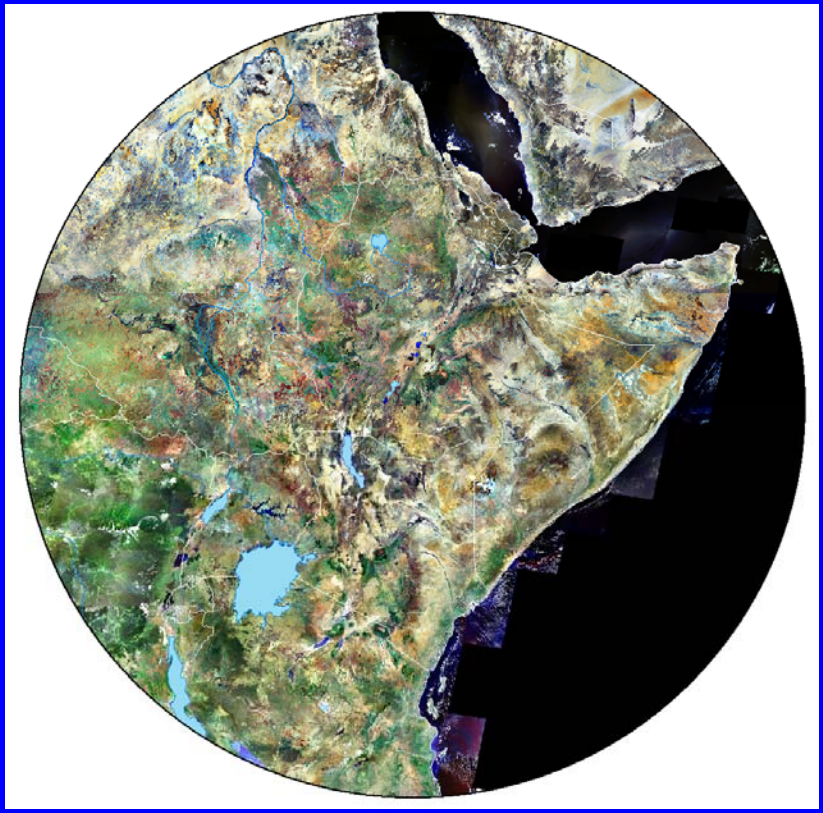
Somalia Water & Land Information Management

Expert Workshop

Potentialities and Limitations in the Use of Remote Sensing for Detecting and Monitoring Environmental Change in the Horn of Africa

BOOK OF ABSTRACTS



12th – 13th June 2007

Nairobi, Kenya

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SESSION 1 - RESOURCE BASE INVENTORY

17/11/2001 Landsat ETM+ image (false colour composite, the sea appears in black) of a mountainous area. Note how the rivers cut the mountains with very narrow valleys.

Integration of Landsat ETM+ image, digital elevation model (DEM) derived hillshade, and topographic map for resource base analysis.

SESSION 1

Using high resolution satellite imagery to improve sweet potato crop statistics in Uganda.

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Abstract

Statistics on crops and production systems continue to be and important source of information for planning and implementation of research and development projects. FAO (1999, 2003) states that for setting agricultural strategies and making decisions for commercial agriculture, as well as for agricultural research on short-, medium- or longer timescales, it is absolutely necessary to have an information system that includes total areas under a specific crop, the extent and size of its production units, agro-ecological zones where the crop is grown, socio-economic conditions of the crop producers and crop calendars amongst others. In recent years the International Potato Center (CIP), has initiated the introduction of orange-fleshed varieties of sweet potato in several countries in sub-Saharan Africa, as a strategy to mitigate severe problems of vitamin A deficiency in human nutrition. This intervention calls for a precise information system including data on the actual area under sweet potato in each country, the areas of potential dissemination of the new varieties as well as the possible beneficiaries, and those data are required with a spatial as well as temporal scale component. This knowledge is necessary to estimate production, volumes of commercial product, per capita consumption and income, required interventions and for guiding the research in general.

There are reasons to believe that available crop statistics for Africa are not always corresponding with the actual areas under a specific crop. This is especially true for crops grown in subsistence agricultural settings, like sweet potatoes, often cultivated by small producers, whereby means of obtaining accurate field statistics are limited. For this reason CIP is currently developing and testing a methodology based on radiospectrometry and the use of high resolution satellite images obtained with remote sensing. In this paper we test the technique to obtain reliable, precise and dynamic information to estimate the area under sweet potato and in this way improve crop statistics for a pilot study site in Kumi District, Uganda, where CIP clones originating from Peru were recently introduced. In Uganda in general, cassava, which is one of the most important basic food staples, is gradually substituted with sweet

potato because cassava suffers greatly from virus attacks and from high post-harvest losses. At present, sweet potato is the fifth most important crop in Uganda regarding crop area, after banana, beans, maize and millet and is the third most important crop regarding fresh weight (Odongo et al., 2004). In eastern Uganda, sweet potato is grown in two periods during the year (from March-June and from August-November), corresponding with the availability of soil moisture related to the rainy seasons. Most sweet potatoes are produced by farmers with limited resources on parcels with a mean size of less then 0.1 ha.

To test the methodology multispectral and panchromatic images from the SPOT 5 satellite were obtained, with spatial resolution of 10 and 5 meters respectively, taken on the 6th of May 2006 (Figure 1). For ground truthing, an Analytical Spectral Device (ASD) FieldSpec Handheld spectroradiometer was used and a Global Positioning System for spatial reference. For digital data processing the Program Environment for Visualizing Images (ENVI) software was used. We first performed an unsupervised classification using grouping algorithms (clustering) to group the image in general land use classes. Then a supervised classification was performed using the spectral signatures obtained with the spectroradiometer in the field to obtain the spatial distribution and area under cultivation of sweet potato making use of the maximum likelihood classifier. The spectral signature of sweet potato can be differentiated from those of the other main crops in the area by a low reflectance in the visual spectrum attributed to foliage pigmentation and high total soil coverage. In the near infrared spectrum (NIR) sweet potato has a high reflectance compared with other crops (Figure 2). The supervised classification of the spot image of May 2006, shows that the major areas under sweet potato can be found in the more humid areas, whereas the drier parts are mainly occupied by pastures. This analysis yields a total area of 28,353 ha under sweet potato for Kumi district, representing 11% of the total image area (Figure 3). This area only corresponds with the area under cultivation for the first growing season (March-June). However, the official data of the Uganda Bureau of Statistics (2000) for Kumi district give a total predicted yearly area under sweet potato of 28,000 ha (for 2003). This would mean the official statistics are underestimating the area under sweet potato by not less then 50 to 60%, assuming there will be a similar or even bigger area under sweet potato during the second growing season (August-November), when climatic conditions are even better. In summary, the use of high resolution satellite imagery in combination with radiometric ground truthing proves to be a promising technique to improve crop statistics in Sub-Saharan Africa. The methodology proves to be effective in discriminating even very small plots of sweet potato from other crops and to make estimations about total area and spatial distribution. The results suggest that traditional statistics on crop area under sweet potato are highly underestimated for Kumi district and most likely also

country wide.

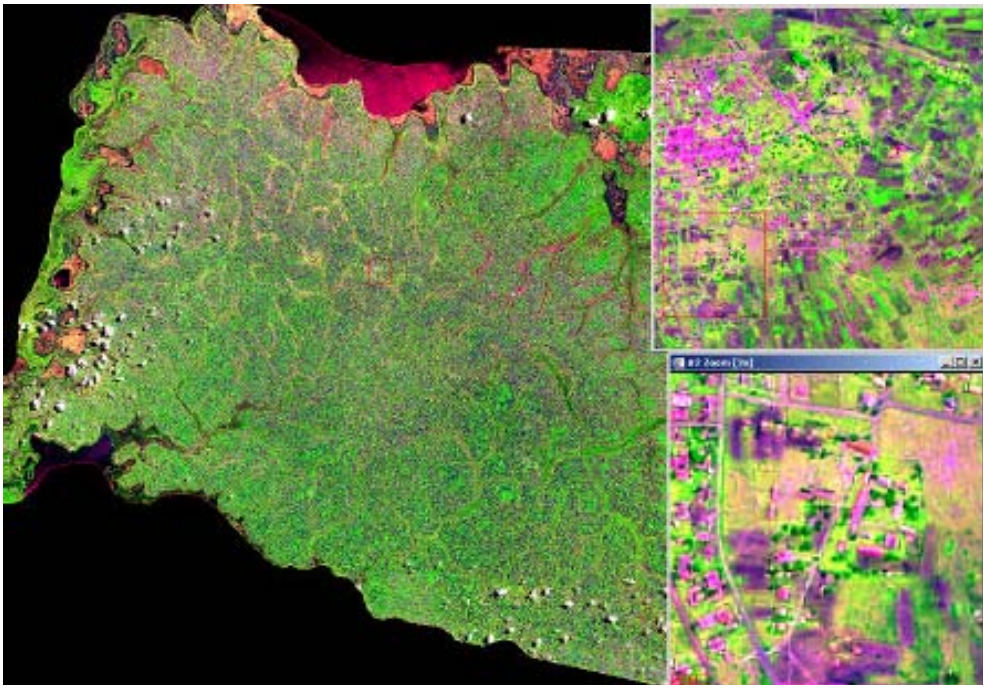


Figure 1. SPOT 5 multispectral image for Kumi district, Uganda.

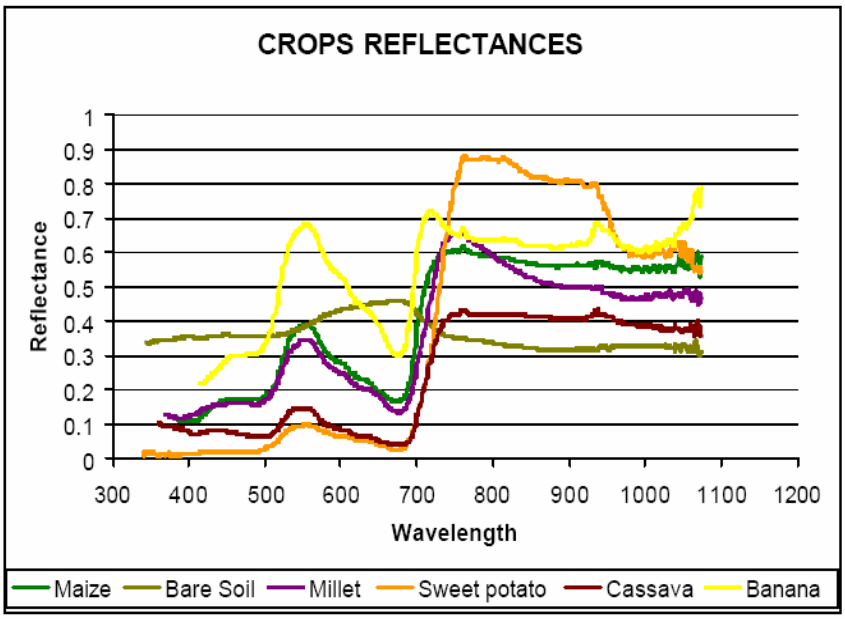
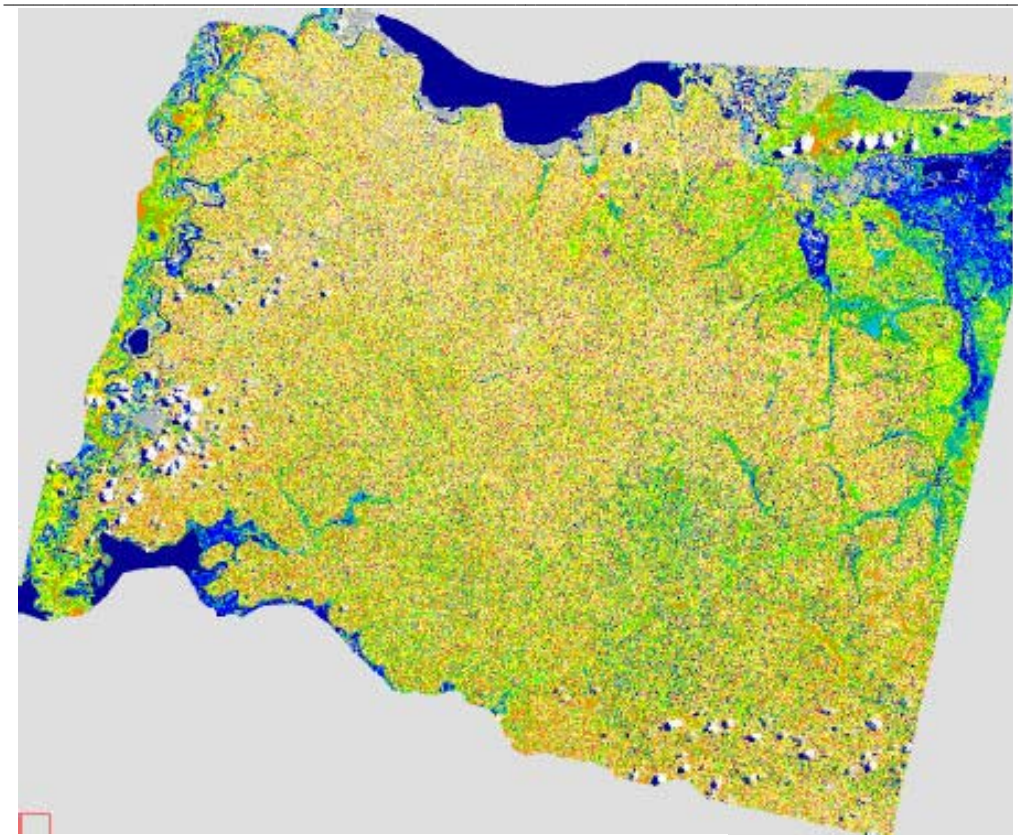


Figure 2. Spectral signatures of main crops of the study area.



LEGEND		
Category	Ha.	%
Water bodies	14769	5.7
Wetland	16886	6.5
Grassland/other crops	109564	42.4
Sweet potato	28353	11.0
Forest/mangoes	30354	11.7
Urban-areas_Bare-soil	31390	12.1
Fallow land	21310	8.2
ND	5822	2.3
	258447	100.0

Figure 3. Supervised classification SPOT image of Kumi district. Colour code for the main crops is indicated in the legend as well as areas in ha and % of total area.

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Land use/cover Mapping and Boundary Delineation of Plantations and Indigenous Forests in Mount Kenya

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Abstract

Mount Kenya is a shield volcano partly covered by dense indigenous and planted forest around its foot. The Mountain has a diverse ecosystem with a forest cover of about 272,153 hectares. Most of the forest cover of the mountain is native mountane and submountane forest with an important coverage of planted forest.The management of the mountain's ecosystem has constantly changed over the years since it was first declared a Forest Reserve in 1932. On 24th July 2000 the Kenya government through legal notice number 93 (Kenya Gazette Supplement No. 48, Legislative Supplement No. 32) transferred the management of the National Reserve (formerly Forest Reserve) from the Forest Department (FD) to the Kenya Wildlife Services (KWS). This new gazettment led to dual gazettment (as the forest status was not revoked) and management confusion.

There was therefore a resource management need to clearly delineate the boundaries between the plantation forests and indigenous forest in order to have a clear definition of responsibilities between KWS and FD. To achieve the above objectives the following maps were to be produced:
Delineation map showing the boundary between the plantation forests and indigenous Vegetation, land use/cover map that will be used in the management of the ecosystem. Relevant satellite imagery for mapping the boundaries of the indigenous and plantation forest was sourced and procured. A full scene, 8 band, Landsat satellite image (Path 168, Row 60) covering Mount Kenya and its environs, acquired in 2003 for purposes of mapping the boundaries of the two forest types and other land uses and cover. The Landsat image was georeferenced using scanned 1:50,000 scale topographic maps to WGS 84 UTM Zone 37 projection; the project area extent clipped; and the 30m spatial resolution bands 1, 2, 3 and 4 pan-sharpened to 15m pixel size based on the 15m panchromatic band (Landsat Band 8). A natural colour pan-sharpened image composite was generated using the combinations of Landsat bands 1 (Blue), 2 (Green), and 3 (Red) while a false colour pan-sharpened image composite was generated using the combinations of Landsat bands 2 (Green), 3

(Red), and 4 (Near Infrared). The pan-sharpening process aided in producing images with better feature edge contrasts for better visual interpretation.

A classification system comprising 9 classes was developed after the field reconnaissance survey. Interpretation of the Landsat image was done by way of on-screen visual feature delineation and attribute entry using the classification system developed. Data analysis was carried to evaluate the size or areas under indigenous forest, plantation forest, tea, among other land use / land cover types.

Mapping the soils of Africa: new initiatives and preserving data resources

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ABSTRACT

In recent years, there has been an increasing awareness by policy makers, land managers, the scientific community and the general public of the vital role that soil plays in the functioning of ecosystems. Soil, like air and water, is one of the world's most important natural resources. Because it lies beneath our feet and is often hidden by vegetation, buildings and roads we may not often think about how much it affects our lives and how much we depend on it.

Soil carries out numerous functions. It provides us with food, biomass and raw materials. It serves as a platform for human activities, our landscape and our heritage and plays a central role as a habitat and gene pool. It stores, filters and transforms substances such as water, nutrients and carbon. In addition, there is an increasing understanding of the critical role that soil plays in the study of global climate change.

It is increasingly important to understand the pressures on soil. Damage to soil structure has repercussions on other environmental media and ecosystems. However, this precious resource is painfully slow to form and can be destroyed terrifyingly fast. A mere inch of soil can take centuries to build up, but if mistreated can be blown or washed away in a few seasons. Unfortunately, very few people are aware of this obvious fact and soil degradation in many parts of the world is accelerating.

The vulnerability of soil and the nature of its functions depend on the properties and characteristics of the soil at a specific location. However, soil is an extremely complex and variable medium, depending on a complex inter-relationships between geology, climate, vegetation, land use, etc . Soil characteristics vary geographically from place

to place but also with depth. This aspect makes the mapping of soil a problematic matter.

In an attempt to provide a harmonized picture of the nature of soil characteristcs, functions and threats for the African continent, the European Commission's Joint Research Centre in Ispra, Italy, has initiated a collaboration with ISRIC World Data Centre for Soil, (Wageningen, The Netherlands), the UN FAO Land and Water Development Division (Rome, Italy) and the African Soil Science Society to develop a Soil Atlas of Africa.

This innovative product, similar to the recently produced Soil Atlas of Europe which has achieved a tremendous impact on EU policy makers and the general public in Europe. The atlas will present an introduction to the functions of soil, soil forming processes and will provide a visual and highly descriptive account of the major soil types of Africa including correlation between the major soil classification systems in use in Africa and the World Reference Base for Soil Resources. At the core of the atlas will be a collection of soil maps of African countries (based on the harmonization of FAO 1:1 million data and information derived from the various SOTER (SO for Soil, TER for Terrain) projects.

Derived maps at continental scale with descriptive text (e.g. vulnerability to desertification, soil nutrient status, carbon stocks and sequestration potential, irrigable areas and water resources) will also be presented as are sources of soil information for Africa, including national contacts and institutions.

In collection with the later point, the partners of the atlas are actively developing a Digital Archive on Soil Maps of the World with the immediate objective to transfer soil information into digital format, with the maximum resolution possible, to preserve the information of paper maps that are vulnerable to deterioration. For some 40 years, ISRIC – World Soil Information has been providing significant support to the international science community by collecting and archiving regional-, national- and global-scale maps of soils and land resources.

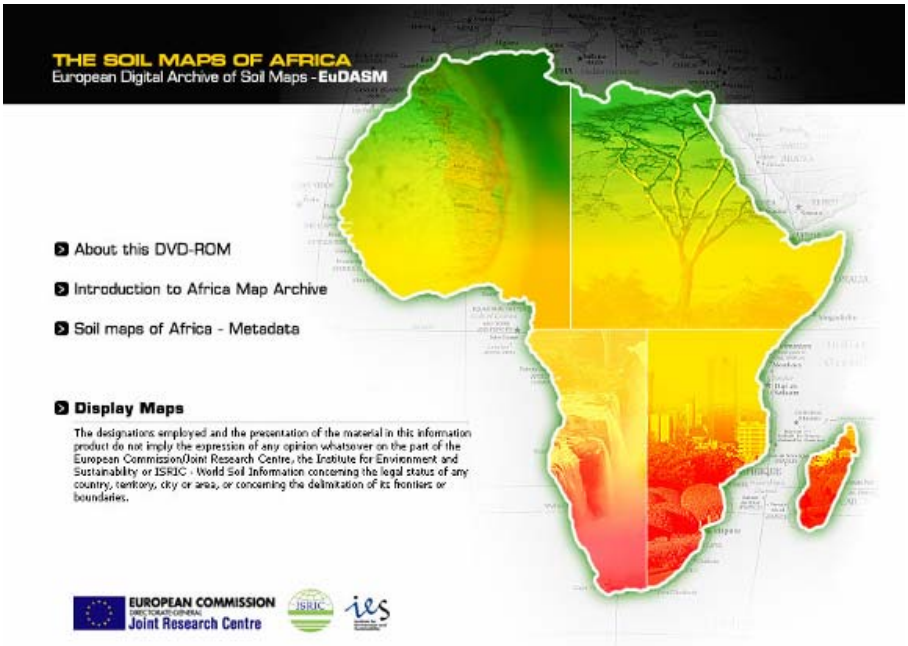
Despite effective procedures for storage and maintenance, most organizations involved in archiving struggle to arrest the deterioration of paper maps and the quality of information they contain. Deterioration occurs for various reasons that include handling, transport, exposure to light, moisture and atmospheric pollution.

Realizing the need to conserve the information on existing maps, which underpin the

fast-developing thematic mapping strategies to support soil protection, the Institute of Environment and Sustainability (IES) in the European Commission (Italy) and ISRIC – World Soil Information initiated the a Digital Archive of Soil Maps. The immediate objective is to transfer soil information into digital format, with the maximum resolution possible, to preserve the information of paper maps that are vulnerable to deterioration.

Beyond data rescue, the archive is expected to develop into a common platform for storing soil maps from around the world and making the information readily accessible.

Maps of different scales and sizes were scanned at 150-200 dpi resolution - based on the map quality and precision of information assumed to be required for future use by land resources specialists. During the first phase, the ISRIC Africa collection of more than 2000 maps was completed. It is expected that the FAO map collection for Africa will soon be added to this archive.



SESSION 1

Towards poverty, conflict and insecurity alleviation: Mapping Gum Arabic and Aloe in Karamoja Region, Uganda

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Abstract

For a long time, drylands were thought to be economically marginal, albeit erroneously. The drylands of eastern Africa were no exception, and as such pastoralism was (and to a large extent, is still) seen as the only means of livelihood for the communities living in these areas. This misconception largely explains the rampant poverty, conflict and insecurity that characterize these areas. Yet, these drylands have a lot more economic potential, that if tapped and harnessed in a sustainable way, will help alleviate poverty, conflict, and insecurity.

Karamoja Region in north eastern Uganda is one such dryland in eastern Africa. The region presents a unique development challenge, for unlike the rest of Uganda, it is semi-arid, and characterized by acute poverty, vulnerability to drought, poor infrastructure and basic services delivery, limited marketing opportunities, natural resource degradation, social and cultural marginalization, long-standing dependency on external aid, and more importantly, chronic insecurity (UNDP Report 2005). The inhabitants of this region – mostly the Karamajong, have practiced pastoralism as their main source of livelihood. The perception that pastoralism is the only way of life in this area is largely seen to be responsible for the poverty, conflict, and insecurity that prevails in this region. Incidentally, the region has other potential alternative economic endowments that remain untapped that can help transition the social and economic lifestyle of the local people through peace, stability and wealth creation.

It is against this background that His Excellency, the President of the Republic of Uganda, Hon. Yoweri Kaguta Museveni, started a presidential initiative that aimed at tapping into the "idle" economic potential of Karamoja as a strategy for poverty, conflict, and insecurity alleviation. Gum Arabic and Aloe, among other dryland resources were identified to kick-start this initiative. Inventorying and mapping of these resources was thus identified as the strategic starting point, upon which the resource base and economic viability of the initiative would be determined. The Regional Centre for Mapping of Resources for Development (RCMRD) and the Network

for Gums and Resins in Africa (NGARA) were approached by the Government of the Republic of Uganda to work with a local co-operative – the Uganda Gum Arabic Co-operative (UGAC) to undertake the resource inventory and mapping using satellite remote sensing and field surveys, and further advise the government on the economic viability of the project and a sustainable strategy for resource exploitation and marketing.

This paper discusses this project that hopefully, will empower the Karamajong.

SESSION 1

Use of ontology web language in remote sensing applications

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Abstract

One of the major challenges in the new millennium is how to manage the World's environment and its resources. As human population grows the pressure on resources also grow with it. Human activities have also increased impacts on climate change, which become major development challenges in the Horn of Africa. One of the ways of ensuring sustainable development is through use of geo-information. Remote sensing is a major way of collecting information. However, geo-information is an expensive resource which needs to be optimized. A considerable amount of remote sensed data of the Horn of Africa is available and quite a number of regional bodies are investing in acquisition of remote sensed data.

A major potential (or challenge) therefore is sharing of this information for effective and efficient decision making. But, how will this information be shared? In principle, it could be through WWW. And how will the user find it? As a user one way to find data is to use search engines such as catalogue services. There are a number of inherent problems with this system i.e. interoperability and processing of data/information in the web by the computer.

This paper explores the limitations of HTML, XML, and XML-S and explores the use of Resource Description Framework (RDF), RDF-Schema, and Ontology Web Language (OWL) for building portals for accessing remote sensed data.

Landform mapping for environmental applications: integration of visual image interpretation and digital terrain analysis

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Abstract

Land Resources inventory of key areas of Somalia is one of the main goals of the FAO-SWALIM Project. Two study areas were chosen according to the population density distribution and to the presence of agriculture activities: one in the northwest and one in the southern part of the Country.

An integrated landform mapping approach was set up and tested in the two areas. It led to the creation of a new, semi-detailed, baseline (scales from 1:100.000 to 1:50.000) of landform. Other products like, for instance land cover, land use, soils types, and soil erosion, accompanied the natural resource baseline creation.
Some of the main challenges were here posed by the final scale of mapping (varying between 1:100,000 and 1:50,000) and by the absence of an international standard for landform legend/mapping to be adapted to the present environment. The existing legends, in fact, have been designed for either different scales (1:1,000,000 to 1:200,000 and 1:10,000 and even bigger) or for different aims, and they usually do not consider some of the factors leading to the creation of relief (for instance the morphogenetic processes) (Batten, 2001; Cooke and Doornkamp, 1990; Cooke et al., 1983; Di Gregorio, 2005; Farshad; Klijn and Udo de Haes, 1994; Ollier, 1977; Scott et al., 1971; Van Zuidam, 1986; Verstappen, 1977; Wielemaker et al., 2001; Zinch, 1988).

The approach followed was thus bringing and bridging together some of the previous landform mapping methodologies, with a particular attention to hierarchical landform mapping approaches (like the FAO SOTER one, among others), and taking advantage of the modern technique of automated digital terrain analysis. Both the "traditional" visual image interpretation analysis and the "modern" digital terrain analysis were integrated under a GIS environment. For this reason it was also necessary to integrate different datasets depicting the morphology of the land, like, for instance: topographic maps, geological maps, DEMs and their derived products, and multi-resolution, multispectral and multitemporal satellite imagery.
A hierarchical landform legend was set up adapting the GeoPedologic approach (Zinck, 1988) and the SOTER one (FAO, 1998) to the use of Satellite imagery, and to

the use of geo-morphometric parameters.

The two study areas differing greatly in terms of climate, geology, morphology, vegetation, land cover and land use, proved to be good test sites for this approach.

The integrated hierarchical legend system here adopted includes three different level of morphologies of decreasing order, that are, from the less detailed (and more comprehensive) to the more detailed: landscape, relief, landform. Beside these, lithology and other morphometric parameters (slope, elevation, ruggedness, etc) were considered during the definition of morphological boundaries.

As a result of the mapping exercise the following main landscapes groups have been identified, in the north area: coastal area, piedmonts, peneplains, hillands, mountainous areas, plateaus, and valleys. From a morphological point of view the northwestern area is characterized by a varying topography (dissected mountains and eroded plateau) in general, with elevation ranging from 0 to 1850 m a.s.l. Three main climatic zones (pertaining to the Arid and Semiarid climates) follow the landscape subdivision. In the southern area the main landscapes groups found are: alluvial plains, domed hilland, piedmont and valleys. This area, corresponding to the lower part of the Jubba and Shabelle river basins, is characterized by a more gentle undulated topography with elevation ranging from 0 to 750 m a.s.l. Here is recorded a higher amount of rainfall than the northern one, but still falling into the Semi-Arid climate.

As a final result two new landform maps and datasets and a semi-automated hierarchical landform legend under GIS environment (using ESRI® Geodatabase) were prepared. An enhancement of the GeoPedologic approach is suggested.

The landform maps were successfully adopted as one of the fundamental layers for : Digital Soil Mapping, land suitability and land degradation application.

The promising results obtained allow us to suggest the use of this integrated landform mapping methodology to other different geological and morphoclimatic context. It demonstrated to be a flexible way of mapping landforms providing results that can be directly applied to other land resource mapping and also to natural hazards analysis.

Key words: landform mapping, GIS, Remote Sensing, DEM, Somalia, Geo-Pedologic approach, integrated approach.

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SESSION 1

The use of remote sensing for soil mapping: A Review

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Abstract

Soil maps are not only veritable decision-support tools for planning land resource utilization but are also the fundamental input into numerous models for predicting environmental change and mitigation methods. Despite their importance, large tracks of land in the world still remain unmapped. Even in the developed world, maps of soils at high resolution are still lacking. High costs and duration of mapping are among the many reasons for gaps in soil mapping. However, with the advent of remote sensing and pedometrics, new opportunities have evolved for expediting soil mapping. Consequently, soil scientists all over the world are beginning to suppose that either the previous mapping methodologies can be dispensed with altogether or high resolution soil mapping can be easily trivialized. It is therefore important that the potential and limitations of the new methods (remote sensing and pedometrics) be critiqued vis-à-vis the conventional soil mapping for a win-win compromise that is capable of promoting scientific advancements towards high-resolution soil mapping. The objective of this paper was to present such a critique as a review. It is anticipated that this review will enlighten scientists towards digital soil mapping of the world.

Keywords: Soil, mapping, remote sensing, pedometrics, field-survey

The Evolution of Aerial Strip Sampling into the Digital Era: Adaptations over 40 Years and Contemporary Relevance to the Horn of Africa, and in particular to Somalia.

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EXTENDED ABSTRACT

Aerial Strip Sampling for Counting Animals

Aerial strip sampling was started as a way to count wild animals. The first reports of aerial sampling in counting animals date from that late 1940's and early 50's, describing counts of bison and moose. Early published accounts of formal sampling procedures in remote sensing evaluations can be found in the work of Skoog (1962) and Siniff and Skoog (1964) in estimations of caribou numbers from a small sampling of rectangular areas of land surface in Alaska, and abundance estimations for red kangaroo by Newsome (1965) in central Australia, using strips as samples . More efficient sampling using stratified strip samples, with the strips extending over the full width of the stratum was first applied in East Africa by Watson in 1966 to the estimation of numbers of zebra in the Serengeti region, (Watson, 1967). Aerial strip sampling has steadily evolved methodologically until it, with line-distance sampling, has become a standard and much used methods for estimating and monitoring numbers of large animals.

The method can be represented in its simplest form by the diagram in Figure 1.

Figure 1-Simplified Diagram Aerial Strip Sampling to Count Animals

Aerial Strip Sampling for Resource Assessments in the Horn of Africa

Considering now the method's application to surveys of a wider number of natural resource features in the Horn of Africa region, the chief problem has been the difficulty observer faces in making observations and collecting records (photographs, intersection times, occurrence locations, magnitudes, etc.) of numerous features, (such as numbers of live and dead animals of particular species, associations, locations and activities of animals, numbers, types, size and use of structures, numbers, types and size of water sources, use of the land including farming system, crops, cropping cycle condition, vegetation and soil characteristics, flood and burn conditions, indications of current or past resource use such as charcoal kilns, fishing nets, snare lines, logging tracks, lime pits, salt pans, thorn "bomas", winnowing sites, harvest stores, etc.) along and within the sampling strip.

Figure 2: Legend

1 Important browse or use tree spp. (e.g. *Boscia minimiflora*)	16 Crop field (ploughed)	27 Cattle (feeding, drought, stall fed)
2 Elephant (large wildlife sp.)	17 Wood lot (*Eucalyptus* sp.)	28 Riverine pool
3 Area of important vegetation (e.g *Salvadora persica* thicket)	18 Berkad (with water)	29 Balli with water, without enclosure
4 Lesser Kudu (small wildlife sp.)	19 Berkado (with no water)	30 Enclosed balli with water
5 Somali grazier houses "in a compound"	20 Underground food stores	31 Thicket of *Suveda* and other halophytes
6 Somali grazier houses "not in a compound" [equal: domed house; other mobile]	21 Grazing reserve (note small garden area)	32 Goats (grazing)
7 Aba. Somali grazier houses "not in a compound" [equal: domed house; other mobile]	22 Important timber tree (e.g. *Borassus* Palm)	33 Sheep with goats (grazing)
8 Abandoned livestock enclosure	23 Camels	34 Sheep with goats in enclosure
9 Used (empty) livestock enclosure	24 Donkeys	35 Dry river bed
10 Used vehicle track	25 Well (in use) [permanent; riverine; coastal; sandiane; unpaved; abandoned]	36 Charcoal pits
11 Crop field (growing maize)	26 Tin roofed ridge- roofed house	37 Dry balli with enclosure
12 Crop field (growing beans)	27 Grass roofed ridge- roofed house	
13 Crop field (recent fallow)	28 Vehicle [4WD; truck; motorcycle]	

Aba. = Abandoned

The method of multi-feature sampling can be represented in its simplest form by the diagram in Figure 2.

KREMU and DRSRS in KENYA

The Kenya Rangelands Ecological Monitoring Unit (KREMU), now the Department of Resource Surveys and Remote Sensing (DRSRS) used teams of several observers, each trained to make observations of different and limited sets of features, flown by a pilot concerned only with flying. (Andere, (1979), Dirschl et al., (1978), Stelfox et al., (1979)).

Aerial strip sampling resource assessments by KREMU and latterly DRSRS have provided a continuous monitoring of Kenya's large animals populations and environmental conditions since 1977.

KREMU and DRSRS have produced over 150 Technical Reports which have been extensively cited in research publications, mostly covering methodology, conservation and environmental issues.

It is clear that this long term programme of aerial sampling has been of significant value in the research, environment and conservation fields. There is less evidence of its utilization by decision-makers for guiding policies and actions. Despite, or possibly because of, its impressive record in providing useful monitoring information for scientists the DRSRS has faced problems in the last few years, with loss of staff and budgetary support (Anon, 2004).

RMR in KENYA, ETHIOPIA, SUDAN & SOMALIA

Over 1968 to 1985, Resource Management & Research, working mostly for Government planning agencies under funding from multilateral and bilateral donors, developed techniques and equipment to be used by pilots flying small and slow flying aircraft. The pilots, research workers with several thousand hours of survey flying experience, used multiple stop watches controlled from the aircraft control column, head-set voice-activated tape recorders, recording radar altimeters, and several 35mm cameras, in an aircraft adapted for low speeds (100 km/h) at low elevation above the ground (100m) with long flight endurance (11- 13 hours). (Watson, (1979, 1982), Watson et al, (1977, 1979, 1985).

These methods were applied to make comprehensive resource assessments, with limited repeat monitoring surveys, over several large regions in the Horn of Africa, including most of the pastoral regions of Kenya (1968-73), much of Ethiopia (1971-74), all of Sudan (1974-76) and all of Somalia (1978-89). These areas are shown in Figure 3.

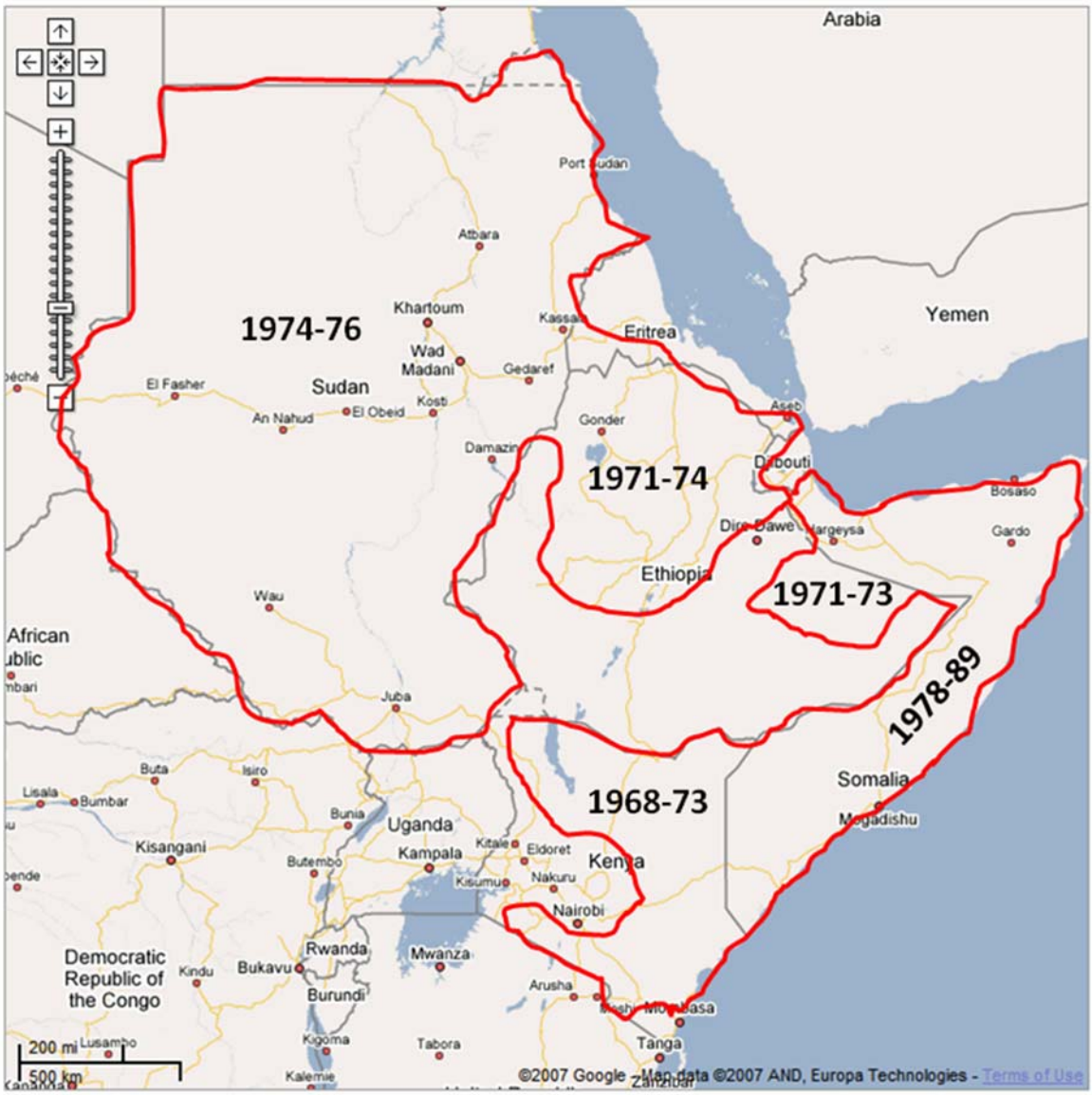

Figure 3 – RMR strip sampling resource surveys carried out in the Horn of Africa 1968 – 1989

It is felt that neither the aerial sampling resource assessments of KREMU-DRSRS and RMR, nor the methods which were developed to such a sophisticated degree in the period 1965 to 1985 in this region, have fully realized their potential for determining policies and plans for countries in the Horn of Africa. This is attributable to three main sets of reasons, broadly classed as financial, political and technical.

Financial Constraints

As a result globalization of financial and economic systems, increased focus on short term bottom line performance and associated perceptions, to some extent of a self-fulfilling nature, that the Horn of Africa is a composed of failed and failing states, the pattern of inward flows of resources in recent years has been of four main types:

1. Large "economically viable" infrastructure projects
2. Small economically viable services replacement provision
3. "Enclave" construction or purchase
4. Relief, Training, Capacity Building and Development Activities

In these investment conditions it is evident that a national resource information infrastructure, which could provide guidance on directions for long term sustainable investments with high national and social benefits is at best unnecessary or at worst an embarrassment.

Political Constraints

National or regional resource assessments by aerial strip sampling can only be made when a country or international agency commits substantial funds to this purpose. An overall sampling cover of 5% of the surface entails expenditure of $2 to $5 per km^2 of territory. With donor funds so committed to demonstrative relief and development works, it would require significant political will within a Horn of Africa country to request and secure funds to build an effective national resource information infrastructure.

As the role of national planning in the region has largely ceased to reflect resource potentials, none of the Governments in the region are likely to put a resource information infrastructure high on their list of priorities.

Technical Constraints

The application of the methodology for national resource assessments took the method to the "analogue" limits in terms of the pilot-operator's capacity to make observations and operate recording devices. The work of interpreting, counting, calculating, analyzing and reporting was a large operation involving radar altimeters, sample strip demarcators, cameras, photo-processing, microscopes, dictaphones, ledgers, stop watches, maps, rulers, calculators (initially electro-mechanical, then electronic), drawing tables, planimeters, stencils, typewriters, printers, and duplicating machines (and more recently photocopiers) , and requiring management of a large team of technicians. These problems in effect prevented widespread commercial adoption of the method for national resource surveys. Digital equipment (computers, radios, cameras, GPS, timers, etc.) and parallel development of programmes and communications) have solved most of the technical difficulties of the method. Furthermore there is now the opportunity for national resource surveys to be easily put into the public domain, enhancing the potential of national land

resources information to play an important role in supporting sustainable and reasonably equitable economic and social development. (Watson, 1990, Nimmo, 1991, Watson and Nimmo, 1993)

The Present Opportunity in Somalia

It is argued that there is an opportunity now to use stratified aerial strip sampling to create an up-to-date resource assessment for Somalia.

The main reasons are:

1. The urgency of starting to stabilize and turn round the highly uncertain Somali situation.
2. The need to fill the resource information vacuum, particularly to permit objective prioritization of relief and assistance measures.
3. Resource information is seen to be a topic where it will be relatively easy to secure the co-operation of parties with administrative authority.
4. It is safe to fly in Somali airspace between 500m and 8000m.
5. Modern GIS and associated tools would allow the 1978 to 1985 national resource surveys of RMR to be rather rapidly and cheaply converted to a base-line GIS, which provides benefits for implementing and interpreting a new assessment.
6. The previous national resource assessment is already nearly 30 years old and needs to be turned into a GIS, and up-dated.
7. Developments of digital equipment and processes now enables a better and safer sampling of resources by aerial strip sampling.
8. Interpretation work, using a range of automated routines, can be managed to involve concerned parties.
9. Digital sampling can be combined with other surveys at negligible additional cost.
10. Digital sampling data can be used to improve interpretation of existing total cover data available from satellites and aircraft, offering an improved route to estimations and mapping of many resource features.

An Outline for a Somali Resources Assessment by Aerial Sampling (SOMRAAS)

Data Acquisition

Acquisition of data for an strip-sampling resource survey for Somalia could be carried out in about 104 operational days (say 150 days) using an aircraft with a cruising speed of 520 km/hour and endurance of 5.5 hours, based in Wajir and Djibouti. Some 540 hours of flying would be needed. If Bosaaso were able to be used as a

SESSION 1

base (for 30 operational days), operational days could be reduced to 95, with flying being reduced to 500 hours. Figure 4 presents a block map showing a tentative flight programme for a SOMRAAS.

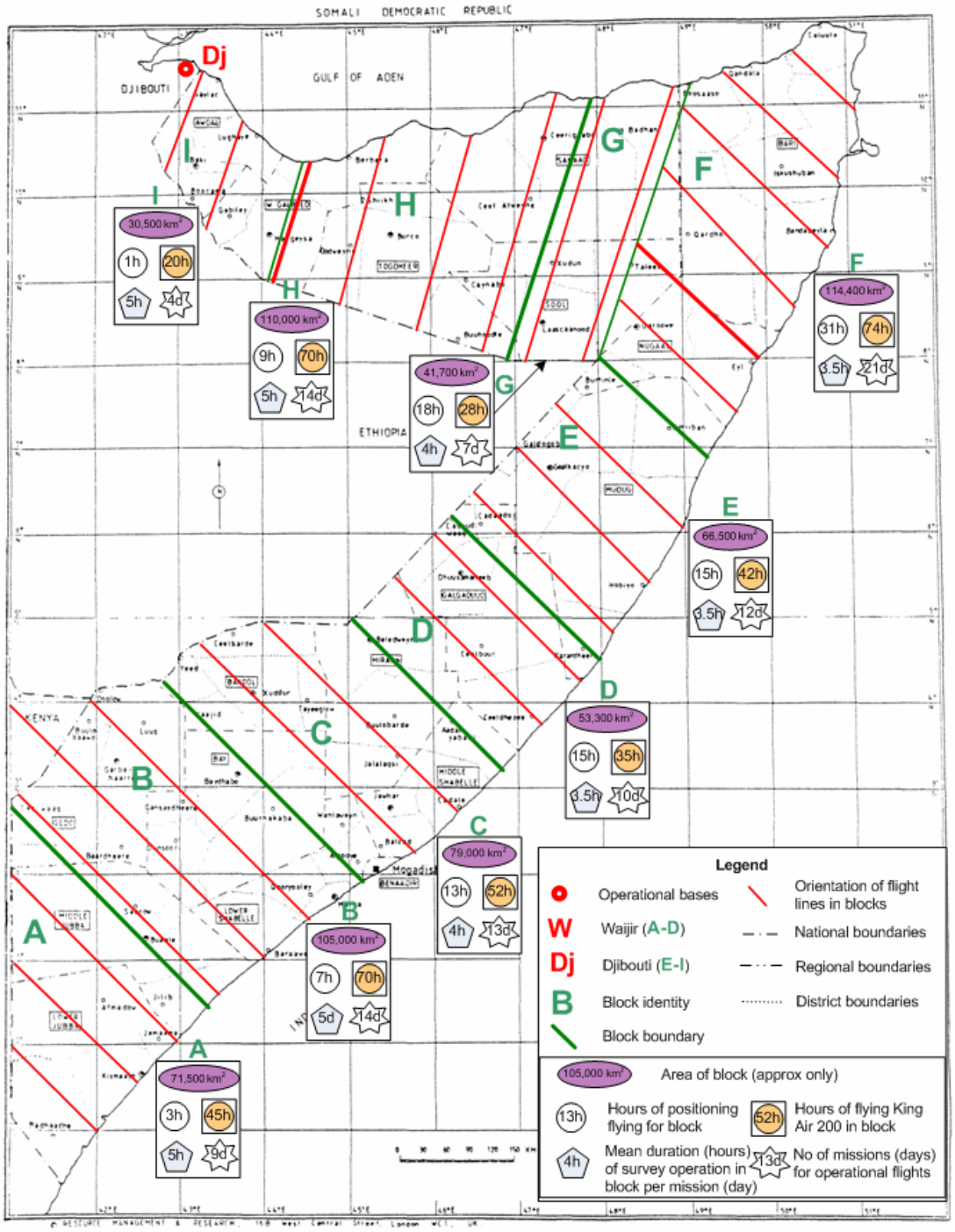

Figure 4. Tentative flight programme showing time requirements and flight line orientations (for 3km spacing of sample centre lines)

Table 1 below sets out the main flight operations information.

Table 1 Flight Operations for SOMRASS with Wajir, Djibouti and Bosaaso as Bases

Base	**Wajir**	**Wajir**	**Wajir**	**Wajir**	**Djibouti**	**Djibouti**	**Djibouti**	**Djibouti**	**Djibouti**	
Block	A	B	C	D	E	F	G	H	I	All
Area (approx) (km2)	71500	105000	79,000	53500	66500	114400	41700	110000	30500	672100
Av. duration of ops. flights	5	5	4	3.5	3.5	3.5	4	5	5	
No. of missions (days)	9	14	13	10	12	21	7	14	4	104
Operations hours	45	70	52	35	42	74	28	70	20	436
Positioning hours	3	7	13	15	15	31	8	9	1	102
Total hours	48	77	65	50	57	105	36	79	21	538

Base	**Wajir**	**Wajir**	**Wajir**	**Wajir**	**Bosaaso**	**Bosaaso**	**Bosaaso**	**Djibouti**	**Djibouti**	
Block	A	B	C	D	E	F	G	H	I	All
Area (approx) (km2)	71500	105000	79000	53500	66500	114400	41700	110000	30500	672100
Av. duration of ops. flights	5	5	4	3.5	4	5	5	5	5	
No. of missions (days)	9	14	13	10	10.5	14.8	5.6	14	4	94.9
Operations hours	45	70	52	35	42	74	28	70	20	436
Positioning hours	3	7	13	15	10.5	3.5	1.3	9	1	60.3
Total hours	48	77	65	50	52.5	77.5	29.3	79	21	496.3

It would be possible to acquire the images simultaneously while carrying out a full stereo-photography cover from which a sub metric DTM, and orthophotos with about 50cm resolution could be acquired.

The data acquisition part of SOMRASS would be most efficiently implemented with a 13MB digital camera, with combined IR and visual wavelength sensors. A strip width of 400m (the probable maximum, although a range between 200 and 400 will be tested) would deliver a ground resolution on the sampled strips of 10cm (= pixel size)

The possibility of making a forward scanning video recording of lower resolution of the same sampling strip will be tested to determine its value in improving interpretation efficiency. A video set slightly in advance of the vertical frame sample has been

found useful in surveys carried out in Laos for detecting movement and identifying species of wildlife, which provides the interpreters additional clues for searching the vertical frames.

Some 463 flying hours would result in about 900,000 frames of 13 Mega Pixel size, which, allowing for one backup copy, require storage of 10,000 gigabytes, (20 of 500 Gigabyte Hard Drives)

Data Interpretation and Quantification

The interpretation of the images requires each frame to be searched, and selected features identified, classified, counted, measured, or plotted. The routine to be applied depends on the nature of the feature and the way it is being managed in the GIS.

Trials have shown that well trained and motivated technicians are able to interpret and evaluate frames of 400m * 300m size in about 150 seconds. Exceptional individuals are able to work at speeds of 1 frame per 45 seconds. These speeds are equivalent to moving forwards in aerial strip sampling mode at about 2m/s (or 7.2 km/hour) and 6.7m/s (or 24 km/hour). These speeds of interpretation can be achieved only if the interpreter has a properly set up work station with appropriate software.

Such a work station comprises a twin-screen desk top work station running the client's preferred GIS (ArcGIS would be the author's choice). Each frame appears and automatically registers itself in the GIS for time and location. The interpreter marks items for counting (as points), measuring (lengths and perimeters) and plotting (lines). Each item entered brings up a hierarchy of menu procedures, called a System for Hierarchical Analysis and Date Entry (SHADE), to ensure full and efficient data entry. The results of identification, location marking and attribute listing enter the GIS and can be used to generate the normal range of statistics (estimates for any specified area or the whole country, standard errors and variances, associations etc.). The data entry sheet for each frame is filed with all associated information (times, cursor movements, errors and amendments) to facilitate quality checking, training performance improvements and needs.

The authors will bring some training images and a version of the System for Hierarchical Analysis and Date Entry (SHADE), already used for interpretation of sampling strips, which can be demonstrated at the workshop, to show a typical Resources Assessment by Aerial Sampling installation .

Assuming frames can be interpreted and dimensioned in 150 seconds, the SOMRASS would need about 37,500 hours of interpreter time. Twenty interpreters and twenty two work stations would be needed to complete the SOMRASS within one year.

The costs of a SOMRASS, including capital costs of all equipment used, assuming interpreters can be hired for 8 Euro/ hour, would be about 1.1 million Euro, or 1.7 Euro per km^2.

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Open web services and SDIs

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Abstract

Open web services offer means for alleviating one of the long-standing constraints to application of remotely sensed data to environment change assessment in the Horn of Africa. Access to the images themselves, access to the data processing methods needed to make them useful information, access to the audiences needing the information are all constrained by the thin, unreliable and expensive data channels common in Africa.

The traditional solution has been for each institution to build an expensive, fragile and potentially unsustainable Stack comprising computer systems suited to the task, skilled analytical competence, data communications bandwidth, the necessary raw data and the computational means for usefully transforming the data. The alternative described here envisages distributed interoperable services based on open standards and an internet bus architecture that allows the bulk of the data transfer, processing and analysis load to be shifted to those parts of the world best equipped for these tasks. Only the light-weight, refined, value-added product need be delivered to the end user. The UN sees similar approaches being crucial to its ability to coordinate its own services to best meet the needs of the member states.

SESSION 2
ASSESSING ENVIRONMENTAL CHANGE

Year 1970 topographic map: notethe position of the Juba river mouth

17/11/2001 Landsat ETM+ image (false colour composite): note the Juba river mouth position and to the sediment plume in the sea.

Monitoring Land Cover Dynamics in Sub-Saharan Africa

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Abstract

Over the last decades sub-Saharan Africa, with its abundant natural resources, has been subjected to a series of major disturbances, both 'natural' and man-made; drought, civil disturbances, large population increases and the impacts of 'globalization'. Each of these has had implications for land-use requirements, with subsequent impacts on natural vegetation cover, biodiversity, socio-economic stability and food security. The modification of the vegetation cover, with a predominant clearing of natural vegetation, may have a long-term impact on sustainable food production, freshwater- and forest resources, the climate and last but not least human welfare (Foley et al. 2005). In many developing countries populations are heavily dependant on freshwater, forests, croplands and fisheries (Homer-Dixon and Blitt 1998) to which we should add pastures. Shortages in these sectors can give rise to increased poverty, environmental refugees (Jacobson, 1988) and even conflict. There is a growing body of literature on environmental scarcity and conflict (Raleigh and Urdal, 2005, Urdal, 2005) which reflects not only current concerns but that of future scenarios based on climate change prediction and its subsequent impact on water resources, land degradation and food production. Just how much land cover change has occurred over the last decades is not entirely clear – as reliable statistics are hard to obtain.

Conventionally, data on land cover, -productivity and -dynamics are available through the Food and Agricultural Organization (FAO) of the United Nations, which collates statistics from the countries themselves, harmonizes and rationalizes them to form global data bases on forests (Forest Resource Assessment – FRA) and on agricultural production (FAOSTAT). While these databases are valuable sources of information, they inevitably suffer from a lack of consistency and completeness both in time and in geographic coverage – relying as they do on the completeness of the national data sources which in some countries are incomplete or out of date. The methods for collecting the data, the actual information collected and aggregation it undergoes may vary markedly between countries, making harmonization and rationalization difficult (see Mathews, 2002, for a similar debate on global forest statistics collected by the FAO). There is therefore a clear need to develop methods to regularly assess and

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report on key resource extent and condition using robust and repeatable methods.

In the framework of the *ACP Observatory for Sustainable Development* the *Monitoring Natural Resources for Sustainable Development* (MONDE) activity at JRC is developing Earth Observation based methods to monitor the environment and its changes in Africa. Low resolution satellite data and its derived products, such as surface water detection, vegetation phenology, land cover change detection and burned surfaces seasonal variation, have been developed under the *Geoland* project and are distributed through the VGT4Africa system to the users.

High resolution satellite images have been used to quantify the areal extent and its changes of four broad land cover classes: forests, natural non-forest vegetation, agriculture and barren areas, at two key dates 1975 and 2000 at sub-Saharan Africa level and at eco-region level. The eco-regions are based on the White/ UNESCO vegetation map of Africa. While the data, such as that available from the Landsat Thematic Mapper, are appropriate for the mapping task they have a restricted coverage both in time and in space. To cover the full sub-Saharan region 1200 such scenes would be required, with important cost implications, both in image acquisition and processing. A standard technique adopted in land cover inventories, is therefore to use a sampling strategy across the target area (*e.g.* Achard *et al.* 2002). The sampling framework of our study consists of a tessellation of hexagons across the study area (Richards *et. al*. 2000, Boschetti *et al*. 2006). A post-sampling stratification was applied using a modified version of the White/ UNESCO vegetation map of Africa, targeting a sampling rate of 1% in each of the strata. Finally, a sample of 57 hexagons was selected and the nearest satellite Landsat TM scene from the World Reference Series (WRS) II grid to the centre of the hexagon selected. From each of the Landsat scenes nine sub-scenes of 20 by 20 km were extracted and used to assess the land cover.

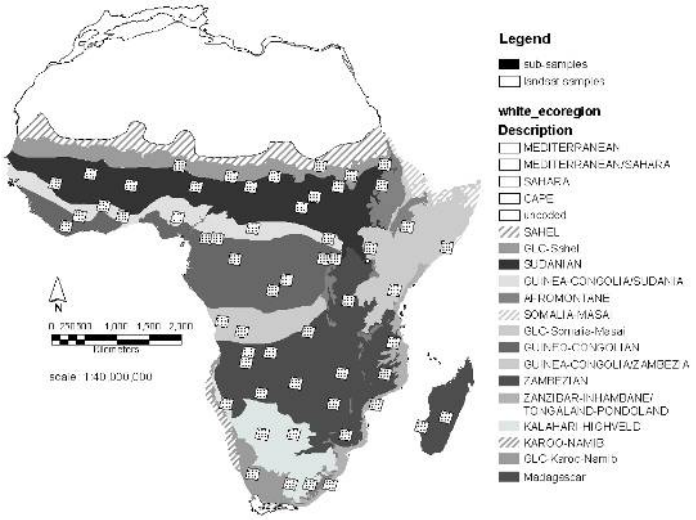

Figure 1: Eco-region stratification and sample sites

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The sub-scenes were independently classified using a statistical unsupervised clustering algorithm and then visually interpreted into the four main land cover classes. The results produced an estimate of the extent of agriculture, forests, natural vegetation and barren areas for sub-Saharan Africa for the years 1975 and 2000 at a continental and at an eco-region level, with a further estimate of the changes in these classes between these two reference years. Our estimates for sub-Saharan Africa's land cover in the year 2000 show that 17.3 % of the region was under agriculture, 18.8 % forests, 60.8 % non-forest vegetation, 2.5 % barren and under 1% water (Table 1). These figures correspond closely to those of the most up-to-date land cover map of the region (Mayaux *et al*. 2004) also produced from satellite data from 2000, all be it of a different spatial resolution (SPOT VGT 1km data). The largest difference between these two estimates is for agriculture (2.5 %). Furthermore, table 1 show that the most dramatic changes in land cover of the period have been the increase (57%) of agricultural lands. The area covered by agriculture increased from 215 Mha in 1975 to 338 Mha in 2000, which gives an annual rate of 2.3 %. This has occurred at the expense of forests and non-forest natural vegetation, contributing 55% and 45% respectively to the total, and equates to some 5.2 Mha (52,000 km^2) of natural vegetation lost a year. In total this means that sub-Saharan Africa has lost some 130 Mha of natural vegetation (forests and non-forests) over the last 25 years, amounting to 8% of the total, some 16% of her forests and 5% of her non-forest natural vegetation. Barren areas have also increased significantly, although due to the limited availability of satellite data our study does not cover 'desertification' processes, which require multi-temporal analysis so as to remove possible seasonal and inter-annual effects.

Table 1: land cover dynamics at sub-Saharan level between 1975 and 2000

	Agriculture	***Forest***	***Non Forest Vegetation***	***Barren***
	(000 ha)	***(000 ha)***	***(000 ha)***	***(000 ha)***
Land cover 1975	215,274	438,917	1,247,980	42,912
Land cover 2000	338,687	367,592	1,189,085	49,477
Total change	123,413	-71,325	-58,894	6,565
Total change (%)	57.33	-16.25	-4.72	15.30
Average annual change	4,937	-2,853	-2,356	263
Average annual change (%)	2.3	-0.7	-0.2	0.6
GLC 2000	330,300	363,800	1,211,000	48,300
Difference from GLC 2000	2.5	1.0	-1.9	2.4

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We hope to demonstrate that such an approach can give consistent and repeatable results for natural resource assessment, valid at sub continental levels. Future work will be part of the JRC-TREES and FAO-FRA project which will assess changes based on a regular sampling strategy framework, high resolution satellite images initially covering the period 1990 – 2000 and in future also 2005 and image segmentation technology to asses the land cover and its changes.

The Broglio Space Centre's Contribution of Remotely Sensed Data for Environmental Change Monitoring in the Horn of Africa Region. Institutional partnership and Challenges in Data Acquisition and Distribution.

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Abstract

Institutions and practitioners in the Horn of Africa are increasingly becoming aware of the importance of satellite data usage in land and ocean resource monitoring and weather predictions. One of the most promising activities carried out at the Broglio Space Centre (BSC) in Malindi, Kenya is the satellite data acquisition, first started in 1997, with the ERS1 SAR images. Satellite imagery regularly acquired at BSC includes the AVHRR sensor on NOAA satellite series, SeaWiFS sensor on SeaStar satellite, and MODIS data on Terra and Aqua satellites. In the near future the Centre will add SEVIRI data acquisitions from the MSG satellite. This will enable the development of several real-time product applications, spanning from early fire detection, sea surface temperature (SST) suitable for the estimation of coral reefs bleaching area forecasts, Ozone and Cabondioxide estimation, statistical cloud cover, given the high observation frequency (15 min.) of MSG. For the polar orbiting remote sensing satellites, the area covered by the receiving antennas has a radius of about 2000 km, covering all the East and central African countries including the islands in the western Indian Ocean region. In the absence of comparing remote sensing infrastructure in the region, the BSC is naturally going to assume an outstanding reference role for the scientific community and the national authorities in satellite data acquisition.

In response and in recognition of the fact that a large amount of data useful for marine applications, land use changes, drought, atmospheric, climate and weather forecasting and assessment is available at the BSC, cooperation was first established with the Kenya Marine and Fisheries Research Institute (KMFRI). In 2006, a team from the Italian Space Agency (ASI) who is in charge of the BSC management, met with officials of the Meteorology department of the University of Nairobi, the Director

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General of IGAD Climate Prediction and Applications Centre (ICPAC), the Director of the Department of Resources Surveys and Remote sensing (DRSRS), the Director of Kenya Meteorological Department (KMD) and also the Director General of the Regional Centre for mapping of Resources for Development (RCMRD). The aim of these meetings was to forge and expand partnership on the way forward as regards suitable and appropriate satellite data to be acquired by the facility at the BSC, which have direct and immediate applications for the regional community. It was viewed that these institutions with their excellent networks, infrastructures and based in Nairobi, could act as hubs for all data generated from BSC for archival and distribution.

Evidence shows that the region has only a small pool of expertise trained in satellite technology, imagery processing, data manipulation and management. In order to promote the use of remotely sensed data in practical applications, three training courses have been organised and conducted at the BSC in the recent past, with participants coming from local universities and governmental institutions. These courses exposed the community attendants on how to set and manage a satellite acquisition ground station, besides first hand experience on the ease and difficulties in satellite data processing, interpretation, archiving and distribution.

A one-year pilot project named Western Indian Ocean Satellite Application Project (WIOSAP) was carried out by KMFRI, BSC and the KMD. The aim of the project was to set up the infrastructure for the development of a satellite-based fishery forecasting system for the entire Western Indian Ocean (WIO) region, specifically for Tuna and tuna-like species, so as to assist commercial fisherman in locating these highly migratory species. In fact a combination of sea-surface temperature with ocean colour data can greatly improve weekly high potential fishing zone maps. On the same line, such parameter may be utilised to map and monitor Ocean hot spots. For the future a regular production of the required information will be implemented by ASI – BSC to be used and disseminated by KMFRI with inputs from KMD. A number of research personnel from KMFRI, KMD, the University of Nairobi, among others, have undergone training courses at the BSC. KMFRI has also organised a tailor made course on satellite applications specifically for the WIO region community. This course was conducted at the BSC premises bringing the participation of oceanographers from the region; Madagascar, Tanzania, Mauritius, Mozambique and Kenya. Further, advanced training in ocean remote sensing, particularly on satellite imagery analysis for SeaWiFS, MODIS and AVHRR and MERIS required by users, will be organised by ASI also in the near future.

Upcoming joint activities of BSC, KMFRI and other interested institutions will include

the implementation of an early warning system for oil spill detection in the WIO region, based on ERS-2 SAR images and the soon to be launched COSMOS Sky-Med satellite constellation. More useful information on ocean parameters could be derived from MERIS and other sensors onboard of ENVISAT satellite, managed by European Space Agency.

Organisations within the region are invited to partner in joint projects with ASI. This will give all institutions the opportunity to disseminate value-added information derived from satellite data to be applied as a tool in assessing environmental changes in their respective areas in the Horn of Africa region**.** All data acquired at the facility are available free of charge to the Kenyan research community and other relevant governmental institutions. Other interested researchers from countries in the region may access these data though partnership with local research institutions or through direct agreements with ASI.

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Rehabilitation of Rangeland, making use of Remote sensing techniques: A Case of Eastern Sanaag Region, Northern Somalia.

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Abstract

Accelerated environmental degradation has been occurring in Eastern Sanaag, Northern Somalia primarily due to cyclones, high intensity storms, and drought events that caused enormous soil/gully erosion with great damage to prime grazing valleys. The four year (2001-2005) drought resulted in environmental crisis and loss of livelihoods by the predominantly pastoral communities. As a result Horn Relief commissioned an Environmental assessment study which used Computer Aided Land Cover Classification by ERDAS Imagine software; FAO's Africover Land-Cover Classification System; and ground observations to assess land-cover changes over a 15-year period (1988-2003). The study showed that 52% of forest has been lost on the Sool plateau, a 32% decrease in shrubs open and 40% decrease in especially in Gebi Valley and Xadeed and a 370% increase in bare land in Soil Plateau, Gebi Valley and Xadeed. Remote sensing techniques were also used to map hot spots with high degradation occurrence and remedial measures undertaken on some areas to rehabilitate especially important rangelands whose vegetation can regenerated by using water spreading and conservation techniques including check dams, permeable rock dams, and soil bunds at selected sites with the aid of topographic maps through cash for work methodology. So far over 20 small and medium to large gullies were controlled and over 30 km^2 of rangelands improved through water spreading and water conservation measures. Observed improvements include deposition of soil sediments, seeds for grass, shrubs and trees from upper parts of the watershed, reduced advancement of gully heads, and remarkable regeneration of vegetation in formerly bare lands.

Case-Study: Use of satellite remotely sensed data integrated with the livelihood baseline information in support of food security monitoring and early warning activities in the Sool & Nugaal pastoral region of Somalia.

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Abstract

The Sool & Nugaal livelihood zone of Somalia depend largely on pastoral and related activities as their main source of livelihood. This region is frequently adversely affected by extreme climatic weather patterns culminating into recurring severe droughts followed by floods. In 2003, their livelihoods were at a brink of collapse following seven seasons of successive droughts, prompting an Inter-Agency Assessment mission in the region. The assessment mission report, underlined the inherent chronic food insecurity problem in the area that requires comprehensive monitoring of all food security indicators and early warning in support of timely contingency and response planning.

This paper focuses on the using a synergy of livelihood (where and how people live) baseline information and remotely sensed products in contextualizing the impacts of key climatic hazards (drought and floods) that affect these vulnerable pastoral communities living in Somalia. Where, there are sparse relevant field data collection systems to support effective and comprehensive monitoring. Ultimately, informing decision making in contingency, response and developmental action plans.

The analysis and results of this case-study demonstrates the efficacy and potential applications of satellite derived products and GIS tools in monitoring the extent and magnitude of drought (using NOAA/NDVI, MODIS/NDVI and WRSI/Rangeland), water resources (CPC/RFE), and environmental degradation (Landsat) caused by over grazing around watering points, i.e wells and "berkads". The approach taken in this case-study could lend its usefulness in developing "best-practice" techniques for

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monitoring recurring droughts and floods for the large populations of pastoralists living within the Greater Horn of Africa.

The use of Remote Sensing information as a proxy of weather and climate in the greater Horn of Africa

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Abstract

Weather and climate information for Africa has been based on the analyses of observed *in situ* data from weather stations spread across the continent. Unfortunately, the numbers of operational stations have been declining for various reasons across the continent. The Greater Horn of Africa (GHA) also experiences similar problems. This paper outlines the work that IGAD Climate Predictions and Applications Centre (ICPAC) is doing in monitoring weather and climate over the GHA in the face of declining *in situ* data. Particular examples for Somalia are presented.

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The African Marine Information System: a tool for ecosystem management in coastal waters

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Abstract

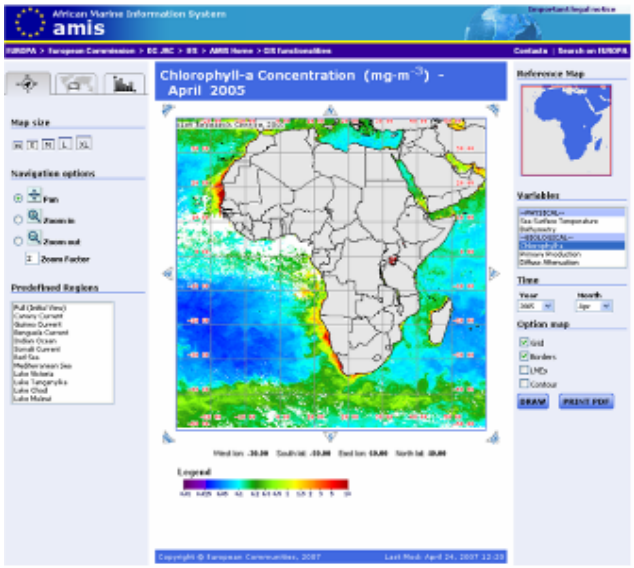
The Multi-annual work programme of the JRC for the year 2007-2013 is firmly set in the context of the Commission policy agenda. The inclusion of "Europe as a world partner", as a Policy priority Theme, indicates a strategic positioning of the JRC on the global arena to support a range of external policies. These include a "Development Cooperation" policy, where the JRC will provide information and tools for planning, monitoring and assessing development programmes. The focus will be on the establishment in ACP countries, specifically sub-Saharan Africa, of satellite based monitoring systems on the state of resources and environment under growing human pressure and climate change. Particular attention will be paid to coastal zone management and marine resources.

The Global Environment Monitoring Unit at JRC is currently processing and distributing ocean colour and thermal products from multiple sensors (CZCS, SeaWiFS, MODIS, MERIS) at global and regional scales. The products include time series of water leaving radiances, phytoplankton biomass, primary production, and diffuse attenuation coefficient in water, using standard (space agency-related) and in house peer-reviewed algorithms. These products represent the basis for research and development activities that support the generation of a system for permanent environmental monitoring in Africa. The system includes:

- the provision of continuous, detailed and accurate information on relevant marine biophysical parameters as derived from optical, and infrared satellite sensors;
- the generation of indicators (up-welling index, primary productivity, primary productivity required, features seasonal timing) for global diagnostic of the coastal state and analyses of changes in marine ecosystems;
- the optimization and implementation of an interdisciplinary system of marine resources information and analysis (GIS) in order to enable decision makers (DG's, African nations) to make full and lasting use of this information;

- training sessions in making use of available information and advanced analytical tools.

As part of these activities, the African Marine Information System (AMIS) has been recently developed to provide the Users with an appropriate set of bio-physical information, of importance to conduct water quality assessment and resource monitoring in the coastal and marine waters. AMIS is a simple and easy-to-use mapping tool application, developed for the publication and dissemination of African marine information via the web. It is a web-based application that allows the provision of scientific information, by way of geo-referenced maps (created in real-time), and supplies the users with basic navigation and interrogation tools.
Geographical sources are mainly raster data, stored in netCDF files, a machine-independent format for representing scientific data. The African Marine Information System application is written in *PHP* and *Perl*, scripted programming languages for developing server-side applications and dynamic web content and it is based on a *UMN MapServer* engine, an open source environment for building spatially-enabled internet applications. Its functions are written in *C* and its interaction with *PHP* is achieved using *PHP/MapScript*, a dynamically loadable module that makes *MapServer*'s functions and classes available in a PHP environment.



The GIS functionalities of AMIS enable the visualization and analysis of a variable through the following steps: variable selection, map navigation, identification of region of interest and statistical analysis.

Regional Marine Analysis

AMIS includes a list of pre-defined regions around Africa, corresponding to major oceanic systems such the Benguela Current, the Red Sea, the Somali Current and others. A set of primary statistical analysis can be conducted on these areas, as well

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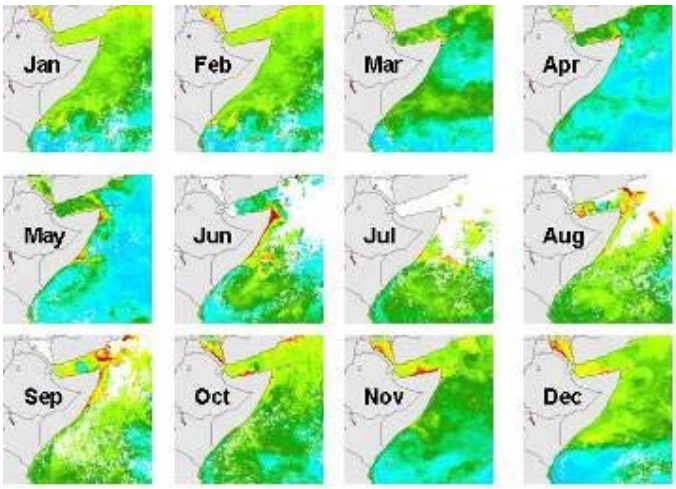
as on any region of interests selected by the user. The identified region can be a single geo-located pixel or a rectangular area selected either by hand or by entering lat/long boundaries of the box. An example is given below for the Somali Current system

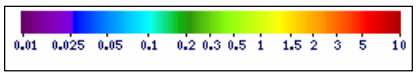
Somalia has the longest national coastline (3025 km) in Africa with an estimated shelf area (depth 0-200 m) of 32,500 km², and Fisheries represent an important sector of Somalia economy. This economy, however, is closely related to the state of the surrounding environment and natural resources. The distribution of fish is highly vulnerable to climatic fluctuations, and the establishment of an adequate environmental monitoring system is compulsory for the development and implementation of strategies to ensure a sustainable control of the resource.

Monsoonal winds and their seasonality produce complex oceanographic features in this part of the Indian Ocean and induce coastal upwelling along the coast. These physical changes directly affect primary production processes but also may be expected to influence the abundance, distribution and diversity of other organisms dependent upon that production.

AMIS makes possible the analysis of time series for various environmental variables of importance to the management of marine resources.



As an example, a time series of monthly chlorophyll concentration along the Horn of Africa highlights the seasonal variation of the various water masses. The frontal structures and meanders are often sites of fish stock congregations and migration. (Data are from the processing of MODIS



In addition to time series, other types of statistical analysis can be done within AMIS on the selected region of interest: basic statistics with histogram display, spatial analysis based on a threshold visualization scheme, and correlation. To get a maximum quality on the output, a 'pixel filtering' is applied to reject outlier pixels that

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can bias the computation of the statistics.

The tool as described in this presentation has been implemented in the JRC web page (http://amis.jrc.ec.europa.eu/) . At present, the user has no free access to the data themselves (available on request), but is generating automatically maps, scatter plots, histograms, time series in a format ready for publication. This tool can then be used in fishery assessment to study the relations among species, the interaction between fish stocks and climate forcing variables, or socio-economic information. Satellite data of temperature and primary production can also be an important factor for determining potential fishing grounds since different fish species have different optimal temperature range and biomass requirements. Additionally, AMIS tool facilitates the monitoring of a number of issues that impact fisheries, such as harmful algal blooms and coastal pollution.

SESSION 2

The Use of Remote Sensing in Land Cover Mapping, Change and Impact Detection in Somalia

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Abstract

Land cover is a tangible indicator of the kind of ecological activity taking place on the earth's surface. In the recent times, it has been significantly modified by human activities. Although some of the modifications may bring favourable environmental conditions, others may exacerbate adverse climatic conditions. Especially in areas surging with socio-political upheavals such as Somalia, the negative modification of land cover can accentuate adverse climate change through the loss of biomass. The endeavour of governments and scientists the world over is to stem negative land cover changes while contributing to the positive land cover dynamics that can sink green house gases and subsequently provide sustainable conducive living environments. One of the prominent contributions has been through the accurate and thorough characterization of land cover dynamics in a way that can allow comparisons over time and space. Especially with the advent of GIS and remote sensing, the characterization of land cover dynamics has been largely trivialized. However, it is important to note that the use of remote sensing employs products and techniques at varied scale and level of accuracy that may affect the intended use of the land cover maps. This study compared the popularly used GLCN products, the automatic image classification approaches, and field observations in assessing land cover change.

The methods involved the Global Land Cover Network (GLCN) visual interpretation approach and a supervised digital classification using the nearest neighborhood algorithm in ERDAS Imagine Software. An accuracy test was subjected to both the maps. The GLCN map identified insignificant changes in land cover of the study area while the digital supervised classification showed significant changes in land cover. Filed interviews with the local people also confirmed that the changes in land cover had been considerable. Vegetated land had changed to bare lands over the years due to overgrazing and tree cutting for charcoal burning.

The study also focused on the impact of human settlements and water-points to the

fragile environment in selected pastoral areas in Somalia (north and south of Garowe). Multi-temporal satellite images (1973, 2001 and 2006) were used to show the change in land cover around the settlements and water-points. Normalized Difference Vegetation Index (NDVI) was used to assess the vegetative vigor around these areas over the time. Field observations carried out in March 2007 were used to validate the image features and to take advantage of the indigenous knowledge, with the people, about the land cover in these areas. The field observations involved scientific approaches of ecology and use of the indigenous knowledge. The results showed that settlements and water-points contributed to increased pressure on the fragile environment and consequently caused negative changes in land cover around the settlements and water-points during the period between 1973 and 2006. The most notable form of land cover change was removal of vegetation and subsequent increase in bare lands. Over the same period, NDVI values reduce around the settlements, thus confirming the claim by the local people that these settlements had experienced considerable change in land cover.

These results show that whereas visual interpretation, on the one hand, produces nice polygon maps on land cover, it is not possible to map smaller changes in land cover due to the inherent inaccuracies in mapping scales. Digital classification, on the other hand, may be more reliable in detecting very small changes in land cover, especially in situations like Somalia where field work is limited. The pixel based nature of this method produces a fuzzy product that for planning purposes requires further aggregation techniques. The accuracy test shows that if ample training sites are used, the digital classification technique could be more reliable and accurate. In the fragile environments like in Somalia, the settlements and water-points put a lot of pressure that may lead to negative change in land cover.

Key Words: Remote Sensing, Land Cover Mapping, Impact Assessment in Pastoral Somalia

SESSION 2

The Key Challenges in Application of GIS and Remote Sensing in Environmental Variables Change Analysis in the Horn of Africa Region. Are we capturing the right indicators of change?

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Abstract

Despite the enormous global investments in GIS and remote sensing, detailed and diversified methods and tools developed for different applications in the last three decades, developing countries still faced with frequent environmental related risks and calamities. In the horn of Africa, several environmental related change analysis studies have been undertaken and new ones are being formulated, however, their impacts are far from being realized. Are these studies capturing the right indicators of change? Are they using the right methods, data, and tool? Or they are simply missing the communication of their finding? Using series of landuse\landcover change analysis case studies in Kenya and Tanzania, this paper reviews key challenges in conceptual approach, data, methods, tools and communication of results to different users. The paper tries to suggest workable options to realize the best practices. It concludes by making keys recommendations in integrated approach to such studies to realize equitable results and impacts.

Key words: GIS, Remote Sensing, Land use Change Analysis,

Application of Remote Sensing for the assessment of drought in Somalia

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Abstract

Drought, as a phenomenon, can generally be defined as a period of months or years when an area or a region experience deficiency in its water supply. This generally occurs when the region consistently receives precipitation below its average. Although droughts do occur naturally, their effects can be worsened by inappropriate anthropogenic utilization of natural resources. In order to appropriately mitigate the effects of drought, accurate assessment and near-real time monitoring is vital. Presently, there is lack of techniques to provide accurate assessment and effective monitoring over time, particularly in places like Somalia that have not had a management central system for many years. This study used a combination of meteorologically measured data (rainfall and ETP), remote sensing products (Rainfall estimates, ETP and NDVI) and tools, and fieldwork to assess drought events for the period 1972-2005 in two study sites known as North Garowe and South Garowe, in Puntland (northern Somalia). Multi-temporal, multi-spectral and multi-resolution remote sensing products were used to study phenological dynamics and physiognomic variability of vegetation as direct indicators of drought occurrence. Using WINDISP5 and VEDAS software, the NDVI characteristics were generated from the NOAA-GAC, SPOT and MODIS data, respectively. Different NDVI curves were generated to show the phenological dynamics and physiognomic variability of the vegetation in the study area. These curves were further analysed vis-à-vis those generated from meteorological data and used as inputs in the assessment of drought events. These outputs were validated with field-data. About 90 sample points from the field gave very high correlation accuracy (≈90%) with remote sensing results. These results show great potential of remote sensing as a tool in the assessment of droughts. However, some limitations have also been noted such as the inability of NOAA to expressly show drought years as obtained using SPOT and MODIS data. In conclusion, results obtained show remote sensing as holding great potential in the assessment of droughts through the analysis of vegetation indices such as NDVI.

Key words: Drought, remote sensing, vegetation, phenology, physiognomy

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Monitoring Vegetation Change in Somalia by Fixed Plots: Opportunities Offered by New Methods in Remote Sensing.

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EXTENDED ABSTRACT

INTRODUCTION

There are two trends or events which represent, for scientists, consultants, planners and decision makers in the Horn of Africa, both a risk and an opportunity.

The first is for more widespread and more highly resolved (temporally, spatially and radiometrically) images of the earth's surface to become available, and more easily found, at ever lower costs. See Tables 1 and 2 in the Presentation Power Point.

The second trend (or series of events) is the increasing difficulty in the Horn of Africa to carry out work on the ground. Between 1967 and 1985 research workers, scientists, technicians, government administrative officers, veterinarians, agricultural extension workers, missionaries, doctors, and teachers could be found spread widely but thinly over the rural regions of the Horn of Africa. This level of ground access is now effectively prevented over large swathes of the Horn of Africa to professional workers. A visit to a ground location needs protection by armed men, which for most investigators raises ethical concerns, and creates methodological barriers or risks.

RISKS OF THE PRESENT SITUATION

The risk presented by the present situation lies in the conditions created by the combination of these two trends. The higher risks and costs associated with work on the ground are seen by many consultants and investigators to be legitimately offset by the lower costs and risks of assembling information from the more extensive and more resolved sources, now easily located and cheaply acquired over the internet. Investigation has become the sifting and re-interpretation of field information collected many years previously, and contained in consultant's reports available on the internet, and old hard copy archives. For up-to-date field information reliance is increasingly placed on remotely sensed data, and surveys conducted without

adequate training and quality control by local "consultants".

The long term result of these conditions is the creation of a set of virtual data about a region or project area which, although progressively more incorrect, becomes increasingly accepted as the true situation, through its apparent internal consistency, its repetition by successive consultants, and its protection from critical review by scientists, unable to make adequate field visits.

There is now, in our judgment a massive gap between contemporary prevailing views of the status and processes of developing societies, and the realities.

Highly resolved remote sensing, available and used without simultaneous work of parallel precision on the societies and ecological processes underlying and responsible for the appearance of the snap shots these images represent, is a dangerously seductive tool, at present being widely misused in the consulting and development industry.

An example drawn from Google Earth's Somali images is presented in Annex 1 to show how remotely sensed imagery at 2.6m resolution for 2006 could be compared with information collected in 1984 at orders of magnitude better resolution at monitoring sites S608 and S609, to support a wide number possible, some contradictory, scenarios of socio-economic and environmental changes.

However until the critical questions which are raised by the two sets of images have been answered and other information assembled, by well-structured field investigations and survey, no explanation has more weight than any other.

In short the risks inherent in the availability of the currently superb remote sensing material, combined with the difficulties of structuring and implementing field socio-economic, production system and environmental surveys, are that persuasively argued descriptions of the status and needs of the rural populations can appear to be supported by remotely sensed evidence, and thus become the accepted basis for investments and assistance. These may not lead to sustainable rural self-sufficiency in food production, improved livelihood opportunities, and better health and education services, and indeed can have the opposite effect.

However modern remote sensing data, deployed in well-structured methodology, can also be the foundation for an opportunity to solve this problem.

OPPORTUNITIES OF THE PRESENT SITUATION

From 1977 until 1984 the two senior authors designed, managed and implemented a national survey of the vegetation of Somalia, (Watson, et al., 1979, 1985, Watson, 1982), under contract to the National Range Agency using funds provided by the World Bank and USAID. An important part of that survey was the establishment and first recording of 1,695 range vegetation monitoring sites on the ground. These sites were also photographed from the air by vertical and semi-oblique colour photographs in 35mm format at scales on the negative of 1:15,000, 1:7,500 and 1:2,700, allowing examination at scales of 1:3,000, 1:1,500 and 1:500 respectively. A further 300 sites were photographed from the air in colour at these scales, but not visited on the ground, and 442 frames of vertical photography were carried out at 127 mm format in monochrome.

On the ground sites were photographed from a centre point along the four primary geographic axes, with a 35mm camera and 24mm (wide angle) lens, from a point about 1.5m above the site centre point. Three frames were taken along each axis, to cover a strip of land from the centre point to the horizon.

Figures 1 and 2 illustrate the photographic cover of each sampling site, and Table 3 shows the quantities of information assembled for the monitoring baseline. The method has been described in Watson and Nimmo (1985), pages 71 to 77, and Nimmo (1991) paragraph 3.8.14.2 pages 194 to 196.

About 35,000 35mm Ektachrome slides, 110m of aerographic film, 2,500 A4 Site Location Cards, and 2,000 Site Location monochrome prints were deposited in the National Range Agency's Monitoring and Documentation Centre, with the intention that these should be a definitive base line of vegetation condition and composition. These were 200kg of un-copied, and therefore unique analogue information, which the senior author rescued on 27 February 2001 from the burning buildings of the NRA in the aftermath of the overthrow of the Barre regime. (Watson & Nimmo, 1992).

The increased resolution and availability of remotely sensed satellite imagery, and the simultaneous development of digitization equipment and software, makes it possible to consider how the two original goals of this work could now be met.

The Permanent Range Vegetation and Land Condition Base Line

The first objective was to establish a permanent base line of range conditions over the

whole of Somalia. It was pointed out to the National Range Agency when the original information was handed over that more work was needed to meet this objective. Most important was the need to make copies of the materials for deposit in a fireproof controlled-climate safe. A second need was described as the permanent marking of the monitoring site centre points.

Copying Unique Material

Scanning the monitoring site photographs and location cards at high resolution for storage on Hard Drives is now possible. This work has been started by the authors using a Canon FS4000 scanner, with each image stored as a tif file of 150MB size, (48 bit colour of a 21Mpixel scene). Significant work is needed to restore the images to the original site-sets. It is intended to return the original analogue material, divided according to the territories of the respective agencies now responsible for managing the rangelands, when the scanning is completed. The digitized images, as a set of 17 hard drives of 320GB, will be available for sale to these agencies and other civilian and research agencies without copyright restrictions. The authors would always retain one set of Hard Drives. Ease of accurate low cost propagation is the best guarantee that this base line is never at risk of loss or degradation..

Physical Marking of Sites

The second recommendation entailed the permanent physical marking of sites, a normal requirement for permanent vegetation monitoring sites which have to be periodically revisited by technicians and scientists. . In 1985 this would have required the sites to be re-visited on the ground, and either substantial monuments constructed, or some concealed markings established, as standard markers in Somalia are vulnerable to destruction or removal within a few months.

Permanent physical markers are now no longer necessary. GPS techniques and geo-referenced highly resolved satellite imagery and orthophotography are make remote geo-referencing simple and low cost. Fixing site centre points using such sources to within a 2 to 3 meters (or better with orthophotographs) without the need to make a ground visit is simple and cheap. Modern low cost GPS sensors can guide a monitoring team or aircraft to within a few meters of a GPS point.. More precise positioning can be achieved with slightly more expensive equipment.

Tests of the utility of currently available high resolution geo-referenced satellite

imagery suggests that centre points of most (>95%) of the monitoring sites could be identified and fixed to within 2.5 m on recent Quick Bird imagery provided free by Google Earth. Examples, for monitoring sites S498-S499, S500-501, S608-609, S610-611, and S673-678 are shown in Annex 2. Provided high resolution (3m or less) geo-referenced mapping imagery is available it would be possible to establish the location of most of the monitoring sites to within 2 to 3m in about 3 months.

Suitable mapping imagery could be procured from one of the commercial sources such as Quick Bird 2, Orbview 3, Ikonos 2 or GeoEye 1 (probably in early 2008) or from the orthophotography at 0.5m resolution under consideration by FAO. Site centre points could then be geo-referenced, ensuring further rounds of vegetation monitoring could be easily accomplished, at least from the technical point of view.

Monitoring of Range Vegetation Trends

The second objective was to monitor changes in rangeland vegetation and environmental conditions with the eventual objective of devising more sustainable management practices. It was believed at the time that the system of use of these resources as common grazing lands under customary clan territorial management was probably insufficiently adaptive to be sustainable in the face of the combined changes induced by growing human populations, increased irrigation and rainfed agriculture, refugee incursions, expanded livestock markets in the Arabian peninsula, improvements in veterinary health, and major expansion various types of water sources.

Today the need to commence monitoring range vegetation and environmental conditions is even more acute because of the following additional factors:

1. Large information gaps about a very dynamic period
2. Base line is ageing with the duration of the interval now starting to limit its utility
3. Base line and an updated round of monitoring will be useful to understand the changes which the next generation of satellite imagery can reveal
4. Climate change analysis will benefit if the base line reaches back to 1978-84
5. Range monitoring is a powerful instrument for national and regional range-use planning and as such serves a positive political purpose

How then could a second round of monitoring be implemented in Somalia, and what

would it cost?

A Monitoring of Changes in the Somali Rangelands over the Period 1978/84-2008-2014: An Outline of Measures

In another paper at this workshop an outline was presented showing how a new Somali Resources Assessment by Aerial Sampling (SOMRAAS) could be made under the present conditions for the whole of Somalia, (Watson et al 2007). A SOMRAAS would be important to enable a more complete understanding of the changes detected at the monitoring sites.

If 0.5m resolution geo-referenced cover as digitized panchromatic orthophotographs or satellite images becomes available over the period 2008 to 2014, the steps which could be taken to conduct a second examination of the monitoring sites, from which credible explanations for past changes, and reasonable evaluations of current needs could be made, are set out in outline below.

1. Digitise Base Line

Complete the digitization of the 1978-84 monitoring site information. About 35,000 colour transparencies need to be scanned at 4000 dpi. Incorporation of other site information into the files would require grey-scale scanning of about 6000 A4 pages. Total cost of this process is about $170,000, and it could be completed within 6 months.

2. Geo-reference the Monitoring Site Centre Points

Geo-referencing of monitoring site centre points using best available sources for about 2,400 sites, clustered to about 1,200 locations. Much will depend on whether geo-referenced orthophotography becomes available, or whether special orders would be needed of commercial satellite imagery. At the present time high resolution imagery is available free for Somalia over about 25% of the area. The cost of 400 high resolution scenes of minimum commercially available size (50 and 64 km^2) would be about $240,000. The work of examining the monitoring site aerial photographs to geo-reference centre points would be about $12.50 per site, and it would require about 30 days.

3. Preliminary change analysis to frame key site-specific socio-economic and production system enquiries

Analyse the changes between 1984 and 2006 evident on the relatively coarse scale satellite or orthophoto images, to identify specific issues and questions to be

SESSION 2

addressed by a ground re-visit teams. (See Annex 1, section 1.11). This analysis takes about 1 to 2 hours per site cluster, implying an overall cost of $60,000 to $120,000 over about 4 months by two specialists.

4. Re-photograph monitoring sites from the air

Re-photograph the sites from the air at negative scales of 1:15,000, 1:7,500 and 1:2,700 with a 22MP digital camera to provide resolutions of 0.07m, 0.03m and 0.01m respectively, in an aircraft equipped with GPS and screen image display system. Photography to be made at 500m, a safe height for flights over Somalia. The cost would be about $150 per site cluster, or about $180,000 for all sites. It could be accomplished in 4 months. It would facilitate a fine tuning of the issues and questions in step 3 above.

5. Selection of sites to be visited on the ground for re-photography, and socio-economic and production system enquiries

Select the sites to be visited on the ground, using information on accessibility, security, and the preliminary change analysis (step 3 above). Ideally all the sites should be visited for re-photography and enquiry, but some sites may have to be omitted and new ones may need to added. Selection of sites, requiring consultation with people working in the field and reference to the preliminary change analysis, will take about two months and cost about $20,000.

6. Ground visits to the selected sites for re-photography and socio-economic and production system enquiries

Assuming 1,100 cluster locations are selected for revisits, 5 teams of 4 Somali technicians each, trained and equipped with GPS, cameras, questionnaire forms etc. could make the re-photography and appropriate enquiries in a period of about 12 months, at a cost of $490,000.

The entire exercise could be accomplished in about 2.5 years, for about $1.2 million.

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SESSION 2

Integration of Remote Sensing and GIS for mapping community rangelands

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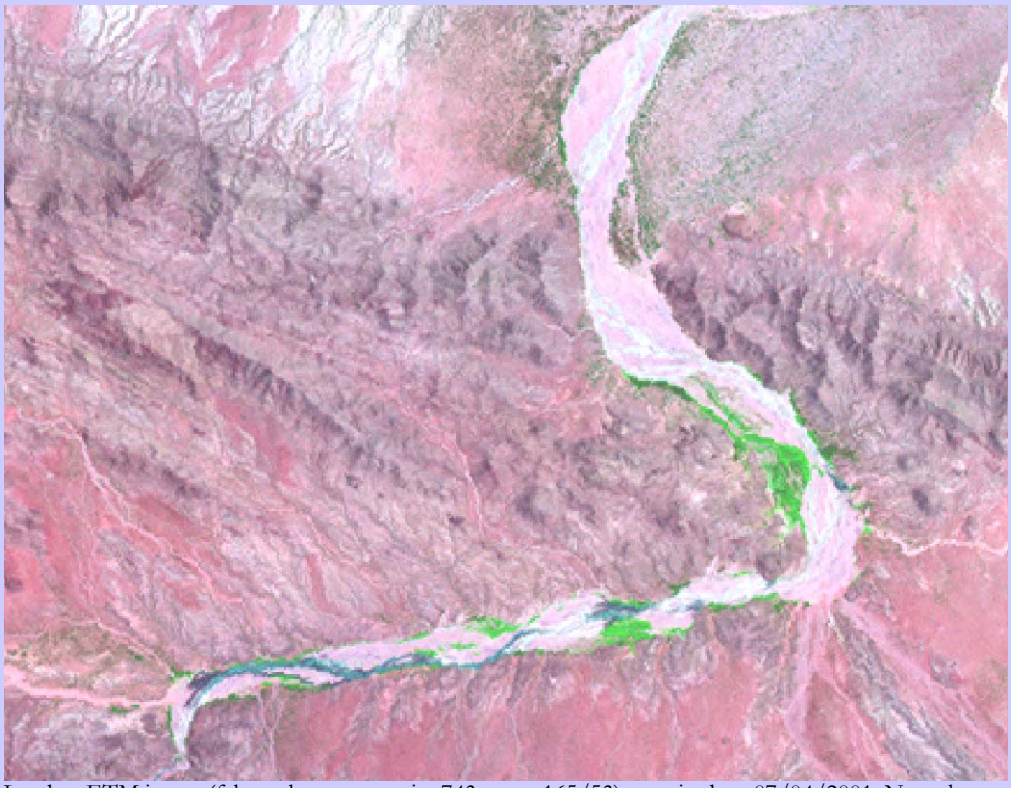
Introduction

In recent years, in Kenya and other developing countries, community game scouts or rangers are being engaged in the process of both protecting their land and the resources therein and also to monitor and track changes in their environment (Lewis, 1995). However due to the vastness of the land, and the limited means of the scouts who undertake patrols and monitoring exercises on foot or bicycles, it is necessary that the designing of sampling techniques focuses on what would give 'maximum returns' enabling the scouts to concentrate on areas of biological importance, covering areas with greater wildlife representation and are accessible and with good visibility.

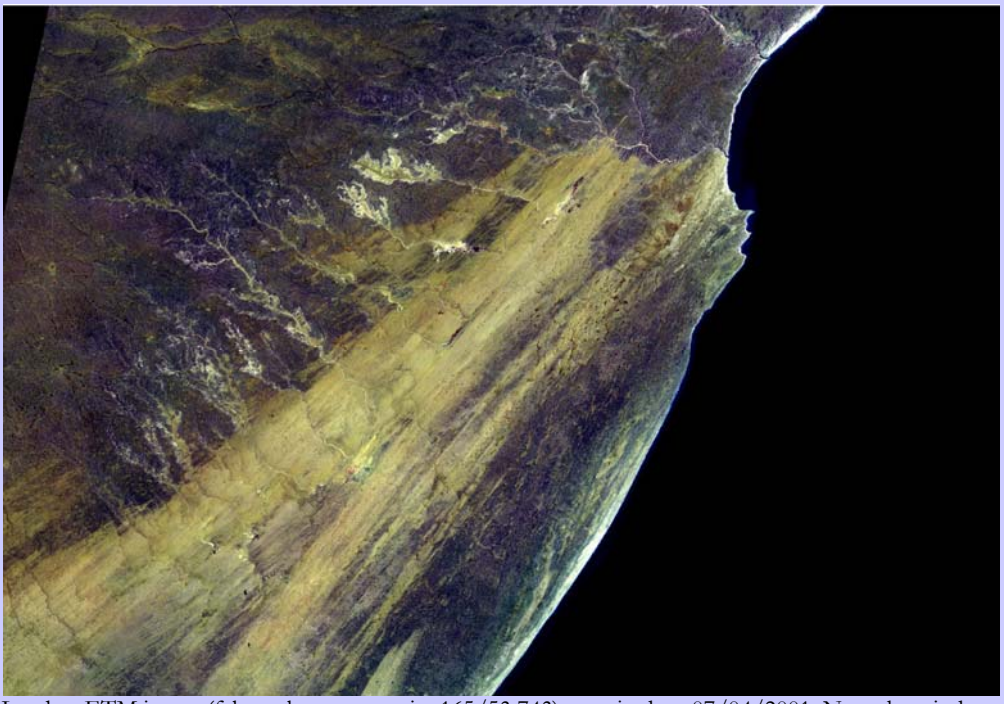
Remote sensing when integrated with GIS shows great functionality for the integration of a wide variety of spatial information, supporting such tasks as natural resource management and regional planning and environmental monitoring.

This study piloted in Kajiado district, Kenya among the Maasai living in communal group ranches, to determine and map the landcover and landuses in community rangelands employs remote sensing techniques and GIS tools together with other ecological information combined with local spatial knowledge, more effective mapping and monitoring of community rangelands is possible. This approach seeks to create more opportunities for participatory mapping of the community rangelands.

SESSION 3 - PROCESS MODELLING



Landsat ETM image (false colour composite 743 scene 165/53), acquired on 07/04/2001. Note the fluvial processes within the narrow alluvial plain.



Landsat ETM image (false colour composite 165/53 743), acquired on 07/04/2001. Note the wind blown sands stripes oriented northeast-southwest, almost parallel to the coast (the sea appears black).

Estimation of soil erosion using GIS: A case study of Taita Hills

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ABSTRACT

Soil erosion is one of the most serious environmental problems in the world today because it threatens agriculture and also the natural environment. Since soil erosion affects the productivity of land and while adversely affecting downstream areas, soil conservation takes a lead role in today's development programs. Therefore soil erosion is a major concern to both farmers and governments in the 21st century.

In addressing the millennium development goals (MDGS) number one and seven soil conservation tops the agenda list.

The Taita Hills (Latitude 3°25´, longitude 38°20´) cover an area of 1000 km2 and are surrounded by both western and eastern sections of Tsavo National Park .While the surrounding dry savannah grassland is at an elevation of 700 m, the average height of Taita Hills is 1500 m, the highest peak, Vuria, being at2208 meters. The annual rainfall varies from 500 mm in the plains to 1500 mm in the hills and there are two rainy seasons: the long rains in March-May/June and the short rains in October-December. Variability of precipitation from year to year is high, especially in lower altitudes. A great number of ecological regions are based mainly on the relief and climatic conditions in the area. Being part of the Eastern Arc, the Taita Hills are very valuable and

rich in biodiversity and have many endemic mammal, bird, and butterfly species. The hills were once covered with cloud forest, but after 1960s the forests have suffered substantial loss and degradation. To date, less than 400 ha of original forest is retained in a scatter of three larger remnants, Chawia (50 ha), Ngangao (92 ha) and Mbololo (220 ha), and nine tiny remnants embedded in a mosaic of human settlements, small-holder cultivation plots and exotic plantations. Taita hills being such a pressured, environmentally sensitive and ecologically important region, needs up to date and accurate land cover information that can be utilized in the production of sustainable land use policies. It is therefore prudent to develop a method of estimating and visualizing the erosion processes and quantities for effective land conservation practices.

The main tool for analyzing the effects of contribution of factors such as climate, physiographic or human factors on soil erosion is modeling. Empirical models have limitations in predicting the spatial distribution of overland flow and soil loss over the

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land surface since they cannot be universally applied. With the advent and spread of GIS, erosion modeling has increasingly aimed at providing spatially distributed prediction. GIS tools have enhanced exponentially the possibilities of handling spatial information such as topography, soil and land use, thus simplifying the implementation of spatially distributed models. The study therefore aims to demonstrate the application of the modern techniques of GIS and remote sensing in soil erosion modeling in Taita, integrating various factors in a database using Revised Universal Soil Loss Equation(RUSLE) and Rating of factors methods.

Using the above mention methods it was found out the soil erosion is highest in Mwatate division of Taita Taveta district with the highest estimates from the RUSLE ranging from 41 tons per ha per year to 83 tons per ha per year. The modelling also shown that open trees and open shrubs are the most vulnerable to erosion especially when they are within altitude of 1200 meters to 1800 meters above mean sea level. In addition it was evident from the study that the mountains and major scarps occupying slope over 30% (i.e. soil developed on undifferentiated basement system rocks) were highly susceptible to erosion as well as highly eroded.

The use of satellite remote sensing for estimating regional evaporation.

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ABSTRACT

Growing world population is putting pressure on the available land and water resources. Scarcity of water is already being experienced as hereto perennial rivers have now ceased to flow during certain periods of the year due to water diversions in the upper catchments of these rivers. The focus today is to conserve and better manage the available water resources in a rational and efficient manner. Evaporation is the loss of water in the form of vapour from the surface of the earth to the atmosphere. In tropical regions, up to 90% of water flowing through a river basin may be used in the evaporation process. Knowledge of the spatio-temporal variations of evaporation is therefore important for the planning and management of water resources. However, evaporation is the most difficult component of the hydrological cycle to quantify because of its high spatial and temporal variations especially in heterogeneous catchments. Satellite remote sensing is a powerful tool to provide measurements at a wide range of spatial scales ranging from an individual pixel to an entire raster image that may cover a whole river basin. Estimation of evaporation has been investigated since the operation of earth resource satellites in the 1970s. However, the operational use of remote sensing methods for the monitoring of evaporation has been limited because of existing cloud cover problems as well as the need for field data by the remote sensing algorithms. In this study, remote sensing methods are used to monitor the spatial variations and temporal evolution of evaporation in Lake Naivasha basin in Kenya. Five NOAA AVHRR satellite images were used to produce daily evaporation maps of the Naivasha basin for 15 continuous days. The evaporation maps were validated with field data and overall good agreement was obtained. This demonstrated that remote sensing methods could be extended for practical use to map both the spatial patterns as well as the temporal evolution of evaporation in catchments and river basins.

Impacts of land cover and land use changes on stream flow; a case study from the Nile Basin

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Abstract

The Mara and Nzoia River basins are 13,834 km^2 and 12,950km^2 respectively, both drain into Lake Victoria hence they are sub catchments of the greater Nile River Basin. The Mara basin is transboundary between Kenya and Tanzania while the Nzoia lies entirely in Kenya along the Kenya Uganda border. In the recent past there has been unprecedented land use change in the two basins, with deforestation in the headwaters and a sharp increase in cultivated agriculture. These anthropogenic related changes have modified many natural processes (runoff, pollution loading, erosion etc) with far reaching consequences for the long term sustainability of the natural resource base particularly the river flows

To address these issues a study was conducted to determine the magnitude of the land use/land cover and their effects on the flows of the two rivers for the last 30 years from 1973 to 2000. The study utilized remote sensing, GIS tools and hydrological modelling to prepare and analyse the datasets. The results showed that from 1973 the forest cover in Mara and Nzoia basins has reduced by 32% and 11% respectively whereas the rangelands which comprise of savannah, grasslands, and rangelands have also reduced by 27% and 32 % respectively. The reduction of forests and rangelands in the two basins has been due to encroachment by destructive deforestation and agriculture which has sharply risen in Mara by over 200% and 41% in Nzoia. These changes in land cover have affected the hydrology of the two basins causing sharp increases in flood peaks by 6% and 10% in Mara and Nzoia basins respectively. The changes have caused the peaks to occur earlier by 4days and 1 day in Mara and Nzoia basins respectively. The increases and early occurrence of peaks could not be associated with changes in rainfall amounts and characteristics. The consequent erosion from the two catchments has caused sedimentation of the river reaches downstream. Sedimentation in Mara Basin is evidence by the increase in wetlands which have increased by over 300% forcing out farmers and livestock from the lands around Mara swamp due to water logging. In Nzoia Basin sedimentation is evidenced by the constant and repeated flooding in the lower reaches of the basin.

Deposition of sediments on the river channel cause rises in river level causing water to spill over the dykes to flood adjacent areas.

Key Words

Land use change, forests, rangelands, Agriculture, Remote sensing, hydrology, flow peaks, sedimentation, floods, Mara basin, Nzoia basin

Land degradation and Change detection of biophysical products in different land use types Using Multi Temporal SPOT NDVI Image Data: a Case in Blue Nile River Basin, ETHIOPIA

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Abstract

Information about changes in biophysical products in different land use types provides valuable insights while devising future natural resource management strategies. Accurate estimates of vegetation biophysical variables using remotely sensed data are valuable as input to models describing the exchange of carbon dioxide and energy between the land surface and the atmosphere and important for a wide range of applications related to vegetation monitoring, weather prediction, and climate change and land degradation. The present study explores the use of SPOT image (1998 to 2004) to derive vegetation biophysical products such as NDVI, NPP and fAPAR to monitor land degradation in different land use types at Blue Nile river basin. The result of the study showed that the overall trend of the NDVI curve decreased in most of the land use types which implies occurrence of land degradation due to the decline in biophysical productivity.

Key words: Land degradation, NDVI, NPP, biophysical productivity, land use

1. Introduction

Land degradation can occur due to the results of natural processes such as climatic variations, volcanic eruptions, changes in river channels or the sea level, etc. However, most of the land degradation is due to artificially or human actions to use the lands which represent one of the main sources of systematic change on local, regional, or global scale (Turner et.al, 1995). Examples of human induced activities are agriculture expansion, overgrazing, fires, land abandonment, etc

Several studies showed that land degradation is a major factor for the low agricultural productivity of Sub–Saharan Africa (Dregne et al., 1991, Reynolds & Stafford, 2002). It is mainly due to the process of progressive deterioration of biological (flora and

fauna) and physical (soil, water, micro-climate, etc.) resources of the land, leading to declining productivity In Ethiopia also land degradation is threatening the biological resources and agricultural productivity. The degradation of land resource due to overexploitation and misuse and consequent economic, social and environmental impacts has intensified the pressure on the land resources of the country (EFAP, 1994). The growths of agriculture and other human activities have exerted pressure on the extents of grazing lands.

Land degradation is measured indirectly using physical indicators of land products and biomass. The characterization of land surface conditions and land surface variations can be efficiently approached by using satellite remotely sensed data mainly because they provide a wide spatial coverage and internal consistency of data sets. In particular, the Normalized Difference Vegetation Index (NDVI) is an expression of contrasting reflectance between red and near-infrared regions of a surface spectrum (Rouse et al., 1974). This expression is a readily usable quantity that can be linked with the green vegetation cover or measure of vegetation abundance. Several studies indicated that Normalized Difference Vegetation Index (NDVI) showed a strong linear relationship with the fraction of photosynthetically active radiation absorbed by the plant (Asrar et al., 1984, Sellers 1987, Sellers et al., 1997). Many studies have also shown strong correlation between NDVI and vegetation cover (Running and Nemani 1998) and above-ground net primary productivity (Running and Nemani, 1988).

Annual Net Primary Productivity (NPP) is one of the most important measurements characterizing the productivity of an ecosystem. It is the difference between the total carbon uptake from the air through photosynthesis and the carbon loss due to respiration by living plants. NPP is generally the energy of biomass that is saved as a dry organic matter in vegetations (Brong and SwedPowe, 2004). Several methods of estimating NPP over large areas have been established. Some are based on complex eco-physiology models that link carbon and nutrient cycles, while others utilize remotely sensed data to provide information on vegetation condition and to monitor changes in leaf area index or canopy light absorption through time. Since field measurements of NPP are time-consuming and expensive, the current techniques are therefore mainly applied to remotely sensed data for the analysis of NPP.

Remote sensing provides the best method of obtaining the spatial distribution and estimation of vegetation productivity. Estimation of vegetation productivity using remotely-sensed information has generally followed two approaches, the first can be by establish direct empirical relationships between spectral reflectance and biomass and the second is by using the spectral reflectance to estimate the amount of

absorbed photosynthetically active radiation (APAR). The first approach has proven useful for estimating live biomass. However, the second approach is likely to be more successful in predicting biomass across different climatic regimes and across biomes (Choudhury, 1987).

Monteith (1972) observed that plant production is correlated with the amount of Photosynthetically Active Radiation (PAR) absorbed or intercepted by green foliage (APAR). He also suggested that the NPP of a well-watered and fertilized annual crop is linearly related to the amount of absorbed photosynthetically active radiation (APAR). The amount of APAR depends on the quantity of solar radiation reaching a site and the ability of the vegetation to absorb that radiation. The amount of radiation intercepted by vegetation is directly related to vegetative leaf area that can be detected using remote sensing. This possibility of detection the vegetative leaf increased the potential use of remote sensing imageries for predicting NPP (Prince, 1991). The main objective of this study is to detect the land use change and identify the trend of land degradation through analysis of SPOT-NDVI image and to determine the amount of net primary product (NPP) and fAPAR.

2. Methodology

2.1 Description of Study Site

Blue Nile is the major part of the River Basin which contributes to the Nile River It is located between 7°45'39.0"N to 12°46'3.9"N and 34°23'27."E to 39°47'38."E(Fig. 1). It has a drainage area of approximately 324,530 km^2 and supplies nearly 84% of the water to the Nile River during high-flow season, making it the main source of water for Ethiopia, Sudan, and Egypt (Peggy and Curtis, 1994). It is characterized by a mean of 1344 mm annual rain fall and a mean annual temperature of 19.5 °C. Its altitude ranges from 1487 to 4261m.a.s.l. Generally the Blue Nile River basin

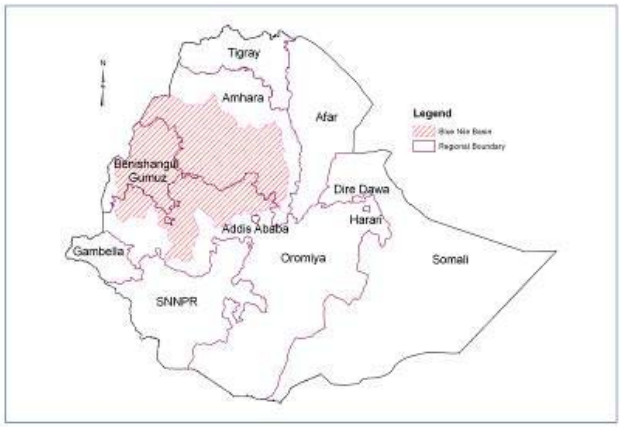

Figure 1. Location of Blue Nile basin

2.2 NDVI analysis

Normalized Difference Vegetation Index (NDVI) is derived from time series data of French SPOT Vegetation satellite. Converting algorithm was used to convert the value of raw digital number reflectance to the NDVI image. During the analysis saturated digital numbers are masked out and NDVI was calculated for each pixel as

$$NDVI = \frac{\rho NIR - \rho RED}{\rho NIR + \rho RED} \quad \text{.....} \quad Eq1$$

Where,

ρNIR is the reflectance value of the SPOT image at Near Infra Red wavelength and

ρRED is the reflectance value of the image at Red wavelength of the electro magnetic spectrum.

The NDVI image from spot satellite was used to investigate the trends of NDVI during seven years time (1998 -2004). The available every ten days (tri-monthly) NDVI dataset for the whole Ethiopia was clipped to Blue Nile river basin boundary and processed to a monthly level NDVI for each types of land use (Figure 2).

There are several types of land use type in the Blue Nile basin. This study is conducted on different land use types by stratifying the land use in to five different classes namely: parks, the Dabus valley park, farm land, forests, grass land and towns. We used the Woody Biomass land cover data in order to identify the different land uses. We also took maximum care while selecting samples for each land use types as land use may change during the seven years time. Multitemporal Landsat imageries of year 1999 and year 2003 are considered as a guidance when selecting

the land use types which we are selecting to consider as a sample area.

After the identification of unchanged land use types using the images, we used the combination of the Landsat and woody biomass land cover map to select sample areas for the identified types of land use. Then after the NDVI value for this different land use types are clipped using polygons of the sample land use types and analyzed.

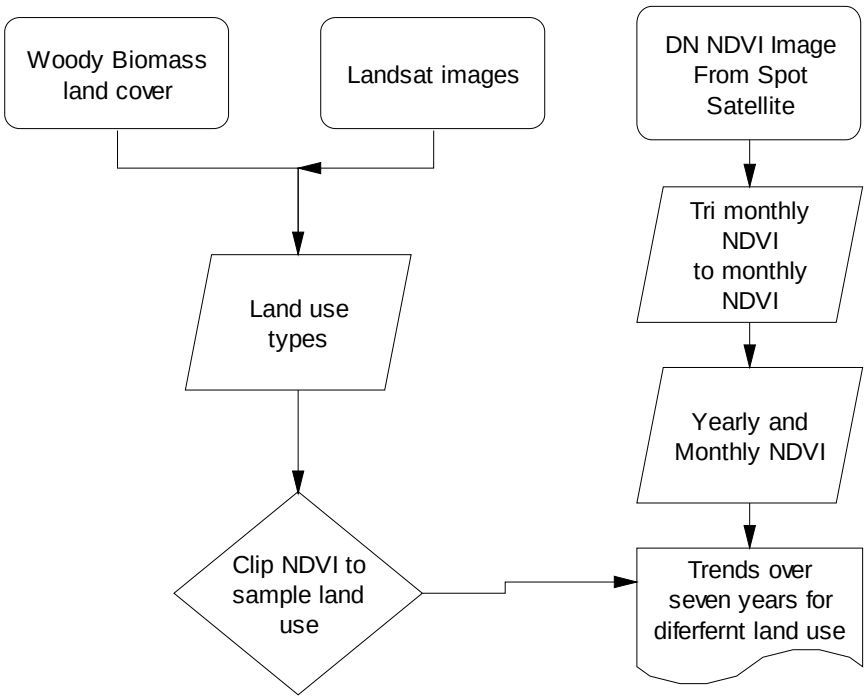

Figure 2 Flow chart of methodology for deriving NDVI for different land use types at Blue Nile basin.

2.3 Net Primary Production (NPP) and fraction of Absorbed Phosynthesiic Active Radiation(fAPAR)

Empirical formulas from literatures are used to derive the Net Primary Production (NPP) and fraction of absorbed photosynthetically Active Radiation (fAPAR).The analysis of NPP from satellite data is therefore done on the basis of production efficiency concept. According to Ruimy et al (1994), NPP is given as

$$NPP = \varepsilon \int \mathrm{fAPAR} * \mathrm{PARdt} \quad \text{.....} \quad Eq2$$

Where:

PAR= incoming photosynthetically active radiation (MJ/m2), fAPAR= fraction of PAR absorbed by canopy (no unit), ε = conversion efficiency of APAR into organic dry

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matter (g/MJ).

Prince and Goward (1995) indicated that fAPAR is linearly related to NDVI as:

*fAPAR = a + b *NDVI …….……Eq3*

where :a and b are constants values. Rumiy et al. (1994) analyzed the relationship of fAPAR and NDVI as:

*fAPAR=-0.025+1.25*NDVI …….…….…… Eq4*

.

The NDVI, which is a ratio of two different spectral bands, were derived from Spot satellite image. It is given as: equation 1.

The ratio has limit of -1 and +1. The higher NDVI indicate the denser vegetation. The NDVI of each decade was first analyzed to get the monthly NDVI. The maximum value of NDVI from each decade in a month was taken to get the monthly NDVI.

The conversion efficiency ε is used as a constant over all biomes and equals to 1.5g/MJ (Ruimy et al, 1994). Using Asrar et al. (1984) inverted relation of PAR and NDVI, the annual NPP value was determine based on the 12 months of NDVI as:

$$NPP = \sum_{1}^{12}[1.5*(-0.025+1.25*\mathrm{NDVI})*(\mathrm{NDVI}*0.087)/0.798] \quad \text{…….….}Eq6$$

3. Results of NDVI analysis

3.1 NDVI Trends in Dabus Park

The Dabus valley park is a park composing of different vegetation type. The majority of the area is covered with scrubs, grassland and forest. Analysis of the NDVI trend was made for Dabus valley for seven years period of time (1998 – 2004). The result showed a negative trend (Fig 3). Since Dabus valley is comprised of different land use type, the NDVI value may be affected by the increment of decrement of one of these land use type. Generally the negative trend on the NDVI value of the park may indicate land degradation.

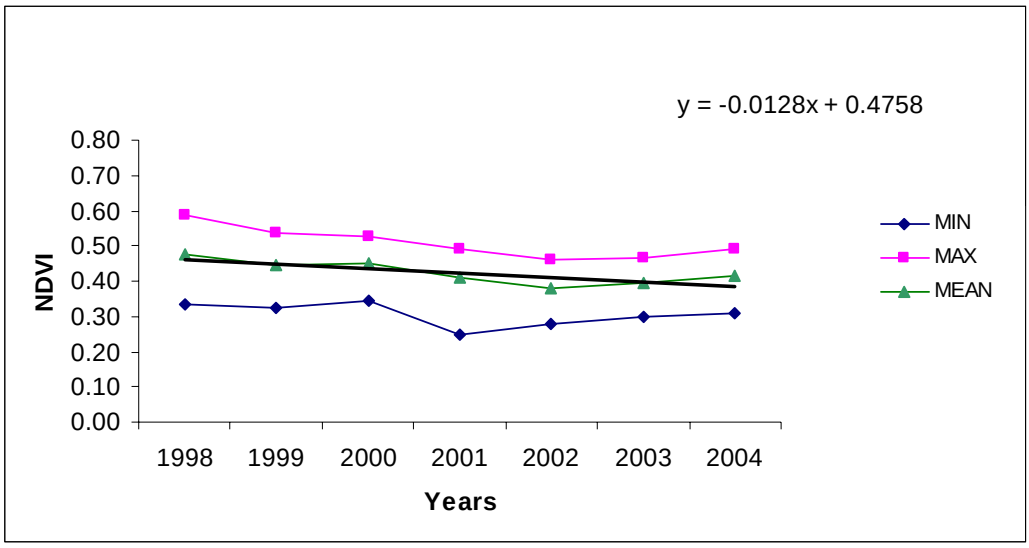

Figure 3. NDVI *trends in Dabus valley park from SPOT images*

3.2. NDVI Trends in Farmlands

A similar trend of land degradation is occurring in the case of the farm lands as well (Fig4). The NDVI curve in figure 4 is showing a negative slope which indicates the decline of NDVI value from year 1998 to year 2004. Farming practice in the Blue Nile basin is rain-fed type. This seasonality is clearly observed on the monthly NDVI values and produced a significant fluctuation of the curves, which can be observed from wide range of NDVI values.

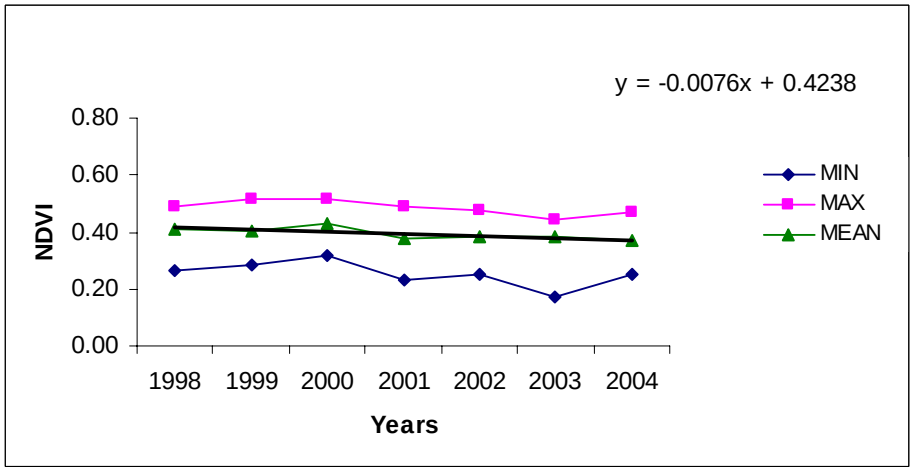

Figure 4. NDVI *trends in farm lands from SPOT images*

3.3. NDVI trends in Forest

Surprisingly the forest cover in the Blue Nile is showing a positive slope for the NDVI curve. This indicates that there is an increase in a vegetation cover over the areas sampled for the NDVI trend analysis (fig 5). The reason for having an increase of vegetation cover might be, due to the growth of forest canopies in the given area of

interest. This doesn't imply that the over all forest cover in the Blue Nile is in a better condition. The sample was taken from the middle of forests to have constant type of land use over 7 years. Another point observed in the NDVI curve of the forest is that, it shows less fluctuation of curves, which can explains the perennial nature of forest covers. The forest showed a steady going NDVI curve, whose minimum is above the average NDVI value of other land use types (Table 1).

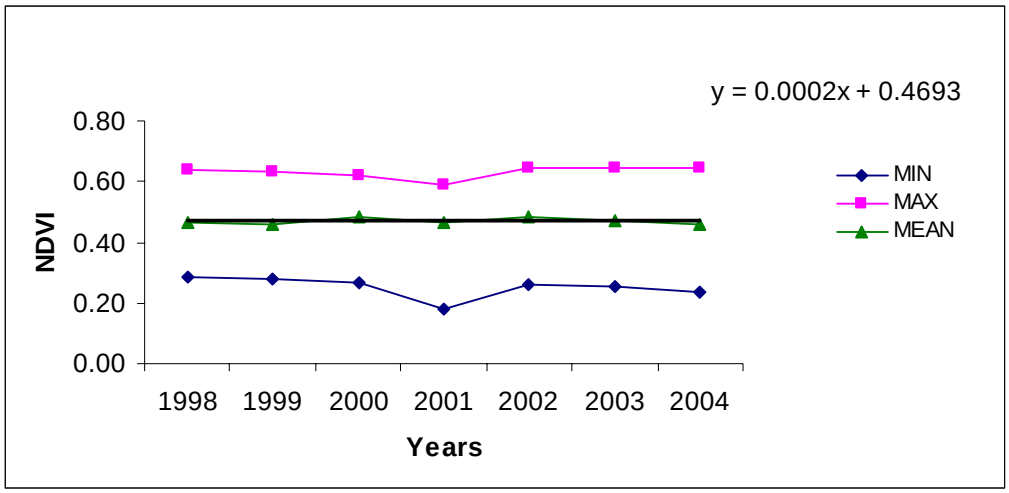

Figure 5. NDVI trends in Forests from SPOT images

3.4 NDVI Trends in Grass land

As other types of land uses the grass land also showed a negative slope of NDVI curve (Fig 6). This also indicated the presence of land degradation in the grass lands. The minimum annual mean NDVI value is also observed in this type of land use. The other point observed in this curve is that, it shows high similarity with the annual mean of NDVI with agricultural land use type.

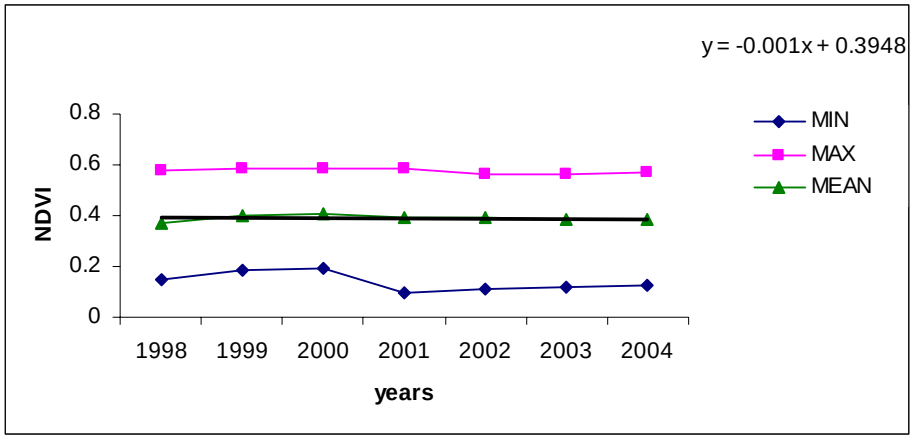

Figure 6. NDVI trends in Grass land SPOT images

3.5.NDVI Trends in Towns

Towns are areas where there exists less amount of vegetation. The data recorded over towns consist of high reflectance than other types of land use. As a result the minimum value of mean NDVI is observed in this type of land use. The NDVI curve, which is used to indicate the presence of vegetation cover showed a negative trend in this type of land use. This might be due to high rate of urbanization in area. As a result high reflectance from the constructed areas contributes to the negative slope of NDVI curves in the towns (Fig 7).

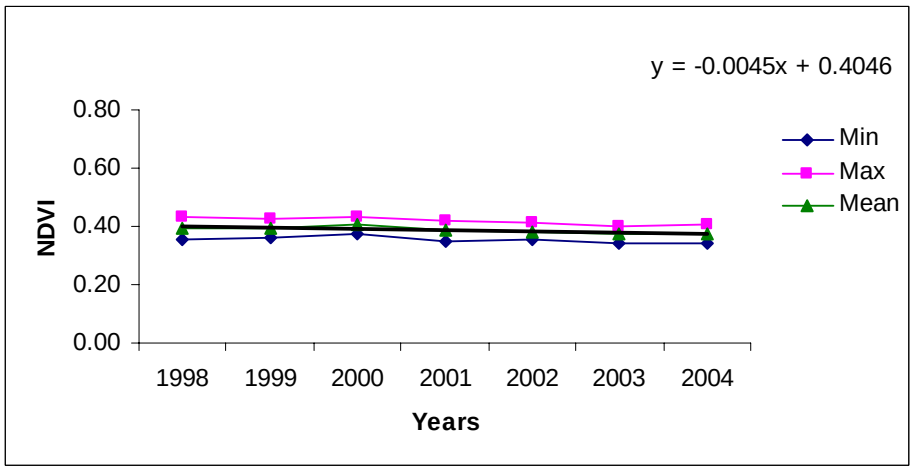

Figure 7. NDVI trends in Dabus park from SPOT images

3.6 Overall Trends of NDVI, NPP and fAPAR in different Land use types

Analysis NDVI for the seven years SPOT time series is conducted for different land use types in the Blue Nile Basin as discussed above. This method flagged local clusters of

pixels showing anomalous behaviour, indicative of either degradation or higher than average vegetation production. By conducting a linear regression analysis, we tested trends in the NDVI time series for the different land use types in Blue Nile region using the 7-year data series. The results showed a negative trend possibly indicating a decrease in overall productivity in recent years except for the forest areas. From the trends observed, we concluded that the biophysical product of the area has shown a decrease from year to year. A trend of decrease in NDVI value is relatively higher for Dabus park where NDVI curve is shown as NDVI = -0.0128x + 0.4758 and followed by the farm land where the curve shows NDVI value trends over seven yeas as NDVI = -0.0076x + 0.4238 when compared to the other types of land use. This kind of decrease might be associated with the over exploitation of the lands due to high pressure of human and animal population and significantly proves the occurrence of land degradation.

The maximum, minimum, mean and range of the mean annul NDVI for all types of land use is calculated (table 1). As a result the minimum value of annual mean NDVI is observed in farm lands which indicate the presence of high land degradation. The result also showed that the maximum mean NDVI value is observed in forest areas followed by Dabus valley park and minimum for built up areas. The forest areas are also the land use type which doesn't show much range of NDVI values. The computed NDVI value ranges for all the land use types considered showed a minimum value for the ranges in the forest area and maximum for Dabus valley Park. The presence of different landscape and wider sampling area for the Dabus valley park might result in the wider variation of NDVI values. The presence of evergreen leaves in the forest area might also contribute to the smallest range of mean NDVI value in this area

The highest value for NPP is recorded in the forest area and the minimum is recorded for towns (Fig 8). The same trend is also observed for the amount of absorbed photosynthetically active radiation (Fig 9). This show that the presence of vegetation in a given land use type absorbs significant amount of photosynthetically active radiation from the incoming solar radiation.

Table 1. Summary of NDVI VALUES AND NPP and fAPAR for the different land use types in Blue Nile.

Land Use	*Mean NDVI*	*Minimum NDVI*	*Maximum NDVI*	*NDVI Range*	*average fAPAR*	*Average NPP*	*NDVI equation*
Dabus park	0.4245	0.3818	0.4768	0.0950	0.505638	0.497924	y = -0.0128x + 0.4758
Farm land	0.3936	0.3690	0.4304	0.0614	0.466962	0.386675	y = -0.0076x + 0.4238
Forest	0.4702	0.4581	0.4850	0.0270	0.562701	0.529594	y = 0.0002x + 0.4693
Grass land	0.3909	0.3728	0.4110	0.0382	0.463586	0.384477	y = -0.001x + 0.3948
Towns	0.3868	0.3731	0.4058	0.0328	0.458514	0.368158	y = -0.0045x + 0.4046

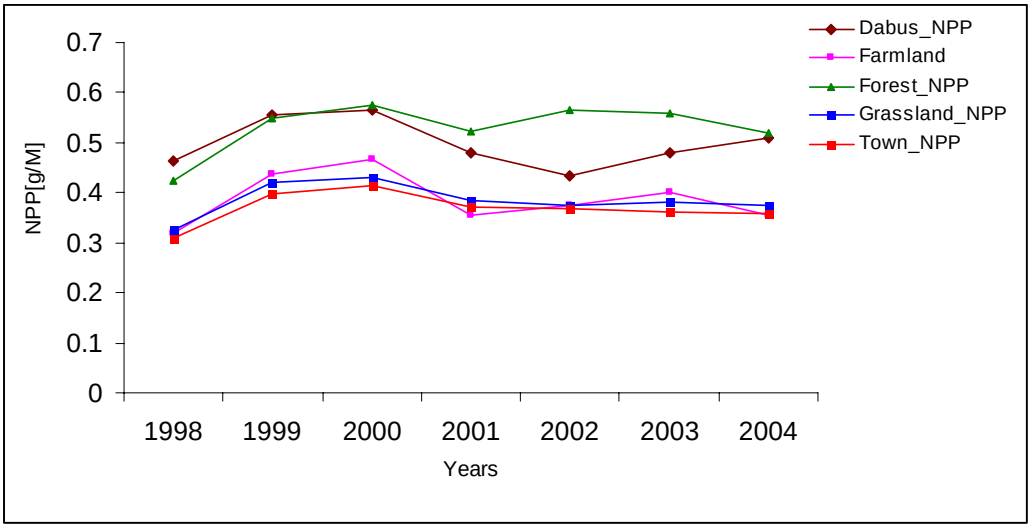

Figure 8. NPP curve for different Land use types in Blue Nile river basin

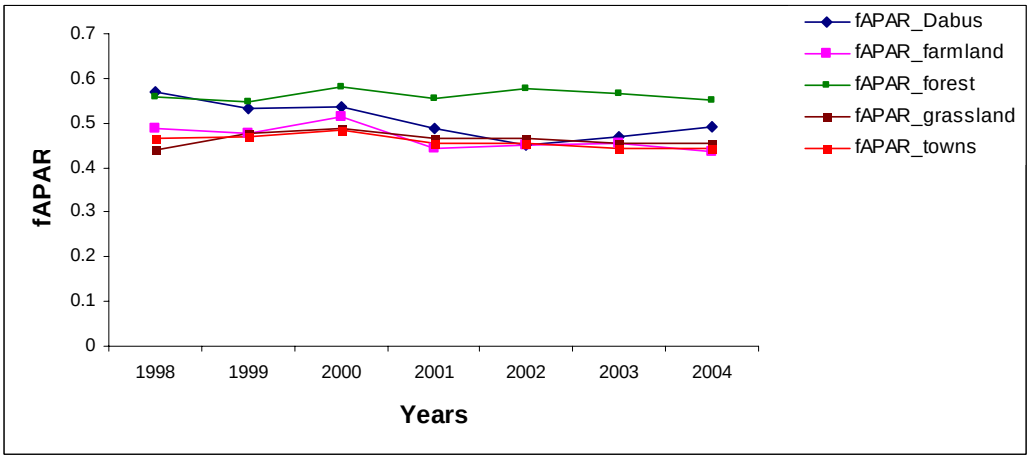

Figure 9. NPP curve for different Land use types in Blue Nile river basin

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Conclusion

Different type of land use is assessed and their NDVI trend showed negative slope except for the forest land use. The NPP and fAPAR are also showed higher value for forest and minimum for town. The analysis of NDVI is a good tool to identify the trend of vegetation cover changes in a given area as it quantifies and measures the greenness over different land use types. This method is also helpful to identify land degradation and detect changes since it shows time series datasets. A comprehensive coverage and considering of larger areas coupled with ground verification measurements of the various land use systems specifically forested area is recommended to see the effect of the NDVI trends over time.

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Mapping of groundwater vulnerability to pollution using modified DRASTIC modeling: the case of Naivasha- Nakuru basin, Kenyan Rift

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Abstract

The Kenyan Rift is an active Quaternary rift system characterized by segmented intensive faulting and volcanic activities. It stretches north-south in a form of alternating half grabens with asymmetric geometry. It contains several lakes with different hydrochemistry; aligned all along the rift floor. The primary control on the origin of these lakes basin is the faulting and volcanism due to rift formation processes in the mid-Pleistocene Period. Naivasha, Nakuru and Elementaita lakes are among the major surface water bodies in the rift, and they occupy its axial part. The study area covers the three sub-basins namely Naivasha, Elmentaita and Nakuru lakes basin.

The lithology and structures of the Naivasha- Nakuru basin was investigated by means of surface and subsurface geological analyses, and geomorphological observations to understand their influence on hydrological flow and pollution controls. The study of outcrops, digital elevation models, topographic maps, soil data, meteorological data, geological maps, satellite imagery and borehole data in the GIS environment were undertaken. Field and laboratory analyses were performed to study the mechanism of development (geometry and kinematics) of the open normal faults and the extension fractures in the rift floor

The DRASTIC model, which is one of the empirical models used in vulnerability mapping, was applied to map the risks in Groundwater pollution in the Naivasha – Nakuru Basin. The pollution risk is basically due to intensive anthropogenic activities (industrial farming, poor waste management, and higher population growth in the area) and natural processes (fluoride problem). The seven GIS layers (Depth, Recharge, Aquifer media, Soil character, Terrain slope, Impact of vadose zone and hydraulic conductivity), required for the computation of DRASTIC Model were successfully generated using various GIS, hydrogeologic and geologic techniques. However, the complex lithologic and structural patterns of the rift and their impact on migration of pollutants were not fully incorporated in the seven pre-defined layers.

Tectonicaly, the study area is dominated by NNW-SSE, N-S -trending faults, ranging

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in length from 0.1 to 25.8 km. However, to the east of Lake Elementeita there are some NE-SW -trending faults. These normal faults significantly controlled the evolution of landforms and the drainage system by inducing surface up-warping and river deflections. Field measurements and observations suggest that the groundwater budget of the basin is primarily controlled by the spatial and temporal distribution of rainfall, the drainage network and the basin geometry. The occurrence of faulted lavas and tuffs, porous and permeable volcanics coupled with anthropogenic activities have made the area vulnerable to groundwater pollution.

Therefore, lineament density and physical properties of the surface rocks were computed to form an additional GIS layer in the DRASTIC model. Experimentally determined weighting and expert based rating was given to the layer and, a vulnerability map that best simulates the reality was derived.

Keywords: Kenya Rift; Normal faults; Groundwater; DRASTIC

Crop monitoring for Food Security – Contribution of Remote-Sensing and challenges for the future

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Abstract

Crop and Rangeland Monitoring with Earth Observation was initiated in Europe 20 years ago by the MARS project of the JRC in support for the monitoring of the Common Agricultural Policy and to The Directorate General Agriculture (DG AGRI).
This Research and Development project resulted in a number of operational products addressing the 2 components of crop production (Area estimates and Yield forecasts) with the integrated use of Remote-sensing, Area frame sampling, Agro-meteorological crop modelling, statistical analysis: Regional inventories (area estimates using area frame sampling and regression estimate with Remote-sensing) and the Crop Growth Monitoring System (CGMS) using both agromet models and low resolution Remote Sensing.MARS STAT regularly provide the DG AGRI with operational crop monitoring and forecasts Bulletins on Europe and neighbouring countries (Russia, Black sea region and Mediterranean area). These Bulletins are official information for the European Union and are discussed in the Outlook Committees with Member States and EUROSTAT.

A similar Crop Monitoring System has been developed by the MARS FOOD action of the JRC, in order to support the EU Food Security Policy on the following areas of interest: the South America (Mercosur Countries + Bolivia) and the Horn of Africa and The main differences in the methodology are the systematic use of ECMWF rainfall forecast data and of different crop simulation models (for instance Water Satisfaction Index). Since 4 years, in relationship with UN organisation (FAO, WFP), the JRC produce regularly semi-operational to operational Crop monitoring bulletins on the countries and region of the Horn of Africa (at the direct request of DG AIDCO).

CROP monitoring can be considered as a mature application, and since more than 7 years, operational pre-processing activities have been outsourced to external contractors: Real time acquisition/ pre-processing of both medium-low resolution earth observation imagery and meteorological data. And the JRC focuses

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on the added value of the crop monitoring (analysis and expertise, including the "level 3" of the Crop monitoring and yield forecast system)
and on a number of complementary research/development actions (cf. ASEMARS project) which orient the future development of the systems.

More generally, at the request of the services of the European Commission, the JRC will have to extend its crop monitoring capacities to reach a global coverage during the 7th Frame Work Program (2007- 2013). This strategy is due to a dramatic change of the global agricultural context with a number of concomitant driving forces:

- The rapid development of bio-fuel crops, such as bio ethanol (from maize in US or Sugar Cane in Brazil) or Bio diesel (from oilseeds in Europe);
- The fast development of emerging countries (Brazil, China, India) and their impact on the world market;
- The incidence of climate change with more frequent extreme events.

Prices of agricultural commodities are globally expected to increase, with possible repercussions on the cultivated areas, reinforcing the importance of independent and objective area estimates. Possible competitions between bio-fuel, food, and feed products (reinforced by the growth rate of China and India, with its consequent increase of the consumption of animal and the import of animal feed) will increase the sensitivity of the market to the global balance of production and demand.

The deployment of any global crop monitoring system faces a number of technical challenges linked to the adaptation of the existing systems to regions of the world where less in-situ data is available.
Remote sensing is a crucial source of information for Crop monitoring in such context, but the present systems relies as much or more on meteorological data and agro-meteorological modelling, and require statistical analysis on sound time series, for the calibration and validation of the models.

The presentation will illustrate the general methodologies of Crop and rangeland monitoring, with example in the Horn of Africa. Then, it will provide indications on the main strength, weakness and promising area of improvement, including the necessary reinforcement of in-situ observations and Agricultural statistics, with its 2 areas and yields components, which remain crucial for the definition of any sustainable Rural Development Policy.

Modelling Ecological Susceptibility of Coral Reefs to Environmental Stress Using Remote Sensing, GIS, and in situ Observations:

A case study in the Western Indian Ocean

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Summary

The rate at which coral reefs are impacted by environmental and anthropogenic stressors threatens them with extinction all over the world where they are found. Understanding coral bleaching patterns and ecosystem resilience will lead to the understanding of how coral abundance will change under the influencing physical factors. This is critical to any projection of how the goods and services of a coral reef will change, and for the analysis of the socio-economic consequences. This study aims to determine relative importance of historical and short-term environmental conditions to coral bleaching, and to develop a susceptibility map of coral reef systems based on parameters which correlate with resistance to thermal stress. We investigate the interaction of these factors in the Western Indian Ocean, at a scale detectable by moderate resolution remote sensors using modelling approach. We use remotely sensed oceanography data for six environmental variables: surface currents; wind velocity; sea surface temperature (SST); UV radiation; photosynthetic active radiation (PAR); and chlorophyll-*a* concentration, to derive predictor variables for the observed coral bleaching. Using Spatial Principal Component Analysis (SPCA) and cosine amplitude-AHP methods, we develop two susceptibility Models (SM1&2) in GIS using fuzzy logic technique. These models predict specific areas with environmental conditions that are likely to result in low bleaching and mortality; and that have a potential of maximum recovery from environmental disturbances. Historical environmental conditions explained 56% of the variation of bleaching observed in 2005; while conditions at the time of bleaching explained 62%. When combined all environmental variables explained 67% of the variation, with variables derived from sea surface temperature (coefficient of variation; positive anomalies), surface currents, wind anomalies, PAR and UV contributing significantly to the total variation. 2005 bleaching event differed from previous events as it affected regions in southern latitudes more than in the North. Susceptibility models identified regions which are highly susceptible and less resistant to environmental stress, as mainly the reef systems along the north-west boundary of the Indian Ocean and some Indian Ocean Islands. Half of strictly no take zones in the region are situated in locations with

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medial to severe susceptibility. Similar studies using moderate to high resolution data should be undertaken as a basis for establishment of marine protected areas to facilitate the mitigation and recovery measures, and to safe guard global coral reef biodiversity.

Key words: susceptibility, coral bleaching, resilience, oceanography variables, Western Indian Ocean.

Study context and conceptual framework

In 2003, a major initiative was launched by the World Bank other partners to support coral reef resource managers with the best available scientific advice on coral reefs response to human disturbances and climate change (Hatziolos *et al.*, 2003). A Modelling and Decision Support working group was established within this framework, with a mandate to:

> *'to develop a coordinated information base that can improve the accuracy and reliability of forecasting and predictive modelling, and to develop modelling tools to handle data on aspects such as community dynamics, oceanography, climate, as well as socio-economic data on fisheries, tourism, and coastal development'* (Hatziolos *et al.*, 2003).

This research is part of a larger study that aims to develop indicators of stress on reefs from in situ data and satellite based observations of sea surface temperature, wind speed, solar insolation, radiation (UV&PAR), and chlorophyll. The ultimate goal is to identify areas less prone to stress at meso scale, based on environmental parameters. In situ bleaching survey data is used here together with environmental parameters as the basis of modelling susceptibility of coral reef systems within WIO.
The outcome of this research aims to contribute to the decision-support system for establishments of marine protected areas to conserve biodiversity.

This study adopted a general conceptual model as outlined in figure1. The initial step involved selection of variables which are known to influence coral bleaching and resilience of coral reef ecosystems. Data were then retrieved and pre-processed to obtain the primary variables. The primary variables and/or their respective derived parameters were used in statistical analysis together with coral bleaching observation data as the response variable. Based on a regression equation a coral bleaching map for the entire region was generated. This map, together with derived parameters maps was used in a fuzzification process to yield respective susceptibility membership grade maps. These maps were integrated to obtain two susceptibility models (SM1&2). Validation could not be performed and instead, the models were calibrated using coral mortality data. The outcome of the calibration may lead to a reiteration

process and if need be, a lurking variable added. Accuracies of all the data used were explored and taken into account in the assessment of model uncertainties.

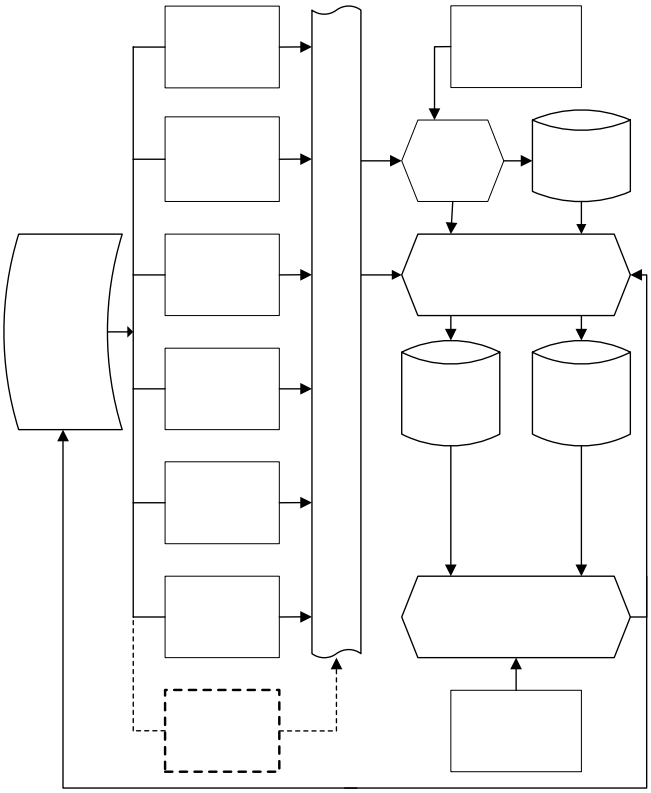

Figure 10: Conceptual framework adopted for modelling susceptibility and analysis coral bleaching. Rectangles represent data; tanks represent models; and hexagons represent data/model analysis.

Sea surface temperature (SST)

Wind velocity

Surface current velocity

Selection of variables based on priori knowledge

Solar radiation at UV

Solar radiation at PAR

Chlorophyll *a* concentration

Lurking variable

Problem statement and justification

Coral reefs are declining at an alarming rate all over the world. It is suspected by many researchers that multiple stressors, including direct and indirect anthropogenic effects, are the root cause of the problem. Deterioration of these ecosystems has led to the loss of livelihood of many coastal inhabitants, mostly in the developing countries where they depend entirely on these habitats for food. This has aggravated poverty levels in these countries. While managers can regulate coral stressors of anthropogenic nature, those related to physical environment are difficult, if not impossible, to manage. Understanding the interactions of oceanographic factors in relation to bleaching and use of the remotely sensed data in monitoring them will increase our predictive capacity over a large area. When used as a basis to determine areas less prone to stress, it may also serve as a decision support system for their management. This could be further used as the criteria for establishment of marine

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protected areas to facilitate the mitigation and recovery measures, and to safeguard biodiversity. Understanding coral bleaching will lead to the understanding of how coral abundance will change under the influencing physical factors. This is critical to any projection of how the goods and services of a coral reef will change, and for the analysis of the socio-economic consequences.

Research objectives

The overall objective of this study is to determine the relative importance of environmental factors to coral bleaching and the general health of the ecosystems at a geographical scale. Interaction of these factors in the Western Indian Ocean, at a scale detectable by moderate resolution remote sensors, will be investigated using a modelling approach, and their capacity to predict similar events in the future will be assessed. In effect specific areas with environmental conditions that are likely to result in low bleaching and mortality, and that have a potential of maximum recovery from environmental disturbances will be identified. Recommendations will be made to the management to possibly incorporate these areas into a strategic networks of marine protected areas designed to maximize conservation of global coral reef biodiversity.

Study Area

The Western Indian Ocean (WIO) region is bounded to the West by the mainland states of eastern Africa, and comprises the island states of the Indian Ocean (Fig. 2). Nations within the region include Kenya, mainland Tanzania, Zanzibar and Mozambique, Comoros, Madagascar, Mauritius, Reunion and Seychelles, Maldives, with South Africa in the southwest and Somalia in the northwest. The marine ecosystems of the region are dominated by extensive coral reefs, mangrove forests, and sea grass beds (Muthiga *et al.*, 1998). These ecosystems support a large proportion of the coastal population and affect millions of lives in one of the poorest and most densely populated regions in the World (Souter and Linden, 2000).

Generally the climate is tropical to sub-humid and is mostly influenced by two monsoon seasons each year. The monsoons have a major influence on wind direction and strength, air temperature and rainfall. They compose the multitude of forces that shape the structure of inter annual SST patterns in the Indian Ocean, rendering it more complex than tropical SST variations elsewhere (Nagar *et al.*, 2005). The recently identified Indian Ocean Zonal Dipole Mode (IOZDM) (Saji *et al.*, 1999) is another basin-scale SST pattern that affects the climate system.

Indian Ocean currents are seasonal and widely controlled by the monsoon. The

dominant currents include the West flowing North Equatorial Current and South Equatorial Current, with the weaker, eastward Equatorial Counter-current flowing between them (Swallow *et al.*, 1983). As the South Equatorial Current approaches the coast of Africa, it curves toward the southwest, part of it flowing through the Mozambique Channel between Madagascar and the mainland, and part flowing along the East coast of Madagascar. Other major currents include Southwest Monsoon Currents which form the Somali current in June-July (Nagar *et al.*, 2005); and the Agulhas Current (Bryden and Beal, 2001).

Coral reefs in the western boundary comprise the continuous fringing reefs and patch reefs. In the WIO island states, reefs circumscribe these islands and form the main ecosystems. Since the threats to these ecosystems are common, these countries have formed regional management initiatives such as the Regional Environment Program of the Indian Ocean Commission (Muthiga *et al.*, 1998) and Western Indian Ocean Marine Science Association. They also have memberships and are host to international organizations such as the Global Coral Reef Monitoring Network (GCRMN) and International coral reef initiative (ICRI).

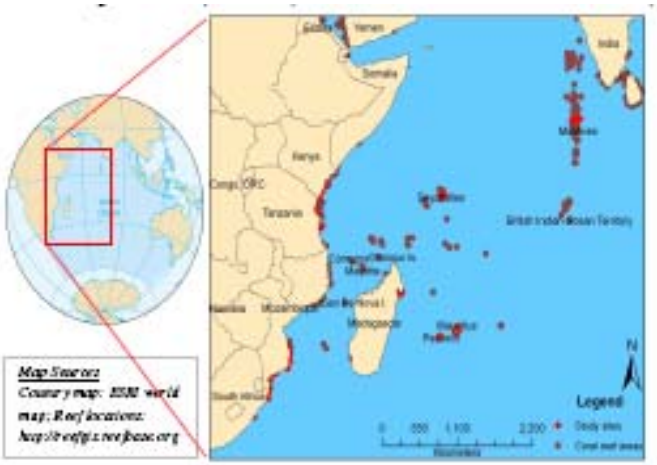


Figure 11: A map of the study area showing coral reef areas and the coral bleaching study sites

Susceptibility model 1 (SM 1)

In this model, Spatial Principal Component Analysis (SPCA) is developed to build the coral reefs susceptibility map. PCA involves calculations of Eigen values and their corresponding eigenvectors of the covariance matrix to derive the new variables in a decreasing order of importance in explaining variation of the original variables (Tran *et al.*, 2002). SPCA input consisted of the 12 fuzzy-normalized parameter raster maps. A matrix denoting the transformation coefficients (calculated from the covariance matrix), and a set of principal component (PC) was obtained as the output. Each variable is transformed into a linear combination of principal component with

decreasing variation. The linear transformation assumes the components will explain all of the correlation in each variable. Hence each output PC carries different information which is uncorrelated with other PC's.

Table 1: Results of SPCA

Selected PC's	I	II	III	IV	V	VI	VII
Eigen value	0.67	0.16	0.1	0.09	0.05	0.04	0.03
Contribution ratio (%)	56.5	13.4	8.4	7.7	4.16	3.66	2.72
Cumulative contribution (%)	56.5	69.9	78.3	85.9	90.1	93.8	96.5

Seven PC's (I – VII) were selected (>1% variance) and used as the basis for calculating the susceptibility index. Susceptibility index (SM 1), is defined as the sum of a couple of weighted principal components shown a shown in equation 1.

$$SMI = \alpha_i Y_i + \alpha_{II} Y_{II} + ... + \alpha_m Y_m \qquad \textbf{[Equation 1]}$$

Where Y_i is the number of the principal component and α_i is the corresponding contribution. Using the table 6 and equation 1, SM1 was calculated as follows:

$$\mathbf{SM\ 1 = 0.5649*A_I + 0.1344*A_{II} + 0.837*A_{III} + 0.765*A_{IV} + 0.416*A_V + 0.366*A_{VI} + 0.272*A_{VII}}$$

Where A_I… A_{VII} are the seven PC's.

The map obtained from the above model had unit-less values ranging from -1 to 2. The lowest value represented highest susceptibility and vice versa. These values were normalized and inverted such that low susceptibility became 0 and high susceptibility became 1.

Susceptibility model 2 (SM2)

Also known as the pair wise weighing, Analytic Hierarchy Process (AHP) is a general theory of measurement, widely applied in decision making process (Saaty, T. L., 1980; Saaty, T. L., 1986; Forman and Gass, 2001; Ercanoglu *et al.*, 2006). It involves indicating for each pair of variables in qualitative terms, to what extent a variable is more important than another. Comparison of items *i* and *j* results in a positive number a*ij* giving the strength of preference of item *i* over item *j*; the larger the number the greater the preference in favour of item *i* while a value of 1 indicates indifference (Stein and Mizzi, 2005). It is an Eigen value approach to the pair wise comparisons, where the principal right eigenvector of variables is derived (Vaidya and Kumar, 2006). The eigenvector shows the dominance of each variable with respect to

the other variables.

Instead of using the traditional AHP pair-wise comparison method, cosine amplitude, a widely used similarity method was employed (Ross, T. J, 2004; Ercanoglu and Gokceoglu, 2004; Ercanoglu *et al.*, 2006; Dubois and Prade, 1980) to evaluate relations of input parameters in relation to susceptibility. In this method, data samples of a set form a data array, say *x* and can be expressed in the following equation for *n* data:

$$X = \{x_1, x_2 \ldots . x_n\}$$ **[Equation 2]**

In this context, $x_1 \ldots x_n$ are the number of normalized parameters being considered. Each of the parameters, x_i in the data array X is itself a vector of length *m*, that is:

$$x_i = \{x_{i1}, x_{i2} \ldots \ldots x_{im}\}$$ **[Equation 3]**

Each of the data samples can be thought as a point in *m*-dimensional space, where for a complete description of each point, *m* coordinates are required. This method calculates pair-wise relation strength (r_{ij}) using equation 19, based on the comparison of two data arrays and range of r_{ij} values that varies from 0 to 1 ($0 \leq r_{ij} \leq 1$) (Ross, T. J, 2004; Ercanoglu *et al.*, 2006).

$$r_{ij} = \frac{\left[\sum_{k=1}^{m} x_{ik} \times x_{jk}\right]}{\sqrt{\left(\sum_{k=1}^{m} x_{ik}^2\right) \times \left(\sum_{k=1}^{m} x_{ij}^2\right)}}$$ **[Equation 4]**

Where x_{ik} and x_{ij} are the elements of the pair wise parameter.

Ross, T. J. (2004) explains that equation 4 relates to a dot product for the cosine function. When two vectors are most similar, their dot product is unity, and when they are at right angles to each other i.e. most dissimilar, their dot product is zero (Ross, T. J, 2004; Ercanoglu and Gokceoglu, 2004).

Normalized data files for all the elements were used as the input for the above equation. A symmetric matrix with values indicative of the parameter relations based on their influence on the subject being modelled was developed. To determine the

score (eigenvectors) of each parameter, average values for respective rows in the normalized matrix were obtained by dividing each row sum by the number of parameters (table 2).

Table2: Pair-wise parameter relation strength (r_{ij}) matrix from equation 19. The upper half of the matrix was filled with the same values before calculating the eigenvector (scores) for each parameter.

	Max SST	SST	UV	Chlorophyll	CV	Bleaching model	Wind speed	PAR	Zonal currents	SST Hotspot	Meridional currents	Slope	
	P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**P11**	**P12**	**Eigenvector \score**
P1	1												0.098
P2	0.92	1											0.092
P3	0.89	0.87	1										0.091
P4	0.51	0.38	0.43	1									0.080
P5	0.90	0.92	0.91	0.59	1								0.097
P6	0.21	0.01	0.00	0.61	0.11	1							0.055
P7	0.87	0.90	0.79	0.43	0.83	0.20	1						0.091
P8	0.79	0.70	0.90	0.37	0.78	0.02	0.66	1					0.084
P9	0.64	0.65	0.69	0.34	0.65	0.03	0.63	0.63	1				0.074
P10	0.48	0.66	0.42	0.66	0.48	0.59	0.39	0.41	0.28	1			0.081
P11	0.49	0.41	0.55	0.35	0.57	0.24	0.50	0.55	0.44	0.37	1		0.073
P12	0.65	0.59	0.54	0.44	0.62	0.44	0.57	0.44	0.38	0.47	0.42	1	0.082

Finally, the partial membership's i.e. fuzzified parameters were multiplied by their respective calculated weights and summed to obtain the second susceptibility model (SM2; equation 5). This method is also called convex combination or weighted sum (Ercanoglu *et al.*, 2006; Burrough and McDonnell, 2005).

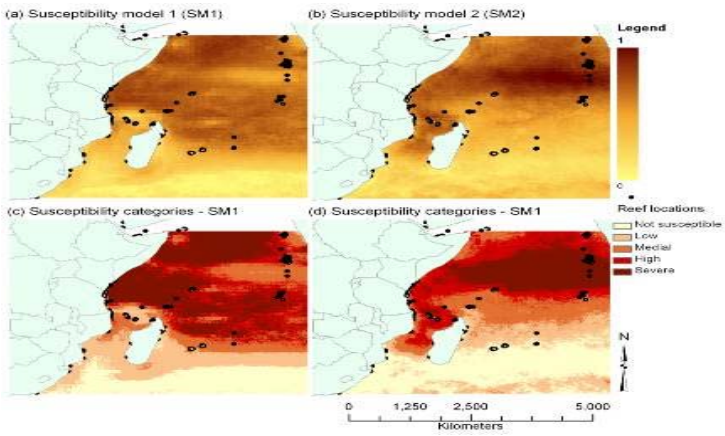
SM2=0.098*P1+0.092*P2+0.0e91*P3+0.080*P4+0.097*P5+0.055*P6+0.091*P7+0.084*P8+0.074*P9+0.081*P10+0.073*P11+0.082*P12

[Equation 5]

Robinson, V. B. (2000) observed that different fuzzy aggregation approaches can yield strikingly different results. Other common methods of aggregating fuzzy sets include the traditional 'AND' and 'OR' operators; which essentially means that for pixel x_{ij} in maps X_1.....X_n, the maximum x_{ij} in fuzzy set maps X_1.....X_n will make the final model with 'AND' operator. If 'OR' operator is used, the minimum x_{ij} is utilized (Burrough and McDonnell, 2005). The final map would only reflect the best or worst case scenario respectively (Robinson, V. B., 2003). 'AND' and 'OR' operators do not account for the effects of the other variables and instead make use of only the extreme conditions (Bone *et al.*, 2005).

Ecological susceptibility

The two models, SM1 and SM2 display common susceptibility pattern in some regions while they differ in some (Fig. 3). SM1 model highlights the north-western region of the WIO from the Kenyan and Somali coast and extending towards the East as severely susceptible areas (Figure 3a,c). Most of the same region is classified as moderate to highly susceptible in SM2. Regions off the coast of Tanzania, Mozambique, South Africa and the East coast of Madagascar are classified as low-moderate susceptibility classes in both models. However, the north-western coast of Madagascar falls within the moderate and highly susceptible categories in SM2, whereas, according to SM1, the same region is classified as low-moderately susceptible.



Map Sources
Country map: ESRI; Reef locations: Reef base

Figure 3: Maps showing estimated susceptibilities by (a) SM1 and (b) SM2; and the classified maps for (c) SM1 and (d) SM2

While the two models generally agree on susceptibility for regions North of 5°S, they differ on the susceptibility estimates for further South (>5°S). The Indian Ocean islands of Mauritius and Re union have relatively low susceptibility estimates: in SM1 they are classified as being low-moderately susceptible while, in SM2, the same region fall under not susceptible or low susceptibility classes.

Seychelles Islands are depicted as being severely susceptible in SM1, and moderate-highly susceptible in SM 2 (Fig. 3). The models also differ for susceptibilities of some reef locations in Maldives (≈ 0-1°N to ≈ 60-75°E), where SM1 indicates moderate susceptibility, while SM2 estimates are high to severely susceptible. However, a sample of 107 reefs in Maldives indicate similar susceptibility estimates by both models with mean susceptibility of 0.61±0.01 and 0.69 ±0.01 by SM1 and SM2 respectively.

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SESSION 3

Predicting and mapping biomass using remote sensing and GIS techniques: a case study of sugarcane

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Abstract

Monitoring biophysical features of sugarcane using ground-based crop cut techniques is not accurate and requires immense resource inputs in terms of time, manpower and equipment. Remotely sensed data could be used to estimate productivity of growing and mature cane, sugarcane health and vigor monitoring, and to understand sugarcane ecological processes. This study examined pertinent crop biophysical parameters that characterize biomass in representative sugarcane fields and used satellite image and spectral reflectance values in TM combinations to calculate vegetative indices. Five vegetation indices [Normalized Difference Vegetation Index, Soil Adjusted Vegetative Index, Red/Near Infrared, Red/Middle infrared and Near infrared/Middle infrared] were calculated and compared with in-situ ground truthed data clipped in two fields in a Mumias nucleus estate sugarcane field. Results indicated that biomass production and yield of a sugarcane crop could be predicted by satellite imagery by employing any of the vegetation indices investigated. Leave area index and Red/Near infrared were the best biomass predictors with coefficients of correlation (r^2) of 0.94 each. A strong relationship also existed between the spectral values and field biomass with the best prediction having correlation coefficients (r^2) of 0.78 and 0.82 for band 3 and band 4 respectively. Temporal maps of vegetation indices developed using transformed values of band 3 and band 4 suggested that yield and biomass could be determined by ETM+ satellite imagery over the senescence stage of sugarcane crop growth. The model developed performed well giving a coefficient of efficiency (C_{eff}) between estimated and measured yields of 0.98 and an average relative percent error of 0.0175. The study showed that remote sensing provides fast data gathering over large areas and that these data sets may be used to estimate the final crop yield. This allows for practicing timely field management operations to yield, which is one of the major elements in biomass utilization.

Processing of MODIS NDVI imagery to characterize vegetation dynamics of SWALIM land cover polygons using the GLCN VEDAS software.

Capecchi Valerio[1], Di Greogrio Antonio [2].
Presented by von Hagen Craig [3,*]

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Abstract

One of the primary interests of the present work is to study the role of terrestrial vegetation in homogenous test areas with the goal of understanding the average vegetation behavior. This requires an understanding of the global distribution of vegetation types as well as their biophysical and structural properties and spatial/temporal variations. Vegetation Indices (VI) are robust, empirical measures of vegetation activity at the land surface. They are designed to enhance the vegetation signal from measured spectral responses by combining two different wavebands, often in the red (0.6-0.7 mm) and Near Infra-Red wavelengths (0.7-1.1 mm). The MODIS Vegetation Index products (also VI, which is referred to as the "continuity index" of the existing NOAA-AVHRR derived NDVI) provide consistent, spatial and temporal comparisons of global vegetation conditions which is used to monitor the Earth's terrestrial photosynthetic vegetation activity in support of phenologic, change detection, and biophysical interpretations. The MODIS gridded VI maps depicting spatial and temporal variations in vegetation activity are derived at 16-day and with a spatial resolution of about 250 meters; moreover they include quality assurance (QA) flags with statistical data that indicate the quality of the VI product and input data. The information one gets from MODIS vegetation average dynamics is intended as enrichment to the SWALIM database.

This paper also describes a methodology to evaluate the uncertainty associated to the prediction of NDVI values at different periods of the year. The statistical bases of the methodology are first presented, consisting of the computation of first and higher order statistics (averages and variances/covariances) describing the relationships between multi-annual NDVI time series of different periods in the year. These statistics are found at per-pixel level and can then be aggregated over suitable land cover polygons, such as those of SWALIM. Next, the statistics can be composed to explicitly express NDVI prediction uncertainty at every time lag during the year. An example of this computation is shown for Somalia using Spot-VGT imagery of 7 years

SESSION 3

(1999-2005). The outputs produced both at per-pixel and polygon levels are finally interpreted in order to preliminarily assess the utility of the proposed procedure.

Seasonal NDVI profiles are indicative of the development of vegetation activity, which is controlled by both natural (climate, soil, etc.) and human-induced (agricultural and forestry operations, etc.) factors. The evaluation of current and near-future NDVI values may therefore be useful to estimate and predict vegetation conditions in response to these factors. This is particularly important in most African countries, where droughts can frequently limit vegetation productivity and determine food scarcity and famines. The current study is aimed at evaluating the possibility of predicting the seasonal evolution of pixel NDVI values at different times of the year. From a statistical viewpoint the study is carried out by applying correlation analyses to inter-year variations of temporally adjacent NDVI MVC image series. More specifically, the correlations between NDVI values at periods of the year N and at period N+1...X are computed at pixel level along multi-annual series of NDVI images. Next, the combination of these correlations with multi-annual NDVI statistics of the same periods (averages, standard deviations) allows the computation of NDVI prediction uncertainty for each pixel considered. Such statistics can be also aggregated to produce the same information for the SWALIM polygons.

ANNEXES

Annex 1: List of participants
Annex 2: Index of institutions
Annex 3: Final Program of the Workshop

ANNEX 1 - LIST OF CONFIRMED PARTICIPANTS

N	Surname, Name	Institution	location
1	Aadan, Mohamed Ali	Ministry of Water and Mineral Resources, Somaliland	Hargeisa
2	Ahmed, Abdiwahid Ibrahim	Ministry of Water and Mineral Resources, TFG – Transitional Federal Government	Baidoa
3	Arabu, Evans	University of Nairobi	Nairobi
4	Balint, Aniko B.	UNEP DEWA	Nairobi
5	Balint, Zoltan	SWALIM	Nairobi
6	Brink, Andreas	JRC	Ispra
7	Castronuovo, Marco	ASI	Rome
8	Cherogony, Reginauld	Hornrelief	Nairobi
9	Claessens, Lieven	CGIAR - CIP	Nairobi
10	Darko, Walter	HATOF Foundation	Ghana
11	Farah, Hussein O.	RCMRD	Nairobi
12	Farah, Suleman Jama	Ministry of Local Government & Rural Development, Puntland	Garowe
13	Farmer, Graham	FAO Officer in Charge for Somalia	Nairobi
14	Gabrielle, Thomas	T-Ana International	Nairobi
15	Gadain, Hussein	SWALIM	Nairobi
16	Galu, Gideon	FEWSNET	Nairobi
17	Gicheha, R.W.	RCMRD	Nairobi
18	Gidyelew, Taye	CGIAR - ILRI	Addis Abbaba
19	Gilbert, Ouma	IGAD-ICPAC	Nairobi
20	Hoepffner, Nicolas	JRC	Ispra
21	Hussein, Abdullkadir Hassan	Ministry of Planning, TFG – Transitional Federal Government	Baidoa
22	Ibrahim Osman, Abdulkadir Haji	Ministry of Agriculture, TFG – Transitional Federal Government	Baidoa
23	Isse, Aden Abdirahman	Ministry of Public Works, Transport and Civil Aviation (Water Division), Puntland	Garowe
24	Jones, Arwyn	JRC	Ispra
25	Khamala, Erick	RCMRD	Nairobi
26	Kirugara, David	UNESCO	Nairobi
27	Korme, Tesfaye	RCMRD	Nairobi
28	Latham, John	FAO	Rome
29	Leo, Olivier	JRC	Ispra
30	Magan, Abdillahi Hassan	Ministry of Agriculture, Somaliland	Hargeisa
31	Maina, Joseph	ITC	Nairobi
32	Marai, Renato	FAO	Nairobi
33	Marimba, Fednance	RAMANI communication	Nairobi
34	Mayaka, Edward	University of Nairobi	Nairobi
35	Mithöfer, Klaus	ICIPE	Nairobi
36	Mohamed, Abdi Abdillahi	Ministry of Pastoral Development & Environment, Somaliland	Hargeisa
37	Mosele, Luciano	EC – Somalia Operations	Nairobi
38	Musse, Mohamed Abdi	Ministry of Livestock, Agriculture and Environment, Puntland	Garowe
39	Mutie, Simon	RCMRD	Nairobi

40	Mwanhudza, Anthony Mwasaha	ASI Italian Space Base	Malindi
41	Nimmo, J. M.	RMR	Vientiane, Lao
42	Nyabenge, Meshack	ICRAF	Nairobi
43	Odhiambo, J.O	University of Nairobi	Nairobi
44	Oduori, Simon Mumuli	SWALIM	Nairobi
45	Omuto, Christian Thine	SWALIM	Nairobi
46	Oroda, Ambrose	SWALIM	Nairobi
47	Ottichilo, Wilber	RCMRD	Nairobi
48	Paron, Paolo	SWALIM	Nairobi
49	Pellikka, Petri	Helsinki Univ	Helsinki
50	Samatar, Abdulkadir Ali	Ministry of Planning and International Cooperation, Puntland	Garowe
51	Schlueter, Thomas	UNESCO	Nairobi
52	Sommavilla, Elio	Water For Life	Nairobi
53	Soyan, Mohamed Elmi	Ministry of Environment and Disaster Management, TFG – Transitional Federal Government	Baidoa
54	Vargas Rojas, Ronald	SWALIM	Nairobi
55	Vazquez, Paula	EC – Somalia Operations	Nairobi
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57	Waruingi, Lucy	African Conservation	Nairobi
58	Watson, R. Murray	RMR	Vientiane, Lao
59	Watson, S.P.	RMR	Vientiane, Lao
60	Wilson, Mick	UNEP DEWA	Nairobi
61	Yusuf, Abdi Omar	Ministry of Livestock, Forestry and Range, TFG – Transitional Federal Government	Baidoa

ANNEX 2 - INDEX OF INSTITUTIONS

African Conservation
ASI – Agenzia Spaziale Italiana (Italian Space Agency)
CGIAR – CIP International Potato Centre
CGIAR – ILRI International Livestock Research Institute
DEWA - Division of Early Warning and Assessment
EC – European Commission – Somali Operations
FAO – Food and Agriculture Organization of the United Nations
FEWSNET – USAID Famine Early Warning System
GLCN – Global Land Cover Network
Hatof Foundation
Helsinki University
Hornrelief
ICIPE – African Insect Science for Food and Health
ICRAF – World Agroforestry Centre
IGAD ICPAC – IGAD Climate Prediction and Application Centre
ITC – International Institute for Geoinformation Science and Earth Observation
JRC – EC Joint Research Centre
Ministry of Agriculture, Somaliland
Ministry of Agriculture, TFG – Transitional Federal Government
Ministry of Environment and Disaster Management, TFG – Transitional Federal Government
Ministry of Livestock, Agriculture and Environment Puntland
Ministry of Livestock, Forestry and Range, TFG – Transitional Federal Government
Ministry of Local Government & Rural Development, Puntland
Ministry of Pastoral Development & Environment, Somaliland
Ministry of Planning and International Cooperation, Puntland
Ministry of Planning, TFG – Transitional Federal Government
Ministry of Public Works, Transport and Civil Aviation (Water Division), Puntland
Ministry of Water and Mineral Resources, Somaliland
Ministry of Water and Mineral Resources, TFG – Transitional Federal Government
RAMANI Communication
RCMRD – Regional Centre for Mapping and Resource Development
RMR – Resource Management & Research
SWALIM – Somalia Water And Land Information Management
T-Ana International
UNEP DEWA– United Nations Environmental Programme Division of Early Warning Assessment
UNESCO – United Nations Educational, Scientific, and Cultural Organization
University of Nairobi

ANNEX 3 – FINAL PROGRAMME

Potentialities and Limitations in the Use of Remote Sensing for Detecting and Monitoring Environmental Change in the Horn of Africa

Expert workshop

12th – 13th June 2007 Holiday Inn Nairobi

NAIROBI, KENYA

Date	Time	Title of the Session	Chair
	8:00	***Registration to the workshop***	
	8:30	**Opening of the workshop**	**Ms. Paula Vazquez-Horyaans** (EC)
	8:40	**Technical notes on the workshop's programme**	**Dr. Zoltan Balint** (FAO SWALIM)
	8:50	**Keynote speech** "Challenges in land cover and land use change detection in East Africa"	**Prof. Petri Pellikka** (Helsinki Univ)
DAY 1	9:30	**Session 1 –** Resource Base Inventory	**Dr. Wilber Ottichilo** (RCMRD)
	10:30	*Coffee break*	
12/06/2007	11:00	**Session 1** – Resource Base Inventory	**Dr. Wilber Ottichilo** (RCMRD)
	13:00	**Session 1** – Session summary	
	13:15	*Lunch break*	
	14:15	**Session 2** – Assessing Environmental Change	**Dr. John Latham** (FAO)
	15:35	*Coffee break*	
	16:00	**Session 2 –** Assessing Environmental Change	**Dr. John Latham** (FAO)
	17:40	**Session 2 –** Session summary	
	19:30	Social dinner	
	8:30	**Session 3 –** Process modelling	**Dr. Arwyn Jones** (JRC)
	9:50	*Coffee break*	
	10:20	**Session 3 –** Process modelling	**Dr. Arwyn Jones** (JRC)
DAY 2	12:20	**Session 3 –** Session summary	
	12:35	*Lunch break*	
	13:30	**Session 4 –** Discussion & Conclusions	**Prof. Petri Pellikka** (Helsinki Univ)
13/07/2007	15:30	*Coffee break*	
	16:00	**Session 4 –** Discussion & Conclusions	**Prof. Petri Pellikka** (Helsinki Univ)
	17:00	**Session 4 –** Conclusions	
	17:20	**Final remarks and conclusion of the workshop**	**Dr. Graham Farmer** (FAO O.i.C for Somalia)

FINAL ACTUAL PROGRAMME

KEYNOTE SPEECHS

	Surname, Name	Institution	location	Title of presentation	Other Authors
1	PELLIKKA, Petri	Helsinki University	Helsinki	Remote sensing challenges in land cover and land use change detection in East Africa	
2	LATHAM, John	FAO,	Rome	Global Earth Observation and Standards overview.	

SESSION 1 – RESOURCE BASE INVENTORY
CHAIR: Dr. Tesfaye Korme (RCMRD)

N	Surname, Name	Institution	location	Title of presentation	Other Authors
3	GICHEHA, R.W.	RCMRD	Nairobi	Land use/cover Mapping and Boundary Delineation of Plantations and Indigenous Forests in Mount Kenya	Ottichilo Wilber , Farah Hussein O.
4	JONES, Arwyn	JRC	Ispra, Italy	Mapping the soil of Africa: new initiatives and preserving data resources	Montanarella Luca, Spaargaren Otto, Nachtergaele Freddy, Thiombiano Lamourdia & Zougmore Robert
5	MAYAKA, Edward	University of Nairobi	Nairobi	Use of ontology web language in remote sensing applications	
6	PARON, Paolo	SWALIM	Nairobi	Landform mapping for environmental applications: integration of visual image interpretation and digital terrain analysis.	Vargas Rojas Ronald
7	VARGAS ROJAS, Ronald	SWALIM	Nairobi	The use of Remote Sensing for soil mapping: a review	Omuto Christian
8	WATSON, Murray	RMR	Vientiane, Laos	The Evolution of Aerial Strip Sampling into the Digital Era: Adaptations over 40 Years and Contemporary Relevance to the Horn of Africa, and in particular to Somalia.	Nimmo J.M., Crees P.D.
9	WILSON, Mick	UNEP	Nairobi	Open web services and SDIs	

SESSION 2 – ASSESSING ENVIRONMENTAL CHANGE
CHAIR: Dr. John S. Latham (FAO)

N	Surname, Name	Institution	location	Title of presentation	Other Authors
10	BRINK, Andreas	JRC	Ispra, Italy	Monitoring Land Cover Dynamics in Sub-Saharan Africa	Eva Hugh, Simonetti Dario, Bartholomé Etienne, Mayaux Philippe
11	MWANGUDZA, Anthony	ASI	Rome & Malindi	The Broglio Space Centre's Contribution of Remotely Sensed Data for Environmental Change Monitoring in the Horn of Africa Region. Institutional partnership and Challenges in Data Acquisition and Distribution.	Castronuovo Marco, Mwinga Juma, Nguli Michael, Kirugara David, Ndugu Jane , Anangwe Byron
12	WARUINGI, Lucy Chege	ACC	Nairobi	Integration of Remote Sensing and GIS for mapping community rangelands	
13	GALU, Gideon	FEWSNET	Nairobi	Case-Study: Use of satellite remotely sensed data integrated with the livelihood baseline information in support of food security monitoring and early warning activities in the Sool & Nugaal pastoral region of Somalia.	Aw-Dahir Mohamed
14	GILBERT, Ouma	IGAD-ICPAC	Nairobi	The use of Remote Sensing information as proxy of weather and climate in the Greater horn of Africa.	

15	HOEPFFNER, Nicolas	JRC	Ispra, Italy	The African Marine Information System: a tool for ecosystem management in coastal waters	Clerici Marco, and Djavidnia Samuel
16	ODUORI, Simon Mumuli	SWALIM	Nairobi	The Use of Remote Sensing in Land Cover Mapping, Change and Impact Detection in Somalia	Vargas Rojas Ronald , Oroda Ambrose and Omuto Christian
17	NYABENGE, Meshack	ICRAF	Nairobi	The Key Challenges in Application of GIS and Remote Sensing in Environmental Variables Change Analysis in the Horn of Africa Region. Are we capturing the right indicators of change?	Wayumba G, Inima A, Omuto C.T
18	ORODA, Ambrose	SWALIM	Nairobi	Application of Remote Sensing in the assessment of Pastoral Resources: Assessing droughts in Somalia	Vargas Roja Ronald, Oduori Simon Mumuli, and Omuto Christian
19	WATSON, Murray	RMR	Vientiane, Laos	Monitoring Vegetation Change in Somalia by Fixed Plots: Opportunities Offered by New Methods in Remote Sensing.	Watson S.P., Nimmo J.M., Watson A.

SESSION 3 – PROCESS MODELLING
CHAIR: Dr. Arwyn Jones (JRC)

N	Surname, Name	Institution	location	Title of presentation	Other Authors
20	MUTIE, Simon	SWALIM	Nairobi	Impacts of land cover and land use changes on stream flow; a case study from the Nile Basin	Gadain, Hussein, Guleid Artan
21	GIDYELEW, Taye	CGIAR - ILRI	Addis Abbaba	Land degradation and Change detection of biophysical products in different land use types Using Multi Temporal SPOT NDVI Image Data: a Case in Blue Nile River Basin, ETHIOPIA	
22	KORME, Tesfaye	RCMRD	Nairobi	Mapping of groundwater vulnerability to pollution using modified DRASTIC modeling: The case of Naivasha- Nakuru basin, Kenyan Rift	Ottichilo Wilber, Barongo Justus and Alamirew Demis
23	LEO, Olivier	JRC	Ispra, Italy	Crop monitoring for Food Security – Contribution of Remote-Sensing and challenges for the future	
24	MAINA, Joseph	ITC	Enschede, Holland	Modelling Ecological Susceptibility of Coral Reefs to Environmental Stress Using Remote Sensing, GIS, and in situ Observations: A case study in the Western Indian Ocean	
25	ODHIAMBO , J.O	University of Nairobi	Nairobi	Predicting and mapping biomass using remote sensing and GIS techniques: a case study of sugarcane	Wayumba G., Inima A. and Omuto C.
26	VON HAGEN, Craig	SWALIM / GLCN	Nairobi	Processing of MODIS NDVI imagery to characterize Vegetation Dynamics of Africover polygons (VeDAS)	
27	ARABU, Evans	Univ of Nairobi	Nairobi	Estimation of soil erosion using GIS: a case study of Taita Hills.	
28	GADAIN, Hussein	SWALIM	Nairobi	Preliminary validation of NOAA CPC satellite derived RFE	Muchiri Peris, Muthusi Flavian

SESSION 4 – DISCUSSION & CONCLUSIONS
CHAIR: Prof. Petri Pellikka (Helsinki University)

WORKSHOP WEBSITE

Please check under the *News & Announcement* section of the main webpage of SWALIM:
http://www.faoswalim.org