Land Degradation Mapping for Modelling of Ecosystem Benefit Flows in the Inkomati Catchment using Remote Sensing

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Land degradation is of great concern in South Africa particularly in the Inkomati catchment. Here a mosaic of different land use types such as plantation agriculture, subsistence farming, irrigated commercial farming, rural and urban settlement, as well as nature conservation affect the natural ecosystems in different ways and magnitudes.
The National Land Cover (NLC2000) project mapped degraded areas in the catchment, but the results lack a differentiation of magnitude of degradation.
For modelling of benefit flows from ecosystems a distinction of areas that are heavily degraded in contrast to only slightly affected areas is necessary. Therefore within a research project of the CSIR a method shall be developed to refine the degradation information of the NLC2000. Preliminary results using remote sensing derived albedo data are presented. The result will be used for modeling ecosystem benefits and their flows, with degraded areas playing an obvious role in defining ecosystems benefits.

The Issue

The NLC2000 product provides general information on land cover degradation. This information is derived from Landsat ETM+ satellite data based on "brightness" values. Degradation is recognized on the basis of "sparse vegetation cover". For many applications this simple labelling "degraded" vs. "non-degraded" (Figure 1) is not sufficient.

Within a research project involving several CSIR research groups involved in modeling the flow of benefits to people from ecosystem services within the Inkomati River Catchment (Figures 2 & 3), the need for a differentiation of degrees of ecosystem degradation (from intact towards totally degraded) arose.

Figure 1. Information about land degradation from NLC 2000 for selected Land Cover classes (colour scheme arbitrarily chosen by authors).

NLC2000 class No.	NLC2000 Class Name		
1	Forest (indigenous)		
18	degraded Forest & Woodland		
2	Woodland		
3	Thicket, Bushland		
19	degraded Thicket		
6	natural Grassland		
15	Bare Rock, Soil (natural)		
16	Bare Rock, Soil (erosion: dongas*)		
17	Bare Rock, Soil (erosion: sheet*)		

not degraded

degraded

Figure 2. Location and detail maps of the Inkomati Catchment in the North and North Eastern part of South Africa (orange rectangle: detail in Figures 4 to 8).

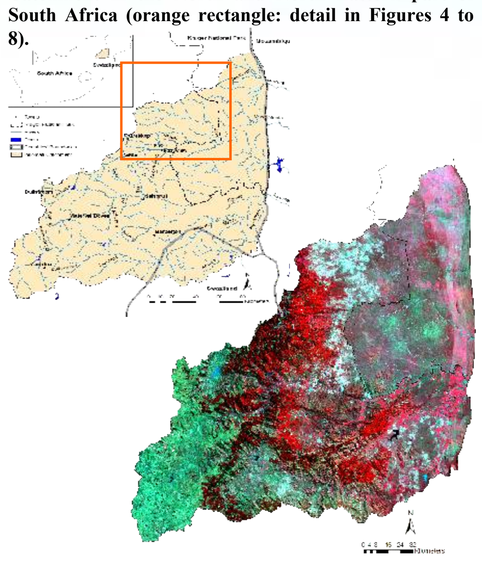

Figure 3. Mosaic of Landsat ETM+ coverage from April/May 2001 for the Inkomati catchment (Scenes 168-77 to 169-78, RGB: bands 4-5-3).

Rationale and Challenge

Following the NLC2000 definition of "degradation" as "reduced vegetation cover" the idea arose to again use remote sensing derived parameters that relate to vegetation density, such as albedo. A high albedo (bright areas in Figure 4) is expected be related to low vegetation cover (=degradation) and low albedo (dark areas in Figure 4) to dense vegetation (=non-degraded ecosystems). The idea was to use this contrast for a more detailed description of vegetation state, with various degrees of degradation scaled between the two extremes of bare land and dense vegetation cover pixels.

Different land cover classes are characterized naturally by different vegetation densities. Thus the challenge was to define an albedo-based scheme that stratifies degradation depending on the natural land cover type.

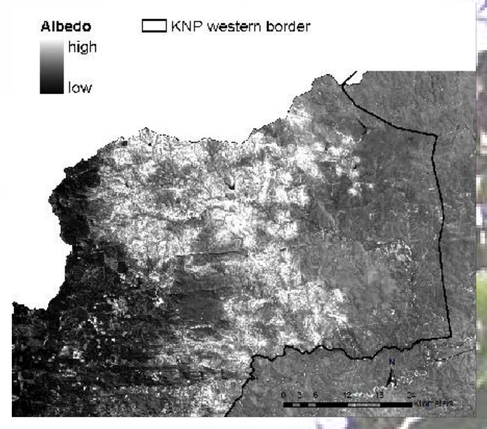

Figure 4. Albedo layer in gray scale, brightness showing degraded areas and dark features showing non-degraded areas.

Methodology

The methodology applied is summarised in Figure 5. Landsat 7 ETM+ images from 28 April and 21 May 2001 (four scenes) were used. The images were radiometrically and geometrically corrected (preprocessing) to provide general spectral comparability of the scenes and to enable mosaicking of the four Landsat scenes covering the catchment. Transformed areas such as cultivated, urban or built-up areas as well as plantations (blue areas in Figures 6 & 7) were excluded from the analysis, enabling the degradation mapping to focus on natural land cover categories. From the mosaic, albedo was calculated by summing up all the spectral properties (bands) except the thermal band (because albedo focuses on reflectance rather than emission). The albedo product was subjected to unsupervised classification to stratify the data, where bright features represented degraded areas and dark features indicating non-degraded areas. Photos 1 to 4 illustrate degraded areas in the field. The classified albedo layer was overlaid with the NLC2000 product for analysis (categorizing degradation levels).

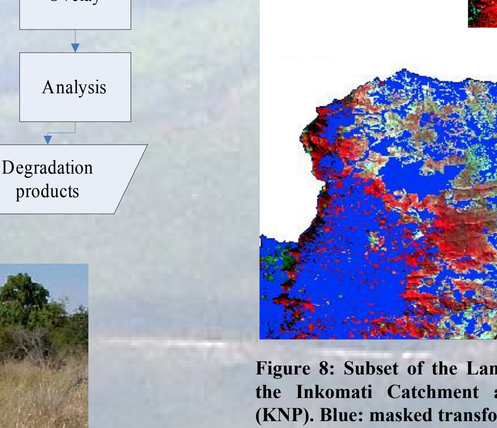

Figure 6: National Land cover (NLC 2000) for a subset of the Inkomati catchment study area. Eastern parts are part of the Kruger National Park (KNP).

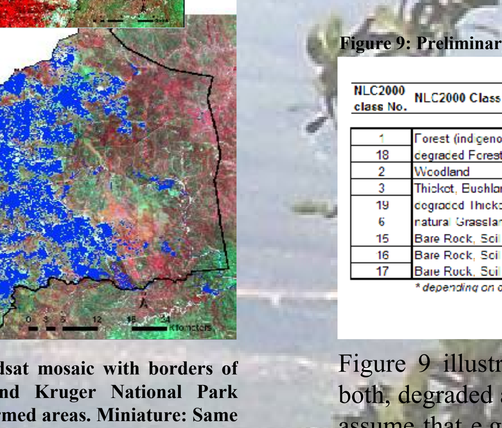

Figure 7: Stratified albedo product. Green: low albedo = high vegetation cover; red: high albedo = low vegetation cover = degraded, blue: masked areas.

Preliminary Results

Comparison between NLC2000 (Figure 6), the stratified albedo (Figure 7) and the Landsat subset (Figure 8) shows that with the albedo product the classification of the NLC can be better differentiated. In analysing the albedo product we tried to define thresholds for four classes:

1. non degraded, 2. slightly degraded, 3. moderately degraded, 4. heavily degraded areas.

We assumed that for naturally dense vegetation (e.g. forests, Figure 8) such thresholds are to be defined low, since moderate albedos (=moderate vegetation cover) can already indicate disturbance. In contrast, thresholds for naturally open vegetation types must allow for high albedo thresholds.

Results derived from Albedo indicate the levels (magnitude) of degradation (Figure 9). These levels of degradations are also shown on Figure 7, where class one (green) indicates areas with no degradation and class 20 heavily degraded areas. Degraded areas are found mainly around built-up areas.

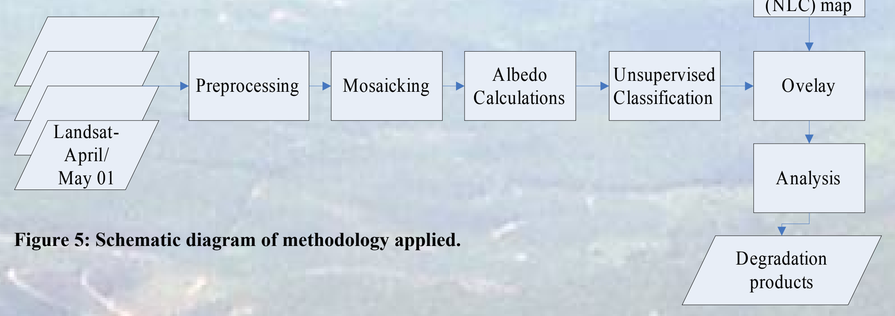

Figure 5: Schematic diagram of methodology applied.

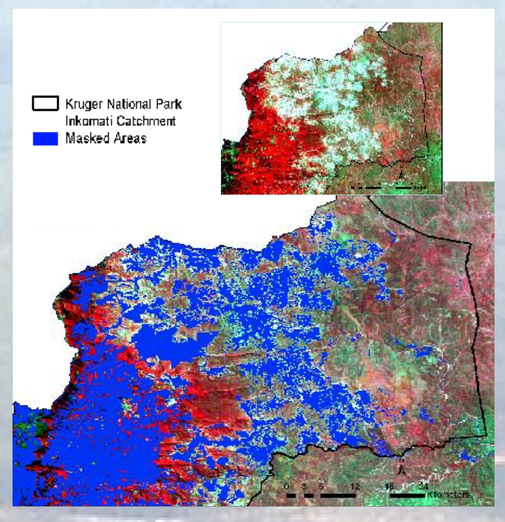

Figure 8: Subset of the Landsat mosaic with borders of the Inkomati Catchment and Kruger National Park (KNP). Blue: masked transformed areas. Miniature: Same area without mask: Settlements (sparse vegetation cover) appear in bright tones, forest plantations in intense red.

Figure 9: Preliminary classification scheme of land degradation from the NLC 2000 and stratified albedo data.

NLC2000 class No.	NLC2000 Class Name	<-- low Albedo / Albedo class No. / high Albedo --> 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
1	Forest (indigenous)	
18	degraded Forest & Woodland	
2	Woodland	
3	Thicket, Bushland	
19	degraded Thicket	
6	natural Grassland	
15	Bare Rock, Soil (natural)	
16	Bare Rock, Soil (erosion: dongas)	
17	Bare Rock, Soil (erosion: sheet*)	

* depending on original vegetation

Degradation classes: not degraded; slightly degraded; moderately degraded; heavy degraded

Figure 9 illustrates the (preliminary) thresholds of the classification scheme. For both, degraded and indigenous land cover types similar thresholds were selected. We assume that e.g. non-degraded forests will perform mainly in the low albedo range, whilst NLC2000 "degraded Forests & Woodlands" can be distinguished within the ranges of slightly to heavily degraded (high albedo classes). Thresholds for erosion classes 16 and 17 have to be defined in relation to the non-degraded former vegetation.

Photo 1: degraded rangeland area

Photo 2: non-degraded rangeland area

Photo 3: degraded rangeland area

Photo 4: non-degraded rangeland area

Discussion

The research is on-going, and the next stage is to validate the results in the field, taking into consideration the season of acquisition for the images used. A stratified random sampling approach will be adopted for validation purposes. Recent rainfall events (prior to image acquisition date) can influence albedo through soil and grass aridity, as can animal damage to vegetation in Kruger National Park, human harvesting of vegetation, as well as other human perturbations like the timing of burning and livestock grazing intensity. Therefore, the location context of high albedo (degradation) pixels needs field verification. Ground truthing will also enable the evaluation of the accuracy of a method employed.

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