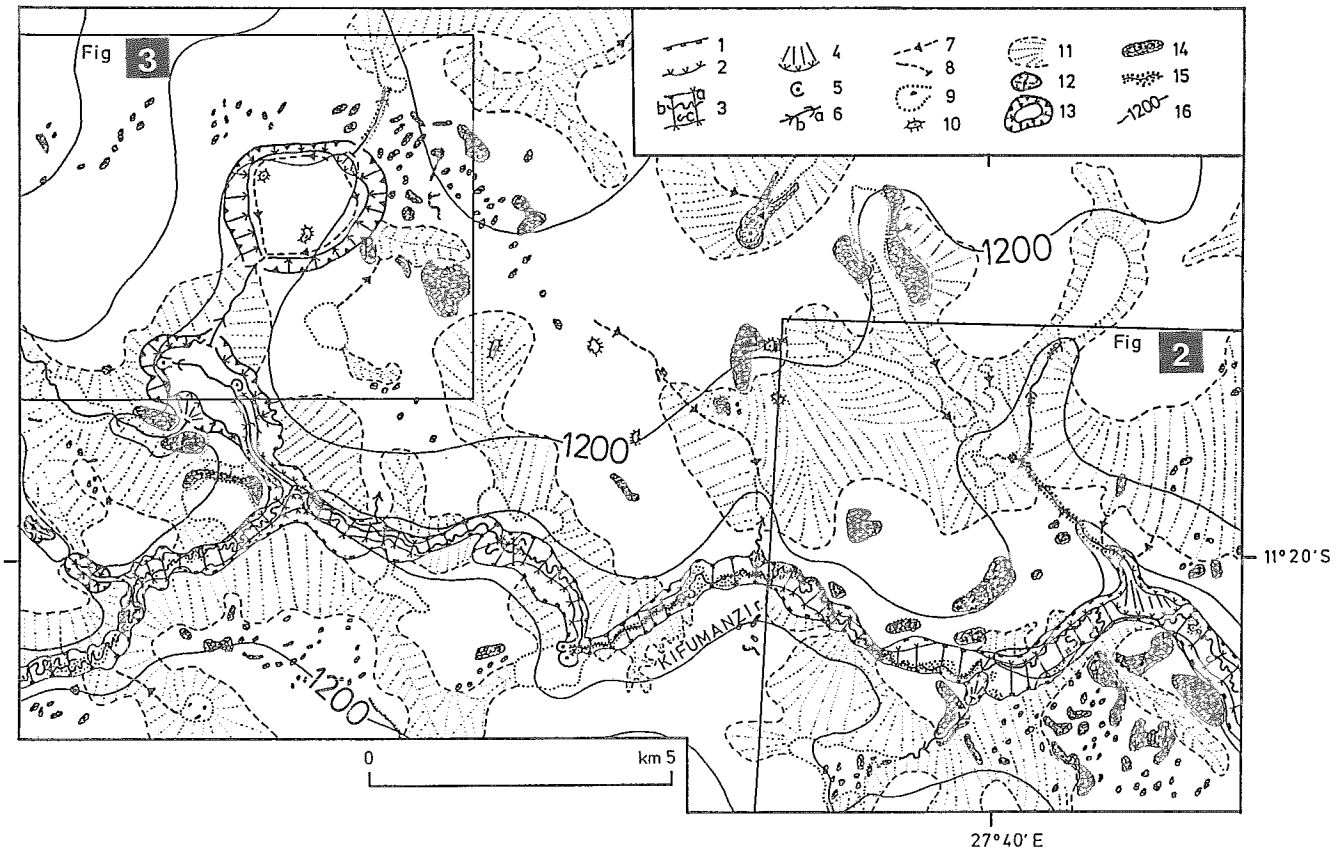

FIG. 1 - Morphographic map of the Upper Kifumanzi testarea. Based on conventional panchromatic B&W aerial pictures on scale 1/40,000 (May 1954). The location of figures 2 & 3 is indicated.
Legend:
1. break of slope at topconvexity
2. base concavity
3. valley flat-bottom: a. floodplain width, b. riverchannel, c. abandoned meander (oxbow)
4. alluvial fan
5. spring amphitheater
6. valley side tributary with: a. arch-like cross-section, b. wing-like cross-section
7. shallow channel in interfluve
8. vanishment of channel
9. dambo, eventually with pan(s)
10. pan, eventually with central depression
11. wash zone
12. isolated low hill
13. dolina
14. dense dry forest (muhulu)
15. riparian dense forest (mushitu)
16. contour line; contour interval: 25 meters.

Luiswishi and the Kafubu. The latter is drained by the Luapula River, belonging to the upper reaches of the Zaire. The Upper-Kifumanzi is developed on the watershed between the Luapula and the Lufira Rivers. On that watershed, situated at an altitude of about 1,250 m a.m.s.l., the features of the vast End-Tertiary planation surface are well preserved. The terrain slopes very gently (less than 1%) and is underlain by deeply weathered sedimentary rocks of the Katanga-system (Upper Precambrian), subdivided in the Roan and the Kundelungu formations (BEUGNIES, 1950; LEPERSONNE, 1974). Part of these deposits have been mineralized (copper, cobalt, zinc); they have been mined in numerous small excavations (f.i. Kinsevere in the testarea) and are actually extracted at the important underground mine of Kipushi. The testarea is situated in the eastward reach of the folded Katanga arc, wherein the stratigraphic units are arranged in a suite of parallel anticlines and synclines. The flanks of the anticlines are mainly composed of sandstone, conglomerate or quartzite and support some inselbergs (SOYER & KAKISINGI, 1981); only one such inselberg, small but well isolated, is present at the western boundary of the testarea (fig. 1).

The Roan formation, largely composed of limestones, dolomites and dolomitized rocks, occasionally crops out in the cores of the anticlines. This is the case in the western part of the testarea and gives rise to three well developed dolinas (figg. 1 and 3).

The macroclimate of the Lubumbashi region is characterized by a wet season (November to March), a dry season (May to September) and two transitory months (October and

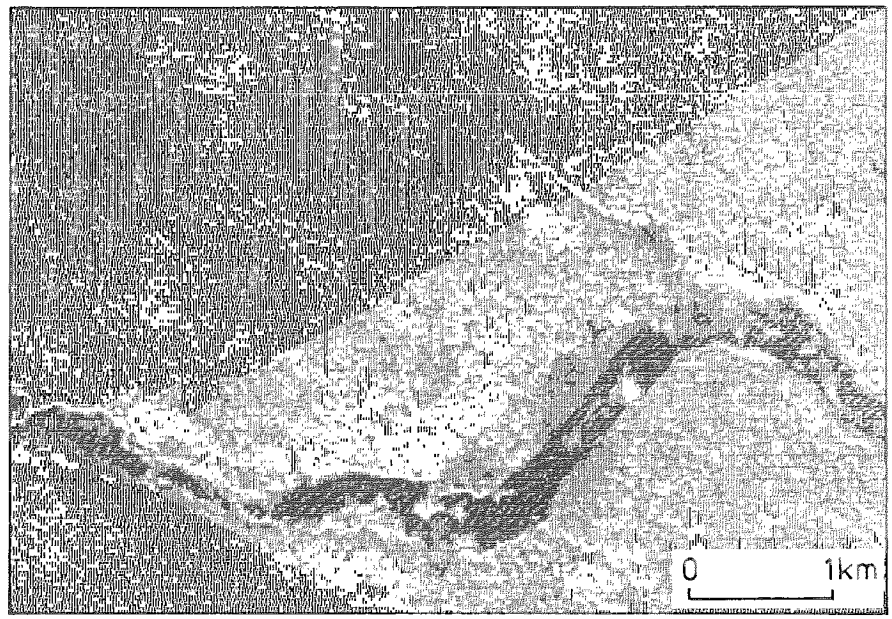

FIG. 2 - B&W outprint of part of the digital SPOT image, indicating biomass indices. The location is indicated on the morphographic map (fig. 1, southeastern part). *(Copyright SPOT, CNES, DPWB).*

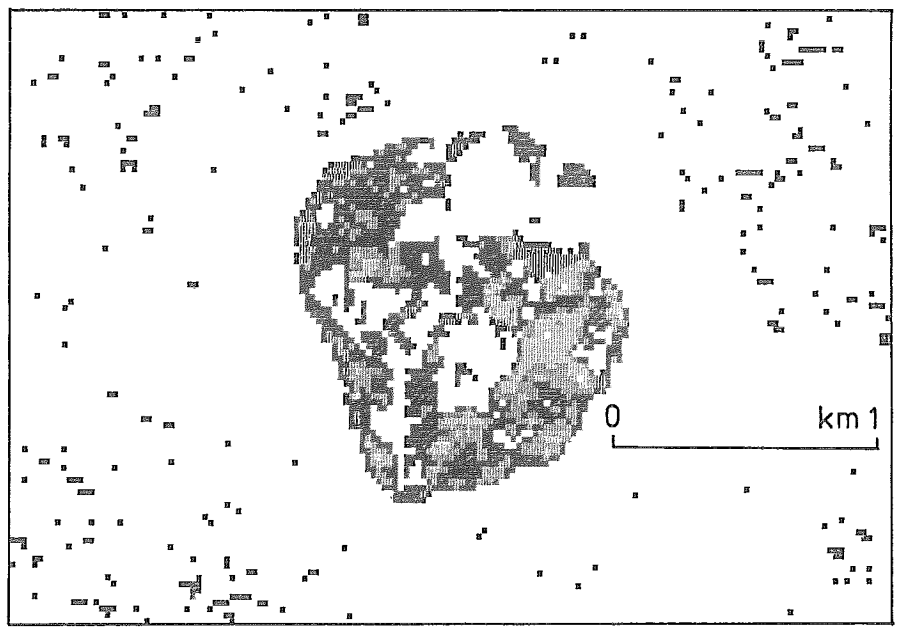

FIG. 3 - B&W outprint of part of the digital SPOT image, indicating soil drainage conditions. The location is indicated on the morphographic map (fig. 1, northwestern part).
Legend:
— light gray: seepage zones
— dark gray & black: poorly drained soils
— white: well drained soils.
(Copyright SPOT, CNES, DPWR).

April). The mean annual precipitation amounts to about 1,270 mm (MALAISSE & *alii*, 1978), although there is a considerable annual variability (extreme values of 717 and 1770 mm, according to LOOTENS & KISHIMBI (1986)). Thus the aerial pictures and the satellite image were taken at the onset of the dry season. The mean annual temperature is ca. 20°C; the coolest month is July (15.6°C), the warmest month is October (23°C).

Well documented data on the vegetation are available for the Luiswishi experimental station, located at 18 km to the S of the testarea (MALAISSE, 1978). The overruling vegetation formation is the *miombo*, an open dry forest dominated by *Brachystegia - Jubelnardia - Isoberlinia*. According to MALAISSE (1978), the miombo is a degeneration phase of the *muhulu*, a dense dry forest that forms the climax vegetation formation. Numerous small islands of muhulu still remain in the miombo (fig. 1). The miombo itself is degraded, mainly by direct human influence, into a wooded savanna. Large termite mounds (8 m high, 14-15 m basal diameter) occur throughout the basin, 3 to 5 mounds per ha (SYS, 1961).

The testarea shows the typical geomorphological buildup of the region (figg. 1, 2 and 3) (DE DAPPER, 1981 & 1985). The Kifumanzi River flows in a flat-bottom valley. The channel, eventually lined by riparian dense forest

(*mushitu*) developed on its banks, meanders in a broad floodplain covered by marshland with *Phragmites mauritianus*; some abandoned meander loops subsist. The valley sides are only a few meters high and are sharply limited by a break of slope, often sustained by a ferricrete layer, at the top convexity. The valley side tributaries are cut in the very gently sloping interfluve and show arch-like or wing-like cross-sections. In some cases they are fed by springs that develop amphitheaters. They form well developed alluvial fans where debouching into the main valley. On the interfluves denudation overrules incision. The headward extension of the tributaries is formed by shallow hardly incised channels and in many cases by typical headwater dambos: shallow broad channelless depressions covered by a grass vegetation with *typha* (THOMAS & GOUDIE, 1985; LOOTENS & KISHIMBI, 1986). In some cases river dambos are developed directly on the sides of the main valley. Some small closed pans are developed in the dambos or close to them. Large wash zones are developed on the interfluves; they extend mainly around the dambos but can also connect directly with the main valley. In the wash zones the miombo is degraded and sheet- and rill erosion predominate.

TREATMENT AND RESULTS OF THE SPOT-DATA

1. DIGITAL TREATMENT

The SPOT satellite digital image is treated on an IBM PC/AT using IBM-PCIPS and own developed software. Different image processing methods are used, such as LAI (Leaf Area Index) and biomass (RICHARDSON & WIEGAND, 1977), multispectral boxclassification (CURRAN, 1985), mask techniques, image stretching (TOWNSHEND, 1981).

2. IMAGE INTERPRETATION AND DISCUSSION

a. *Detection of savanisation by vegetation density assessment*

To assess the vegetation density, the LAI and biomass methods are applied. The best results are obtained with the biomass method. The floodplain of the Kifumanzi, holds the photosynthetically most active vegetation. Miombo-muhulu and mushitu are grouped in one class. They can only be separated by their specific geomorphological position in the landscape; miombo-muhulu shows a dotted pattern and is present on the interfluves; whereas mushitu shows an elongated pattern lining river channels. The interfluves are characterized by a medium dense vegetation cover. Zones with sparse vegetation are located on the valley sides of the main river, around dambos and in wash zones. Alluvial fans, which represent highly morphodynamic environments, are also characterized by low biomass indices (figg. 1 and 2).

The boxclassification method combined with a mask technique allows to distinguish following classes in the northwestern part of the testarea (fig. 1) (tab. 1):

(1) non classified
(2) miombo
(3) wash zone
(4) wet soils in dolina bottom
(5) confusion zone: zones endangered by denudational erosion
(6) muhulu and mushitu (by mask technique)
(7) confusion zone: non identified.

Class 5 represents a confusion zone of the boxes 'miombo' and 'wash zone'. On the ground it coincides with areas marginal to the wash zones and spreading into the miombo. Also from the spectral point of view, class 5 holds the middle between miombo and wash zones. In this way it is possible to detect those transitional, endangered zones in an early stage. In this case respectively nearly 5% and 3% of the investigated area is respectively dominated or endangered by denudational erosion. The zones endangered by erosion are located near the top convexity of the valley sides and the dolinas as well as around dambos. One may expect those wash zones to enlarge to the detriment of the surrounding miombo.

Class 6 is extracted from band 2 by using a mask technique between pixel intensity values 16 and 19. This mask was superimposed on the image of the boxclassification.

TABLE 1 - BOXCLASSIFICATION FOR VEGETATION DENSITY TYPES IN THE NORTHWESTERN PART OF THE TESTAREA

Class	Box limits			N° Pixels	Percent	Surface (ha)
	B1	B2	B3			
1				3344	5.26	133.76
2	27-31	18-24	38-51	51418	80.34	2056.72
3	29-38	23-30	47-62	3098	4.84	123.92
4	28-32	20-24	30-39	1361	2.13	54.44
5	29-32	23-24	47-51	1786	2.79	71.44
6		16-19		1819	2.84	72.76
7				1174	1.83	46.96
sum				64000	100.00	2560.00

Classified : 92.94%
Non-classified : 5.26%
Confusion : 1.83%

b. *Detection of microrelief by assessment of soil drainage conditions*

A mask technique and a linear stretch method, allows to make an assessment of soil drainage conditions in the bottom of a dolina in the northwestern part of the test area and in the flat valley floor of the main Kifumanzi river in the southeastern part of the test area (fig. 1).

The flat dolina-bottom shows a pronounced microrelief that gives rise to outspoken differences in soil drainage. The mask technique allows to extract the wet soils, included in the pixel intensity values interval 31-39, from the IR-band. According to KRINOV (1947), bare soils are more absorbing and less reflecting, the higher their moisture content is. A linear stretch subsequently applied on the same pixel intensity value interval leads to a maximal contrast on minimal spectral reflection differences (GOOSSENS & VAN CAMP, 1987).

Figure 3 shows the results of the linear stretch applied on the dolina bottom. On the northern side an alluvial fan is developed. Channel water entering the fan, seeps at the lower edge and gives there rise to very poorly drained soils. The higher parts of the dolina bottom, colonized by grasses and low shrub, represent well drained soils, whereas the rest of the bottom soils are poorly drained.

The flat bottom of the Kifumanzi River is characterized by local differences in soil drainage conditions. These differences can be detected on SPOT band 3, while the detection is doubtful on the bands 2 and 1. Pixel intensity value profiles crossing the flat bottom clearly show reflection differences which can be correlated with microrelief phenomena giving rise to different soil drainage conditions.

Abandoned meanders clearly show less infrared reflection as compared with the surrounding flood plain. This is due to the higher water content of these soils, caused by their higher clay content and persistency of water bodies after the wet season overbank floods.

CONCLUSIONS

Digital SPOT image processing, combined with conventional panchromatic B&W airphoto interpretation and field observations, is an efficient method to survey and map geomorphological phenomena and landdegradation by savanisation in a tropical wet-and-dry forested environment. B&W airphotos allow for stereoscopical vision (and thus replace the rare and very expensive stereoscopical SPOT data), whereas SPOT-images provide wider spectral information and a more comprehensive overview.

If applied in a multitemporal sequence, the method used permits to survey the evolution of vast areas endangered by denudational erosion. Those zones spread out from established wash zones and profilerate to the detriment of the miombo forest; their progress is a measure for the savanisation, an important land degradation process in the miombo environment.

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