MONITORING SOIL EROSION AND LAND-USE CHANGE IN NATAL USING REMOTE SENSING WITH SPECIAL REFERENCE TO THE MFOLOZI CATCHMENT

by ULRICH LOOSER

ABSTRACT

Part I: Pre- and post-Domoina flood LANDSAT images were interpreted visually to detect sediment source areas and to estimate the damages related to the Domoina flood, especially on the Mfolozi Flats.

Part II: Aerial photography from 1960 and 1984 was used to look at changes in land-use over a 24 year period in three sample areas in the Mfolozi catchment.

1. Introduction

During the time period 30 January to 2 February 1984, the tropical cyclone Domoina hit the northern part of Natal. Heavy floods caused extensive damage, especially in the Mfolozi catchment. To estimate the damages and to detect sediment source areas, pre- and post- Domoina flood LANDSAT images were visually interpreted.

Aerial photography from 1960 and 1984 was evaluated for three sample areas in the Mfolozi catchment in order to monitor changes in land-use and the changes brought about by cyclone Domoina.

This paper gives a detailed description of these evaluations. The sample areas are indicated on Map 1.

2.1. Interpretation of Landsat Images

1. Black Mfolozi catchment above the weir W2M06. The position of the gauging station is S28°04', E31°33'.

2. Mfolozi catchment east of longitude 31°50'E.

The following LANDSAT images at the scale of 1:250000 were used:

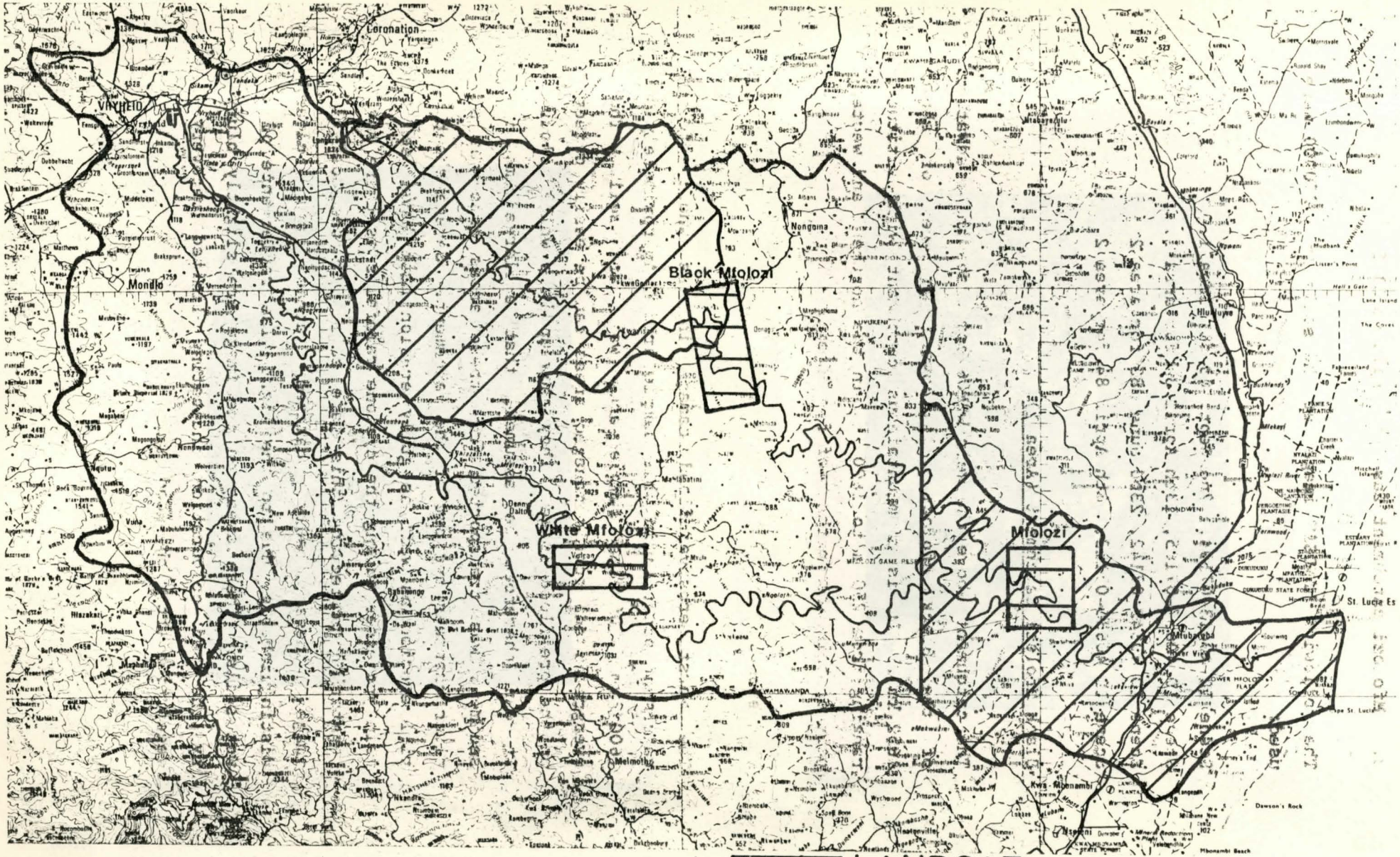
Scene ID 40413-07194, 2nd Sept. 83 for area 1.
Scene ID 40637-07165, 13th April 84 for area 1.
Scene ID 40342-07142, 23rd June 83 for area 2.
Scene ID 40630-07113, 6th April 84 for area 2.

2.2. Black Mfolozi Catchment (Area 1)

The catchment above the weir W2M06 comprises the headwaters of the Black Mfolozi. It covers an area of about 1652 km^2. It is a mountainous catchment with altitudes ranging from 250 m to 1600 m. In the northern and western part of this area patches of forest exist.

2.2.1 Land erosion

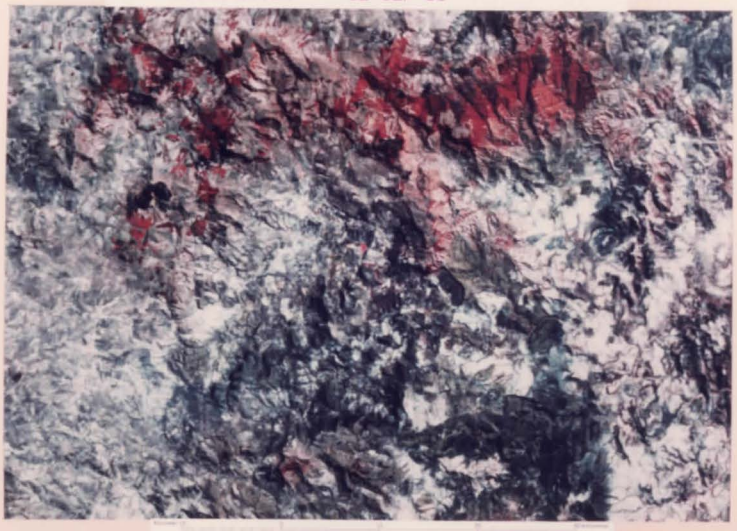
The worst erosive flood damage in the whole Mfolozi catchment occurred in this sample area. Approximately 36% (600 km^2) of the sample area was bare soil. These overgrazed and poorly managed areas can be easily detected on the pre-flood image. They show up in a white colour. It can therefore be assumed, that a large amount of sediment was transported from these areas into the main river channels and out of the catchment. Severe sheet and rill erosion as well as gully erosion must have been the main processes during the cyclone rainfalls as there was no vegetation protecting this bare soil. On the post-flood image these badly damaged areas are clearly distinguishable, due to the light blue reflectance of the wet soils. These areas on the image are slightly blurred by the red colouration indicating limited recovery of vegetation after the good rains.


Coronation
VRYHEID
Mondlo
Nongoma
Black Mfolozi
White Mfolozi
Mfolozi
Hlazakazi
Mpuluzi
Melmoth
Kwa-Mbonambi
Nseleni
St. Lucia Es
Dawson's Rock
Mbonambi Beach
0 10 20 30 km
LANDSAT
Aerial photography

Map 1

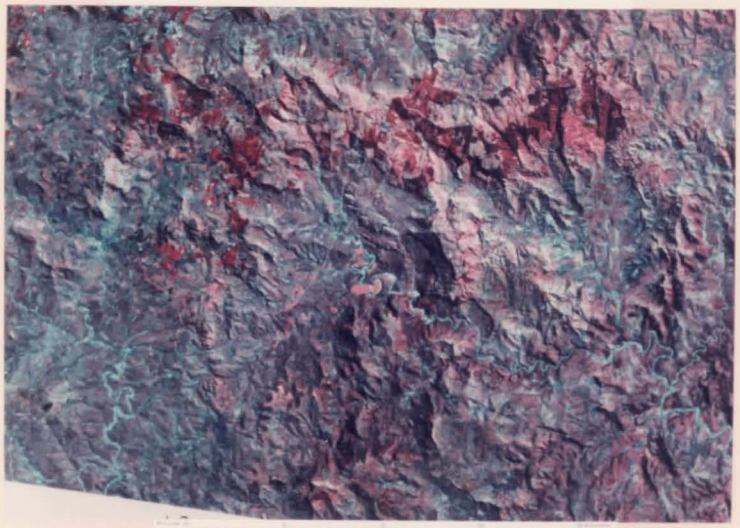
BLACK MFOLOZI CATCHMENT ABOVE WEIR W2M06

40413-07194 02 SEP 83



BLACK MFOLOZI CATCHMENT ABOVE WEIR W2M06

40837-07165 13 APR 84



2.2.2 Widening of river channels

It can be clearly seen that river channel widening occurred from the watershed to the Mfolozi flood plain. The gradients of the rivers in this area are steep, therefore floods which had a very high erosive power necessary for streambank erosion and channel deepening had the potential to significantly alter channel geometry. As a result the river channels are all well defined on the post-flood image in comparison to the pre-flood image.

2.2.3 Sediment deposits in river channels and on cultivated areas.

Sedimentation occurred in the river channel, especially on the inside of river bends and where the river flooded flat areas next to the channel. Thus sedimentation mainly took place during the latter stages of the flood. However, these sediment deposits are probably negligible compared to the amount of sediment which was exported from the catchment. There is no clear indication of sediment deposition on cultivated areas.

2.2.4 Changes in riverine and irrigated vegetation.

Due to the widening of river channels and the flood waters breaking the river banks a large amount of riverine vegetation was washed away. Damage to irrigated vegetation was not observed.

2.2.5 Changes in vegetation cover over the catchment generally.

The post-flood image shows a clear recovery of the vegetation in the whole catchment. Only in the severely overgrazed and damaged areas (which are easily distinguishable on the pre-flood image) did poor vegetation recovery take place. Large areas of bare soil still remain. These appear as a light blue colour on the post-flood image.

2.3. Mfolozi Catchment (Area 2).

The Mfolozi catchment east of longitude 31°50'E covers an area of 1580 km^2. The western part consists of hilly land. The Mfolozi Game Reserve is situated west of the confluence of the White and Black Mfolozi. The eastern part consists of the Mfolozi flood plain and includes large cultivated areas. Large areas of afforestation also exist.

2.3.1 Land erosion

The white patches on the pre-flood image indicates that 19% (300 km^2) of that sample area is severely overgrazed and damaged. It can be assumed that the worst erosion occurred in this area.

2.3.2 Widening of river channels

Widening of river channels only took place in the western part of the catchment upstream of the Mfolozi flats. The well defined river channel on the post-flood image shows this clearly.

2.3.3 Sediment deposits in river channels and on cultivated areas.

A considerable amount of sedimentation took place in the Mfolozi flats. On the post-flood image approximately 110 km^2 of sediment deposition can be seen. These sediments cover one third (about 60 km^2) of the cultivated areas on the Mfolozi Flood Plain.

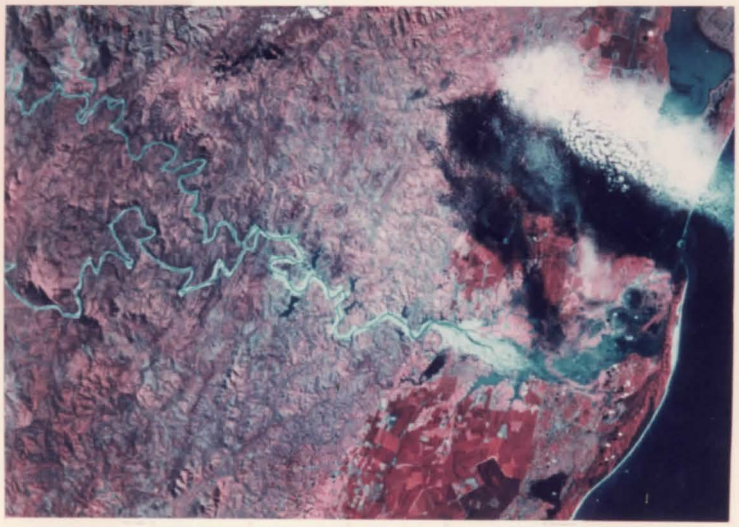
As the flood waters subsided sedimentation also occurred in the river channel downstream of the confluence of the White and Black Mfolozi. This is shown by the easily visible white areas adjacent to the river channel on the post-flood image.

MFOLOZI FLATS EAST OF 31-50 E

40342-07142 23 JUN 83

MFOLOZI FLATS EAST OF 31-50 E

40630-07113 06 APR 84



2.3.4 Changes in riverine and irrigated vegetation

A significant change in riverine and irrigated vegetation took place. The riverine vegetation was washed away on the banks of the White and Black Mfolozi. Downstream of the confluence of these rivers the riverine vegetation was buried under sediment deposits. Approximately 60 km^2 of irrigated land on the Mfolozi flood plain was also buried under sediment deposits. About 7,5 km^2 of irrigated lands were still standing under water on the 6th April, two months after the flood. Approximately 38% of the total cultivated area in the Mfolozi floodplain was destroyed by the Domoina flood.

2.3.5 Changes in the vegetation cover over the catchment generally.

Apart from the destroyed flood plain and the areas in the vicinity of the main river channels the vegetation appears to have recovered fairly well. However, large areas which were overgrazed and damaged by erosion still do not have the necessary vegetation cover to protect the soil from further erosive events.

3.1 Interpretation of aerial photographs

Three sample areas in the Mfolozi catchment were selected to study the changes in land use and erosion processes (see Map 1). The following aerial photos were used:

Job 442/60: April and June 1960 - 1:40 000
Job W302 : April 1984 - 1:10 000 (after Domoina)

For each of the three selected areas transparencies were made from the 1960 and 1984 aerial photos. These transparencies show the following features:

(a) Sedimentation: sediment deposits along the drainage channels.

(b) Cultivated area: ploughed-land only, unploughed pasture is not included.

(c) Forest and shrub: shrub and bushland with dense canopy.

(d) Water: lakes, dams and main river channels.

(e) Quarry: excavations for building material.

(f) Kraals and buildings.

(g) Roads.

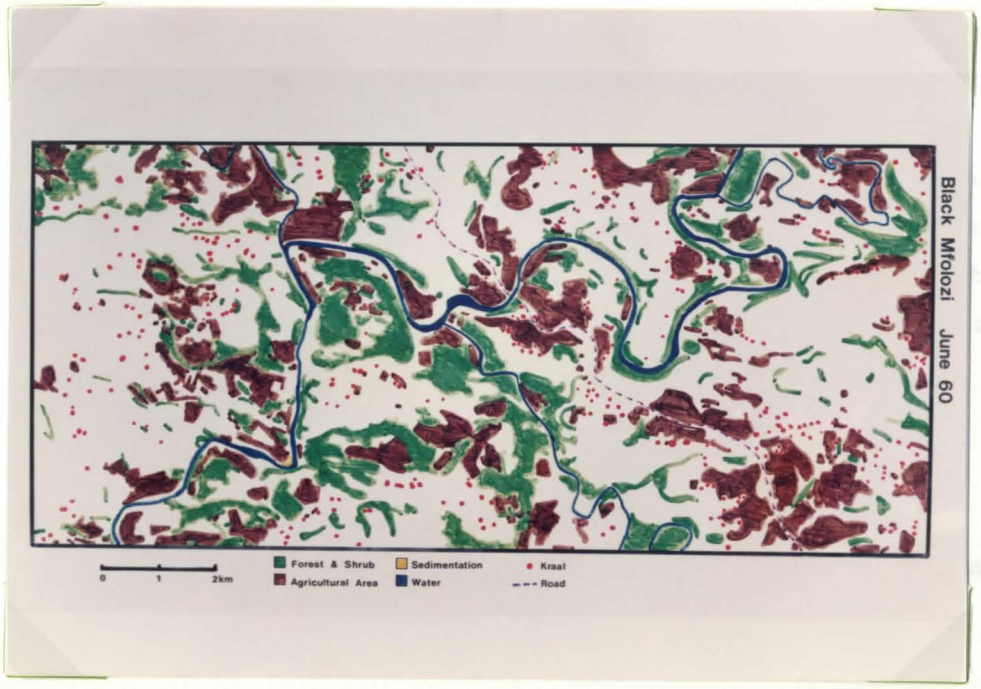
After drawing transparencies for the 1984 photos they were reduced to the scale of 1:40 000 for better comparison with the transparencies of the 1960 photos.

3.2 Black Mfolozi (Sample area 1)

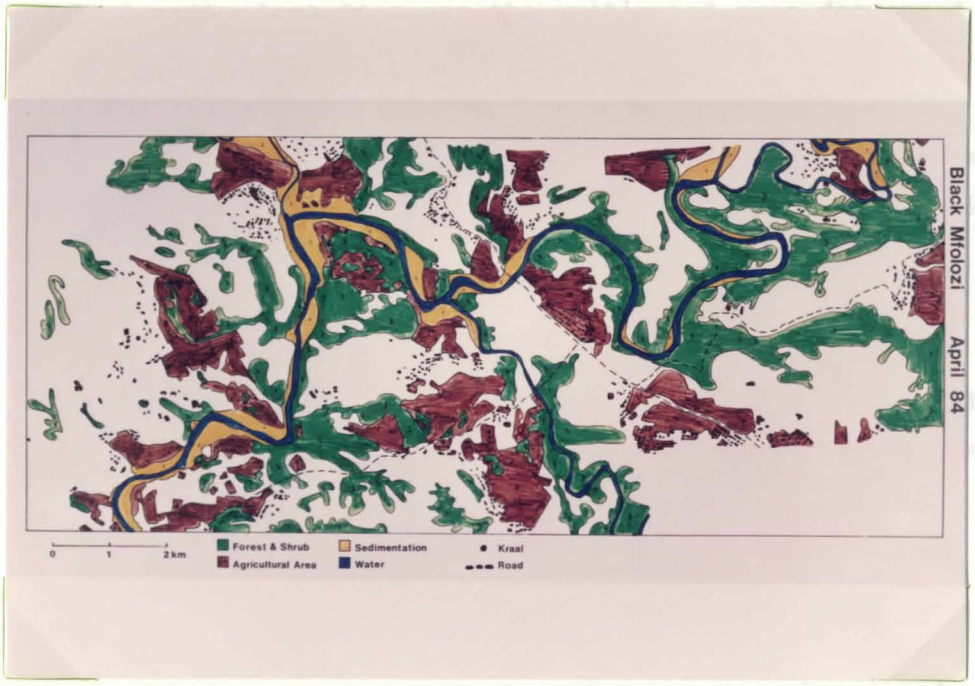
This 102 km^2 sample area is situated in KwaZulu. The main road from Mahlabatini to Nongoma crosses the sample area from the west to the north-east. The topography is hilly with altitudes ranging between approximately 200 m and 560 m.

3.2.1 Erosion and sedimentation

Evidence of extensive erosion can be observed on the 1984 photos. Sheet and rill erosion affected almost all the veld. In some cases even in shrublands these processes can be seen. Most probably erosion in these areas is triggered off by overgrazing.



Black Mfolozi JUNE 1960



Black Mfolozi APRIL 1984

Gully formation can be observed in virtually every small tributary, especially at the head of these small drainage channels. It seems that in this area a very large amount of sediment was transported from the catchment into the main river channel. However, the 1984 photos also show clearly that during the Domoina flood river channels deepened and widened. So the sediment transported out of the catchment has two origins, namely the catchment itself and secondly the main drainage channels.

The 1960 photos show almost no sediment deposits along the Black Mfolozi. This was significantly changed by the Domoina flood. On the 1984 photos approximately 278 ha of thin to medium sediment deposits can be observed along the main river channel, affecting a fairly large area of cultivated land. These sediments were deposited at the recession of the high flood waters, when the flood lost turbulence and velocity.

3.2.2 Cultivated areas

During the last 24 years the cultivated area decreased from 1 687 ha to 1 350 ha. However, on the 1984 photos approximately 230 ha of this cultivated area, along the Black Mfolozi, is covered with sediments or has been washed away. In addition to this there was a decrease of 6% in cultivated area.

Most of the cultivated area on the 1984 photos is in a generally good condition with only a few signs of sheet and rill erosion, except for the areas which had been directly affected by the flood along the Black Mfolozi.

3.2.3 Forest and shrubs

The area covered by shrub and trees has increased since 1960 by 6% to a total of 1 612 ha. Large parts of these areas are affected by erosion processes. In some of these

areas the spaces in between the trees are large and there is no grass cover due to overgrazing. Only few patches of dense growing trees can be found along the Black Mfolozi and some of the small tributaries.

3.2.4 Population and human activities

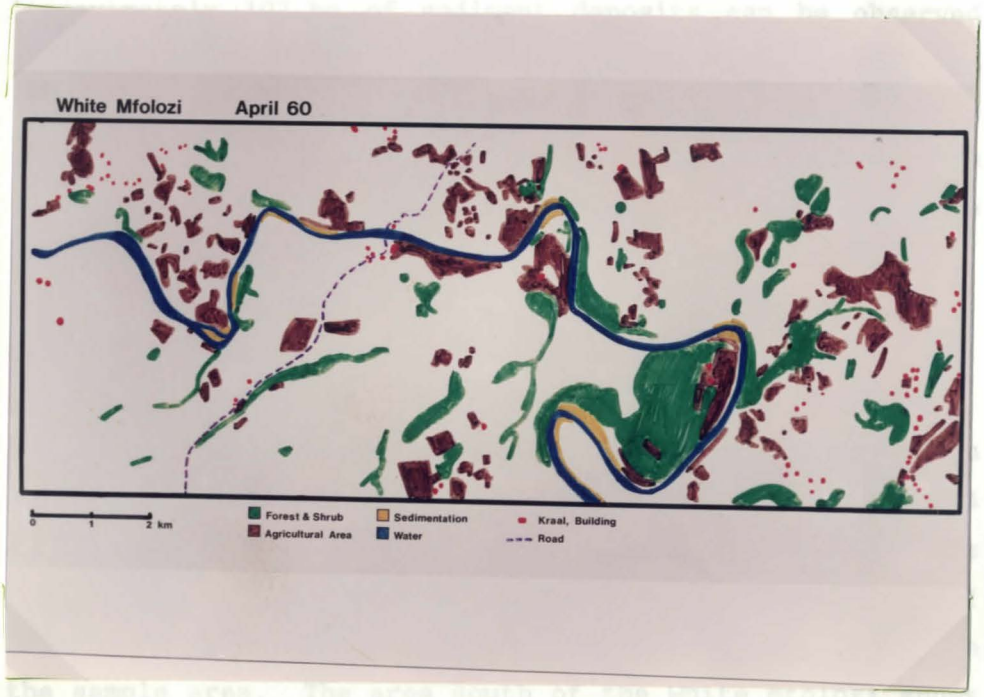
The population has increased significantly during the last 24 years. This can easily be seen by the increase in kraals from 300 in 1960 to 640 in 1984. There has also been a significant increase in roads, tracks, footpaths and cattle trails. These activities are contributing to erosion, increased run-off and sediment delivery.

3.3. White Mfolozi (Sample area 2)

The sample area is located in KwaZulu. The topography is hilly with altitudes varying between 410 m and 810 m. The convex slopes of the White Mfolozi river-valley are very steep with mostly a very dense vegetation cover. The main road from Melmoth to Mahlabatini crosses the 79 km^2 sample area from the south-west to the north-east.

3.3.1 Erosion and sedimentation

The 1984 photos show that in most of the veld and shrublands moderate sheet and rill erosion occurred. Only the land in the most southwestern part of the sample area and the surroundings of the new town of Ulundi are seriously affected by sheet and rill erosion. Overgrazing might be an explanation for the erosion damages on the southwestern part of the sample area, whereas the surroundings of Ulundi is criss-crossed with tracks and paths, which are responsible for the erosion damage. Also in this sample area, gullying can be observed on both the 1960 and 1984 photos along small tributaries and drainage channels. This back cutting and down wearing is responsible for a large sediment delivery to the main drainage channels.


White Mfolozi April 60
0 1 2 km
Forest & Shrub
Agricultural Area
Sedimentation
Water
Kraal, Building
Road


White Mfolozi April 84
0 1 2 km
Forest & Shrub
Agricultural Area
Sedimentation
Water
Quarry
Kraal, Building
Road

On the 1984 photos, river channel widening and deepening is visible along the whole course of the White Mfolozi.

Approximately 107 ha of sediment deposits can be observed on the 1984 photos along the White Mfolozi. Cultivated areas along the river banks of the White Mfolozi were affected. But the amount of sediment deposited during the retreat of the flood waters are negligible compared to the amount of sediments transported out of the catchment.

3.3.2 Cultivated areas

A decrease in cultivated area from 752 ha in 1960 to 295 ha in 1984 has occurred in the sample area during the last 24 years. Maybe the development of the new town of Ulundi is responsible for this phenomenon together with a shifting of the agricultural areas to more favourable regions outside the sample area. The area south of the White Mfolozi shows a significant decrease in cultivated area since 1960. This may indicate more extensive farming practices. Most of the cultivated areas that were abandoned since 1960 are now covered with shrub and trees.

3.3.3 Forests and shrubs

Due to the decrease of cultivated areas shrubland and bush increased significantly from 824 ha in 1960 to 1 765 ha in 1984. Even in the close vicinity of Ulundi an increase in area covered by shrub and bush can be noticed.

3.3.4 Population and human activities

The development of Ulundi is the most significant change during the last 24 years. The central function of Ulundi is responsible for a concentration of population limited to the town and three scattered settlement areas to the north. On the 1960 photos 65 kraals were found spread all over the sample area. Approximately 90 kraals can be

counted on the 1984 photos, but they are all concentrated in the already mentioned three settlement areas north of Ulundi. An increase in population in the KwaZulu area north of the White Mfolozi can therefore be clearly noticed, but with a totally different distribution pattern.

An increase in buildings on the area south of the White Mfolozi can be noticed, but most of the new buildings are associated with the construction of the tarred road.

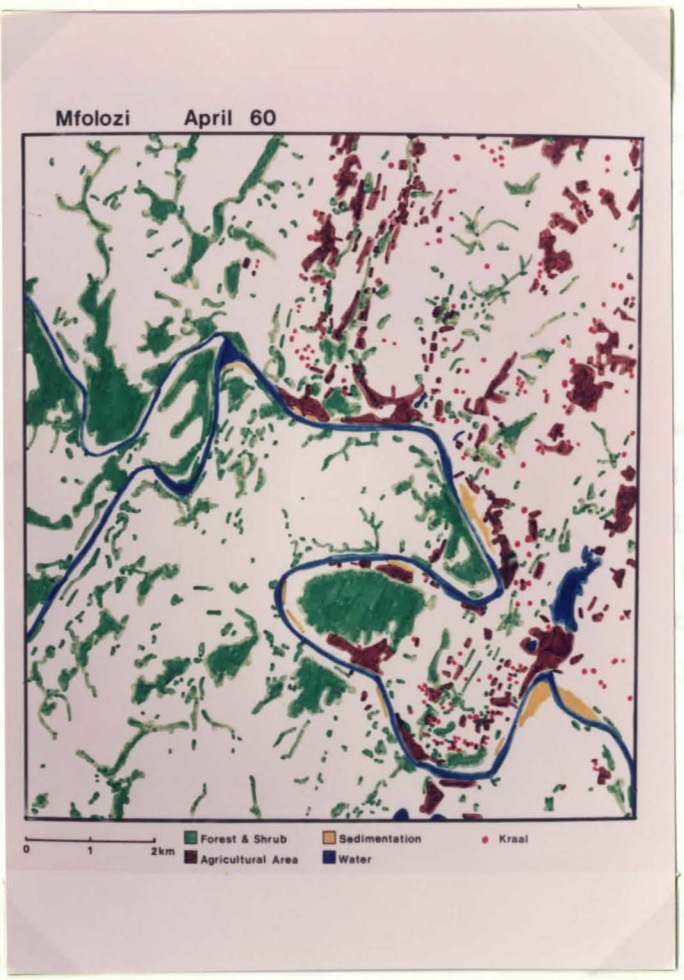
Six large excavations for building material can be seen on the 1984 photos. This building material was used for the construction of the tarred road, the town of Ulundi and the Ulundi airport. At this stage material is still needed for building activities in Ulundi. All these excavations enhance erosion and sediment delivery.

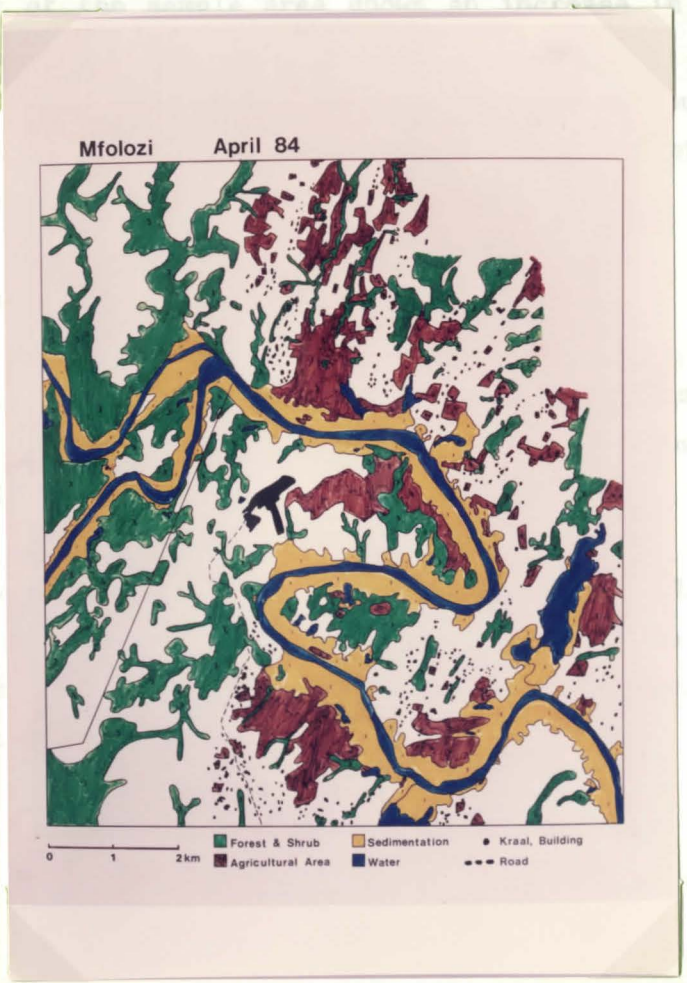
3.4 Mfolozi (Sample area 3)

This 90 km^2 sample area is situated at the confluence of the White and Black Mfolozi. The western part, south of the Black Mfolozi, falls in the Mfolozi Game Reserve. Other areas of the study site are either State land or belongs to KwaZulu. The topography is undulating with altitudes between 30 m and 245 m.

3.4.1 Erosion and sedimentation

On both the 1960 and 1984 photos almost no erosion processes are evident, except along some tracks and along the river-bed of the Mfolozi. The most eye-catching characteristics are the 851 ha of sediment deposits along the Mfolozi on the 1984 photos compared to the 50 ha in 1960. The Domoina flood buried a large amount of cultivated land along the Mfolozi under medium to thick sediment deposits. These deposits often cut off and dammed up the water courses of the small tributaries. It seems that more sediment was deposited in the sample area than


Mfolozi April 60
0
1
2km
Forest & Shrub
Agricultural Area
Sedimentation
Water
Kraal


Mfolozi April 84
0
1
2km
Forest & Shrub
Agricultural Area
Sedimentation
Water
Kraal, Building
Road

exported. The erosive power of the Domoina flood altered the course of the Mfolozi at two places. Cultivated land was washed away, but no houses were endangered by that process.

3.4.2 Cultivated areas

During the last 24 years the cultivated area increased from 433 ha to 783 ha. The 1984 figure does not consider the approximately 300 ha of cultivated land in the sample area which was seriously affected or totally destroyed by the Domoina flood. The 1984 photos show that the cultivated areas not affected by the flood are in a generally good condition with almost no signs of erosion processes.

3.4.3 Forest and shrub

Forest, shrub and bushland increased in the sample area from 1 620 ha in 1960 to 1 720 ha in 1984. Especially the western part of the sample area shows an increase in shrub and bushland whereas in the remaining parts of the sample area shrub and bushland, was reduced in favour of cultivated land. In general the shrub and bushland show no sign of severe erosion processes or damage.

3.4.4 Population and humam activities

This sample area shows a significant increase in population. On the 1960 photos only 121 kraals could be counted. The 1984 photos show 350 kraals and a new settlement in the centre of the sample area. This settlement consists of approximately 90 kraals. Although there is a significant increase in population, there is no evidence that erosion processes increased significantly due to human activities.

3.5 Conclusions of the aerial photograph interpretation.

The main features of the three evaluated sample areas are listed in Table 1 for better comparison.

In all three sample areas the 1984 photos do show a significant increase in sediment deposits along the main river channels. Erosion processes along the river channels were enhanced in all sample areas by the Domoina flood, but erosion processes in the catchment increased only in the sample areas 1 and 2.

Cultivated area decreased in sample areas 1 and 2 but increased in area 3. Large areas of cultivated land are covered with sediment deposits or had been washed away on all the 1984 photos.

Shrub and forest increased in all three sample areas. This could be due to the intrusion of shrub and bush into overgrazed and poorly managed veld. This feature is very interesting and should be subject to further investigation.

Population increased significantly in all three areas during the last 24 years. Together with the increase in population there had been an increase in roads, tracks, footpaths and cattle trails. Quarries for construction works and other human activities are evident in areas 1 and 2. These activities, together with an increase in population are enhancing erosion processes and sediment deliveries to the main river channels.

Table 1: Comparison of three sample areas in the Mfolozi catchment.

	Black Mfolozi Sample area 1		White Mfolozi Sample area 2		Mfolozi Sample area 3	
Date	June 60	April 84	April 60	April 84	April 60	April 84
Size of sample sample area	102 km^2	102 km^2	79 km^2	79 km^2	90 km^2	90 km^2
Sediment deposit	0 ha	278 ha	0 ha	107 ha	50 ha	851 ha
Erosion damage to the river channel	Slight	Severe	Slight	Severe	Slight	Severe
Erosion damages to the catchment	Moderate	Severe sheet, rill gully	Moderate rill, gully	Moderate severe sheet, rill gully	Slight	Slight
Cultivated area	1678 ha	1350 ha	752 ha	295 ha	433 ha	1083 ha
Cultivated area covered by sediment	0 ha	230 ha	0 ha	Little	0 ha	300 ha
Shrub and trees	1521 ha	1612 ha	824 ha	1765 ha	1620 ha	1720 ha
Roads and tracks	-	Significant increase	-	Significant increase	-	Slight increase
Kraals and buildings	300 kraals	640 kraals	65 kraals	90 kraals + Ulundi	121 kraals	350 kraals + one new settlement

4. Conclusion

Remote sensing has a distinct place in monitoring soil erosion and changes in land-use. Both, satellite information and aerial photography have this application depending on the type of work to be done.

The high resolution aerial photography has its advantages in detailed studies of small amd linear features. But if large areas must be investigated, satellite information comes to its full capabilities. The big advantage of satellite information lies in the digital computer compatible information, the multi-spectral scanning ability and the continuous updating of this information. But this information requires an Image Processing System to fully exploit the data.

So the question is not "is satellite information a substitute for aerial photography?" but "which is the right tool for a specific task?"

DEPARTMENT OF WATER AFFAIRS

HYDROLOGICAL RESEARCH INSTITUTE

REMOTE SENSING

APPLICATIONS IN WATER RESOURCES

COLLOQUIUM PAPERS

OCTOBER, 1985

PRIVATE BAG X313

PRETORIA

0001.

CONTENTS