Deforestation and Degradation in Central and Southern Africa

Project Title: "Deforestation and Degradation in Central and Southern Africa"

Description:

An integrated land degradation and deforestation detection system will be developed for the Southern African Development Community (SADC) region plus southern Zaire. The scale for the inventory and monitoring will 1 km2. Using our past experience with degradation studies in Africa, the analysis of very large volumes of Landsat data, socio-economics of land and fuelwood, and inference of biophysical variables for large areas from remotely sensed measurements, we will map land cover and biophysical properties of the land surface related to degradation, thus moving beyond classification of land cover to monitor the processes involved. Socio-economic drivers of land cover change as well as biophysical factors will be employed to select processes that can be expected to cause degradation and to choose representative study areas. Radar and optical methods will be implemented to measure biomass. Primary productivity of crops, rangelands and forests will be monitored using models driven by remotely sensed data. Soil moisture and runoff will be derived from surface water and energy balance models also driven with remotely sensed data. Finally biophysical, socio-economic and cultural variables will be combined to create empirical models that we hope will identify leading indicators of environmental degradation. The 15 year archive of Advanced Very High Resolution Radiometer data constitutes a baseline having an appropriate temporal scale for this purpose. Up to ten detailed study sites will be selected in which representative degradation processes are known to occur. Landsat (1972 - present) and synthetic aperture radar data will be acquired where higher spatial resolution is needed to understand the mechanisms of land cover change that are taking place. The aim of the study will be to develop a prototype degradation early warning system (DEWS) that can be applied to the whole of southern and central Africa and provide a pattern for similar areas worldwide.

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Publications:

Prince, D.D., Geores, M.E. and Boberg, J., 1998. Coping strategies in the Sahel and Horn of Africa: a conceptual model based on cultural behavior and satellite sensor data. In GIS in Natural Resource Management: Balancing the Technical-Political Equation. Ed. by S. Morain. High Mountain Press (in press).

Prince, S.D. and Geores, M.E., 1998. Global Vegetation Production and Human Activity. In GIS in Natural Resource Management: Balancing the Technical-Political Equation. Ed. by S. Morain. High Mountain Press (in press).

Prince, S. D., Brown de Colstoun, E. and Kravitz, L. L., 1998. Evidence from rain-use efficiencies does not indicate extensive Sahelian desertification. Global Change Biology 4, 359-374.

URL:
See WWW page address:
http://www.inform.umd.edu/Geog/LGRSS/Projects/degradation.html

Report on NAG54811

Deforestation and Degradation in Southern and Central African Savannas

Period 1
May 1998

Abstract

The first 10 months of activity on degradation and deforestation of southern central Africa has been concerned with parameterization of the Global Production Efficiency Model (GLO-PEM) for the region. Results have been compared with a potential production model and the a global comparison made an human factors used to suggest causes for the reduction of actual below potential production. Some previously unknown conditions have been found that cause some of the GLO-PEM algorithms to fail and work is in progress to rectify these in a new version of GLO-PEM. New satellite data sets are being prepared with improved corrections and spatial resolution. Significant progress, including a paper in press, has been achieved in developing an index of degradation - the rain use efficiency - and applying this to African degradation. Also collaborations have been established with several groups in the region who are studying degradation at a local scale. Landsat TM data have been acquired for these field sites and will be used to compare the regional satellite degradation predictions with the field conditions. Some new data sets and models have been acquired, including an archive of land cover data for the SADC region. Finally an empirical human coping strategy model has been developed for semi-arid regions for which a preliminary report is in press and is now being tested in the southern African region.

Progress

1. Land cover map of southern and central Africa.

The extent of degradation is linked with the specific land cover type and is very variable between cover types. Land cover maps are needed to stratify the region into degrees of susceptibility so that monitoring of cover change can be targeted effectively. Two land

cover maps of the study region at 1km resolution have been completed by our collaborators, Drs. Townshend and DeFries (UMD) and Dr. T. Loveland (USGS), both using NOAA Advanced Very High Resolution Radiometer (AVHRR) data. These maps are being reviewed with the help of more local vegetation maps, aerial photography and personal knowledge of the PI and collaborators in the region. The basis of our assessment of the comprehensive 1 km land cover maps is an extensive digital archive of land cover maps that has been assembled in collaboration with the Southern African Development Community (http://www.zimbabwe.net/sadc-fanr/intro.htm), the IGBP GCTE Miombo (http://miombo.gecp.virginia.edu) and from other sources (e.g. Texas).

2. Global Production Efficiency Model (GLO-PEM)

The key variable in the identification of degradation is the net primary production (NPP). NPP can only be measured for small field samples, and even then only certain components are easily measured. The GLO-PEM model uses remotely sensed data to estimate NPP over the entire sub-continent. So far, GLO-PEM has been applied to a nine-year run of data using NOAA/NASA Pathfinder AVHRR Land (PAL) data at 8 km resolution. The results have indicated important variations between years in the pattern of NPP, but also it has revealed some previously unknown difficulties with some of the algorithms used in the current version of GLO-PEM (ver. 2.0). These difficulties relate primarily to the estimation of air temperature and water vapor pressure deficit, two environmental variables that are critical to the calculation of NPP. In the arid and semi-arid parts of southern Africa there is insufficient variability in vegetation cover to be able to specify the correlation relationship of cover and surface temperature - the basis of the air temperature algorithm. In more vegetated parts of the region the same problem may arise, but the solution is much simpler. Work is in progress to rectify these problems using modified techniques which are being incorporated into a new generation of the GLO-PEM model (ver. 3.0).

Significant advances have been made in the processing of AVHRR data since the PAL data set was completed. AVHRR Pathfinder-2 has developed improved calibrations for the thermal channels and a water vapor correction for channel 2 as well as improved cloud screening. Dr. C.J. Tucker has added further corrections for aerosols and for the bi-directional reflectance distribution function (BRDF) as well as experimentally incorporating SeaWiFS data. Through collaboration with these two AVHRR data projects, a complete reprocessing of the African AVHRR data set is nearing completion. When available GLO-PEM ver.3.0 will be run with the 17 year data set.

In order to increase the resolution of the NPP products, 1km AVHRR data are being acquired from USGS for 2 years. It is hoped to be able to assemble a 12 year 1km archive in the next period of activities.

The GLO-PEM runs completed so far have been compared with a global potential NPP map from Dr. C. Prentice?s BIOME3 model. The differences between the actual (GLO-PEM) and potential NPP (BIOME3) have been calculated and discussed relative to supposed human impacts on the land surface at a global scale (Prince et al.1998a).

3. Selection of degradation issues

Through the Miombo network a group of local collaborators has been assembled who are studying degradation at a local scale in a wide variety of circumstances and in countries from Tanzania to Botswana. An informal agreement has been reached with these partners to acquire Landsat TM data (Table 1), to process this to various image formats and to use this as a means to bring together the detailed field work and the regional degradation monitoring undertaken in the NASA LCLUC project.

A field program is being planned for 1999 when the UMD team and the local collaborators will visit each site and assess the technical aspects of the satellite products and models dependent on them and attempt to identify the human factors responsible for the degradation.

The Landsat data acquired are as follows. The processing of these data sets will be undertaken in the next phase of the project.

Table 1. Miombo Landsat TM data acquired

(Table 1 To be added)

4. Crop, forest and rangeland production

The CERES-Maize model has been acquired and is being prepared for the application of African climate data. As the GLO-PEM climate products are improved it is planned to use these to drive both CERES and GLO-PEM itself. Land cover maps (see 1 above) will be used to stratify the GLO-PEM output so that the productivity of specific vegetation types and crops can be monitored.

5. Woody biomass

In addition to the GLO-PEM biomass product which depends on visible reflectance changes with biomass, L-band radar data are being examined from NASDA JERS. Through collaboration with Dr. S. Saatchi of JPL a proposal is being prepared fro the processing of JERS data for southern Africa.

Plans are advancing for the deployment of an airborne Lidar (LVIS) to southern Africa as part of the Vegetation Canopy Lidar (VCL) program. It is anticipated that this will enable much improved canopy structural data to be recovered including standing biomass.

6. SAR data

See 5 above.

7. Water balance modeling

The VIC-2 regional hydrological model is currently being parameterized for the southern Africa region by Drs. Dubayah and Lettenmaier. Once the essential parameterizations are completed, GLO-PEM climatological products will be used to drive the VIC-2 model.

8. Degradation indices

Considerable progress has been made with the development of rain use efficiency (RUE) as an empirical index of degradation in Africa (Prince et al.1998b). RUE is the ratio of NPP to rainfall and is particularly useful in arid and semi-arid regions where rainfall is an important determinant of NPP. RUE identifies areas in which the NPP is lower than would be anticipated from the rainfall. The work so far has shown that RUE is strongly affected by soil type and that reasonable correlations can be found with independent maps of degradation (e.g. GLASOD desertification map). Work has also been completed on the use of satellite estimates of rainfall to calculate RUE.

9. Empirical models of land cover changes

The work on human dimensions of degradation has developed an empirical model of the relationship between NPP and the interannual variability or predictability of NPP (Prince et al.1998c). Essential differences between low NPP and low and variable NPP are recognized and a simple typology of NPP and variability is developed into a predictive model (Prince et al. 1998c, attached).

Attachments Prince, D.D., Geores, M.E. and Boberg, J., 1998. Coping strategies in the Sahel and Horn of Africa: a conceptual model based on cultural behavior and satellite sensor data. In GIS in Natural Resource Management: Balancing the Technical-Political Equation. Ed. by S. Morain. High Mountain Press 1998 Prince, S.D. and Geores, M.E., 1998. Global Vegetation Production and Human Activity. In GIS in Natural Resource Management: Balancing the Technical-Political Equation. Ed. by S. Morain. High Mountain Press.

Prince, S. D., Brown de Colstoun, E. and Kravitz, L. L., 1998. Evidence from rain-use efficiencies does not indicate extensive Sahelian desertification. Global Change Biology 4, 359-374.

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Prince et al.1998a
Text to be added

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Prince et al.1998b

Global Change Biology (1998) 4, 359-374
Evidence from rain-use efficiencies does not indicate extensive Sahelian desertification

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Abstract

Desertification is regarded as one of the major global environmental problems of the 20th century and the African Sahel is often quoted as the most seriously affected region. Previous attempts to map the occurrence and severity of desertification in the Sahel have been unsatisfactory, mainly because of the lack of any readily measured, objective indicators. We explore here the properties of the ratio of net primary production (NPP) to precipitation - the rain-use efficiency (RUE) - calculated from remotely sensed vegetation indices and rain gauge data. Negative deviations from the normal range of RUE values are shown to be an indicator of desertification. Observations of NPP of the entire Sahel were possible using satellite platforms for the period 1982-90, including the 1984 drought. The results suggest that NPP was remarkably resilient, a fact that was reflected in only little variation in the RUE during the period of study. Thus, in much of the region, NPP seems to be in step with rainfall, recovering rapidly following drought and not supporting the fears of widespread, subcontinental scale desertification taking place in the 9-year period that is studied. In fact the results show a small but systematic increase in RUE for the Sahel as a whole from 1982 to 1990, although some areas contained within the region did have persistently low values.

Keywords: AVHRR, degradation, desertification, NDVI, net production, rain use efficiency, rainfall, Sahel

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Prince et al.1998c
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