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Identification of soil patterns with LANDSAT data in the central Namibian savannah region

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1. Introduction

Within the interdisciplinary BIOTA South Africa project (*www.biota-africa.de*) an assessment of the carrying capacity of farm areas is needed as an input for socio-economic modeling. The capacity is mostly defined by climatic and soil related data. Thus our investigation aimed at a regionalization of soil properties with satellite imagery data. As a low cost data source with sufficient spatial resolution we choose LANDSAT-TM 5 data and selected two farm areas in the central Namibian savannah region (together 236 km^2) to test the approach. The work was conducted in cooperation with subprojects S01 (DLR: image processing) and S06 (Botany: vegetation mapping).

2. Soils of the investigated farm areas

The investigated area is situated 120 km north of Windhoek on an elevated plain (1500 m a.s.l.), receaves mostly summery rainfall of 300-350 mm a^{-1} and is vegetated by a thorn-bush savannah. The farms are used for cattle grazing and hunting.

The soils were classified acc. to the WRB. On the upper level seven and using the first qualifier 30 types could be identified (number of profiles in decreasing order):

Luvisols	35
Cambisols	10
Calcisols	9
Arenosols	4
Leptosols	2
Vertisols	2
Regosols	1

The range of relevant soil properties (texture, pH-value, organic and inorganic carbon) was wide, with the exception of the vertisols the soils were not saline.

3. Methodological approach

The methodological approach followed five steps:

Step 1) Selection of two LANDSAT TM 5 scenes **2)** unsupervised classification of the dry scene 21.11.1984 (n=30 classes) and supervised classification using plant communities of the wet scene - 17.5.2000 (n=31 classes) **3)** Selection of 62 pixels (n=2 per class) with a maximum of homogeneity in the surrounding area **4)** Investigation at 62 sites: soil/vegetation description; soil surface color at 13 positions each; 0-1 cm composite sample from 30 x 30 m area; one profile in pixel center: soil horizon samples; **5)** laboratory analyses on standard parameters.

Using the Munsell Conversion 6.5.1 software the topsoil colors have been converted to four different color space systems.

4. Results

4.1 Relation between LANDSAT imagery data and soil surface color

The mean values of the 13 topsoil colors of each pixel area have been correlated to the six TM 5 spectral band data (30 m resolution) of the dry scene. An example (band 1 – soil color converted to the a-value of the C.I.E. LAB color space) with a comparatively good correlation (r=-0,707) is given by fig. 1.

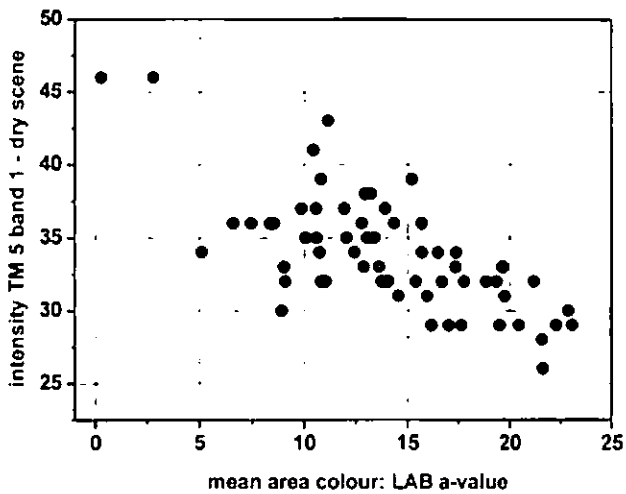

Fig. 1 Mean soil surface color of 30 * 30 m area vs. intensity of LANDSAT-TM band 1

By multiple regression analyses based on all LANDSAT TM band data the different soil surface color values could be predicted with a coefficient of determination of about r^2 = 0.30 – 0.62. Within the compared color systems the CIE LAB color space showed the highest degree of predictability. In this case the prognosis of the topsoil color can be determined by three significant variables: intensities of band 1 (0.45-0.52 µm), band 2(0.52-0.60) and band 5 (1.55-1.75).

4.2 Relation between topsoil color and other topsoil properties

The mean soil surface color was correlated to the results of the laboratory analyses of composite soil samples (0-1 cm depth) of the pixel area. Tab. 1 gives the correlation coefficients between surface color and the values of the LAB color space.

The luminance (L-) value increases significantly with inorganic carbon and decreases with total Al, Ti and Fe. The a- (green → red) and b-values (yellow → blue) significantly correlate with numerous topsoil properties caused by the interrelation of soil properties with each other. With a maximum of r ≈ 0.55 the

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coefficients are too small to predict top soil properties properly.

Tab. 1 Correlation coefficients between the soil surface color and topsoil properties (0-1 cm depth)

	mean color values of 13 MUNSELL soil surface determinations		
	L-value	a-value	b-value
pH in $CaCl_2$	-0,018	**-0,400**	**-0,551**
EC in 1:5 extract	0,072	**-0,414**	**-0,552**
C total	0,139	**-0,459**	**-0,551**
C inorganic	**0,312**	**-0,512**	**-0,550**
C organic	-0,078	**-0,311**	**-0,445**
N total	-0,141	**-0,290**	**-0,446**
S total	-0,135	**-0,316**	**-0,448**
Al total	**-0,286**	-0,037	-0,194
Ca non-calcareous	0,220	**-0,494**	**-0,553**
K total	0,022	**0,293**	**0,396**
Mg total	-0,174	0,103	0,050
P total	-0,201	-0,178	**-0,426**
Ti total	**-0,383**	0,138	-0,144
Fe total	**-0,308**	-0,072	**-0,325**
Mn total	-0,131	-0,242	**-0,392**
Si total	0,097	**0,306**	**0,493**

bold values: significant ($p<0,05$)

Even with multiple regression techniques based on the parameters of different color systems for the soil surface color the top soil properties could not be predicted with a coefficient of determination of higher than r^2 = 0.2 to 0.4. By this the predictability is decreasing with total Fe = inorganic C > total Si > organic C.

4.3 Relation between topsoil properties and properties of deeper horizons

For the examples of pH-value and organic carbon figures 2 and 3 depict a comparatively strong correlation between soil properties analyzed in the mixed

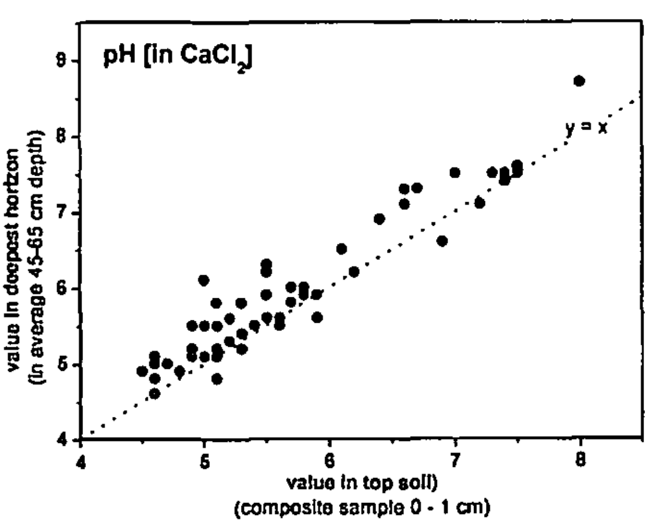

Fig. 2 Top soil (0 – 1 cm) properties vs. properties of deepest horizon: pH (in $CaCl_2$)

sample (0-1 cm) and in the deepest horizon of the center-profile (on an average 0.45-0.65 cm).

These findings are true for many soil properties in the investigated area, implying that the vertical differentiation of the savannah profiles is the smallest uncertainty in the prediction of soil properties with LANDSAT data.

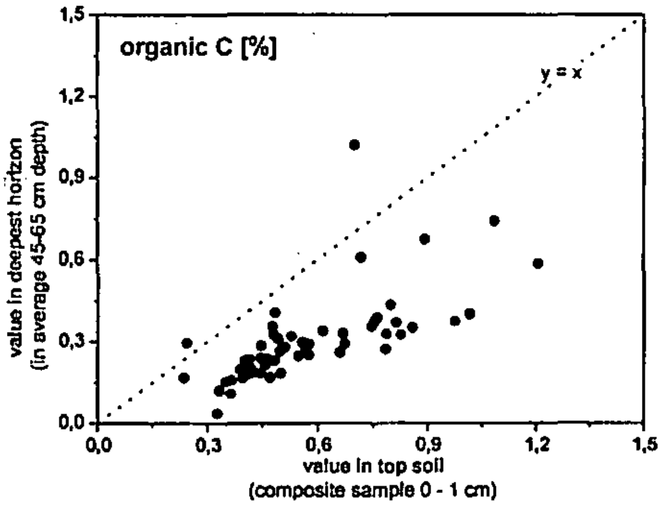

Fig. 3 Top soil (0 – 1 cm) properties vs. properties of deepest horizon: organic carbon

5. Conclusions

It could be shown that the distribution of two types of soils (vertisols, leptosols, 6 % of sampled profiles) could be accurately predicted from the LANDSAT-TM data directly. In contrast, for the dominant remaining share of the soils the total predictability of soil properties like pH, elemental composition and salinity is lower than 22 %.

Based on the wet scene with the LANDSAT-TM data a rough estimate of vegetation coverage and biomass production is possible. But the different plant communities within the thorn-bush savannah which have some structural similarities could not be discriminated satisfactorily. Thus the approach to indirectly identify soil features by vegetation mapping has failed.

Hence the use of LANDSAT-TM data for the mapping of soil properties in the plain savannah region of central Namibia is inappropriate. For the future a correlation to hyper spectral air-born data with higher spatial resolution is planned with the same set of soil data. As one part of the low predictability is caused by the soil properties, esp. the occurrence of a loose coarse sand top layer for many profiles an improvement on the remote sensing data will not necessarily lead to a better prognosis of soil properties. Thus, for the regionalization of soil features classical mapping techniques seem to be inevitable.