A MANUAL GIS SYSTEM FOR MACHAKOS DISTRICT, KENYA

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ABSTRACT

In 1991 a need arose to establish land use changes, which took place in Machakos District, Kenya during the past five decades. The study, among others, included environmental, population, conservation, farming systems, and production changes and trends. A GIS was designed mainly to assess the impact of land terracing on the reduction of soil erosion and agriculture productivity.

The available material was aerial photographs dated 1948, 1960, 1978 of varying scales and qualities. Selected sites at different locations were identified, and map bases were established from available topographic maps. Stereoscopic interpretation of the aerial photographs covering the selected areas was conducted to delineate the boundaries of the chosen land categories. A set of three temporal uncontrolled aerial mosaics for each area was assembled, one from the interpreted aerial photographs of each date. A half-tone negative was produced for each mosaic. The negative was re-projected to form positive transparency of appropriate scale conforming with the map base. The areas of the various categories were measured and the temporal changes in land use were defined by comparing transparencies of different epoch. By this method it was possible to obtain quick information with reasonable accuracy and cost to meet the set objectives.

The exercise had clearly demonstrated that, in the absence of recent computer technologies, it was still possible to use the available material and facilities to ***produce*** and provide useful information to satisfactorily meet certain objectives. However, for sustainable development, there should be awareness of the direction of the development in the country, and identification of the suitable technologies to meet its needs. It is, therefore, recommended to acquire suitable computer based GIS paralleled with appropriate training and follow up. The expansion of the educational base in this field is of prime importance.

INTRODUCTION

A study, which aimed to relate long term environmental change, population growth and technological factors to sustainable development, was carried out on Machakos District, Kenya in 1991. The general objective of the study was to measure the changes that have occurred in this semi-arid District over a period of six decades. Degradation of the District's natural resources raised concern in the 1930's as rapidly approaching an alarming rate (Maher, 1937). Today, the area has a populations five times as great and the value of the agricultural output per head is estimated to be three folds larger than it was then (English, 1994). On the other hand contemporary observations, local eye witnesses, and official statistics of estimated landuse revealed that landuse in the District during the period 1940-90 has been subject to change in large scale, and in particular, extension of cultivated land at the expense of rangeland and woodland. Much of the area used is now under continuous cultivation, and almost 100% of the cultivated area is now subject to some form of terracing. This had contributed to sharply reduce soil erosion and enhance agricultural productivity. Therefore, a long term perspective is essential to study land use change patterns, and the driving forces leading to such changes, since temporary factors, such as a run of poor rain fall year, can can confuse analysis of change if only few years are considered.

The study covered a wide range of environmental and related concepts . These included environmental profile (Mortimore, 1991 a), technological changes (Mortimore 1991 b), landuse profile (Rostom, 1991), conservation profile (Gichuki, 1991), population profile (Tiffen, 1991 a), production profile (Tiffen, 1991 b), and farming and income systems (Tiffen, 1991 c).

The project was initiated and coordinated by the Overseas Development Institute (ODI). It was carried out by staff members from the University of Nairobi and with the assistance of the Ministry of Reclamation and Development of Arid, Semi-arid and Wastelands in Kenya.

This paper presents the method adopted and the results of landuse changes in the District. It is based mainly on the ODI working paper on the landuse profile (Rostom, 1991).

SELECTION OF THE STUDY AREAS

Five study areas that are quite spread and believed to be representative of the range of conditions found in the District as a whole were selected. They were Mbiuni, Masii, Kalama, Makueni and Ngwata. At later stage, it was realized that the makueni and Ngwata locations did not show substantial changes in the early period and have large size compared with other locations. For these reasons, it was decided to cut down these areas to sample portions only (see fig. 1).

PREPARATION OF DATA SOURCES

The data sources for the selected areas were identified as the available topographic maps and aerial photographs of different epoch. The District is covered by six topographic map sheets of scale 1:250,000 and 34 sheets of scale 1: 50,000, all published by the Survey of Kenya. The selected locations for studies of the landuse changes were each covered by either one or two sheets of scale 1:50,000. This scale was considered adequate to meet the objective of the study. The required topographic maps were purchased from the Survey of Kenya.

Aerial photographic coverage of the selected study areas was available for the years 1948, 1960-61, 1967 and 1978. The average scale of the photographs was 1:30,000 for the 1948, 1: 50,000 for the 1961 and 1967, and 1:20,000 for the 1978 photography. The 1978 photographs are of acceptable quality, while those from 1961 and 1967 have poor contrast and a lot of cloud cover. The 1948 photography is also of poor quality and the negatives for the production of prints are in the United Kingdom. The numbers of the 23*23 cm format aerial photographs covering each area for a certain date are shown in table 1. The necessary photographic prints were purchased from the Survey of Kenya and the Royal Air Force, Huntingdon.

Table 1: Total Number of Photographs / Location / Epoch

Location	1948	1961	1978
Mbiuni	26	16	81
Masii	16	22	86
Kalama	26	18	109
Makueni	14	16	96
Ngwata	-	18	83

METHODOLOGY

In the absence of a computer based facilities, It was decided to create a manual GIS. This was achieved by producing a land use transparency for each epoch for an area which, if over laid, would show the landuse changes both in extent and location. In addition the transparencies can be used to derive numerical data (e.g. areas) by direct measurements. Besides, they can be used in association with other attributes, whether geometrical or non-geometrical, to obtain necessary information. The transparencies, therefore, would have to be compatible and of the same format. The base maps of the transparencies were derived from the 1:50,000 topographic maps of the area.

Production of the transparencies

The topo-maps covering each area were assembled. The boundary of the area was carefully drawn, and the area outside the boundary masked out by opaque paper. The grid and graticule values in the margins were kept as frame information. This information gives the necessary georeference for the area, and would be particularly useful for later digitizing if need arises in future. The assembly was then edited and appropriately titled. The transparencies were produced from the maps so assembled by contact photography through the negative and positive processes. The positive print was adjusted to be in faint print to better show up the subsequent landuse information.

Classification categories

The development of classification scheme is crucial in that many man-hours can be wasted if a series of maps are produced that are of little use because they are incompatible with the other elements of a GIS or because the categories are impractical. Classification development in this project took into consideration the need of the project, the time and financial resources available to do the work, the type of data source (maps and imagery) available, their spatial accuracy, resolution and quality. Potentially useful classification systems were considered, including the USGS landuse/landcover classification system (Anderson et al., 1976) and the classification for rangelands in East Africa (Pratt, 1977). Members of other groups in the project were consulted to determine practical categories that would be in harmony with the other themes considered in the study. A classification was then adopted to include the following classes of landuse/landcover:

(i) Agricultural land, not terraced
(ii) Agricultural land, terraced
(iii) Bush/scrub/grazing land
(iv) Forest/woodland
(v) Others, including unclassified land

The landuse class 'agricultural land' means land that is normally cultivated. 'Bush/scrub/grazing land' means grassland with a more or less dense cover of woody plants, often of shrub form. 'Forest/woodland' means mature woodland or plantations with a continuous canopy. 'Others' means none of the foregoing classes including cloud cover.

Photointerpretation

The interpretation was done by visual methods. Stereo models were constructed from overlapping photographs under the mirror stereoscope, and the delineation of each land use category was indicated on the photographs by different colours and symbolization. Whenever necessary, differences in height were measured by parallax bar to aid in interpretation. A sample stereopair in each strip was interpreted by an expert to serve as a reference key for models in the strip. The rest of the models in the strip were then given to well-trained technicians for interpretation. The photographs interpreted by the technicians were then checked by the experts.

The photointerpretation of the 1948, 1961 and 1978 photographs include sub-classifying the cultivated land into terraced and unterraced. Under the mirror stereoscope the terracing lines between two levels of the terraces are very clear in the stereomodels of the 1978 photographs, owing to their large scale and good quality, however, on the 1960-61, and 1948 photographs, the interpretation of the terraced cultivated land was not easy, due to the smaller scale (1:50,000) and/or the poor quality of these photographs. Terrace maintenance could not be assessed nor the adequacy of the structure or design. Field visits and checks were meaningless due to the long time-lapse between the date of photography and the time of conducting the study.

Construction of aerial mosaics

Mosaics were assembled from the aerial photographs with the delineated land use categories. The assembly was done on cartridge boards, and the only control criterion adopted was to form a continuous image of extended photographed features. The aerial mosaics were then reduced to the required transparency scale of 1:50,000 by photographic means, using well separated and positively identified features on the mosaics and topographic maps as control.

Transfer to land use sheets

The land use information was transferred from the reduced aerial mosaics onto the transparency base maps by manual tracing. The main guide during this transfer was the local registration of corresponding map and mosaic features such as rivers, roads, hills, etc.

This approach minimized positioning errors due to tilt, relief and, more important, due to error accumulation in the mosaic assembly.

RESULTS

The transparencies had shown the landuse information. There were three maps for each area representing the distribution of landuse categories in 1948, 1961 and 1978 (except for Ngwata where only two maps for 1961 and 1978 are presented due to non-availability of photo-cover of 1948). On the transparencies, it was possible to discern spatial patterns from the contour lines and correlate it with the terraces. It was also possible to superimpose two (or more) of the transparencies of one area corresponding to different dates for the identification of changes of landuse at particular locations for a certain epoch. Fig. 2 presents a reduction of the transparencies for the location Mbiuni as an example.
Areas of each landuse category in three years were measured from the transparencies by a planimeter and overlaying a dot grid. The percentage change in the area of every category was also calculated: 1948 – 1961 (13 years), 1961 – 1978 (18 years) and 1948 – 1978 (30 years). Land under cultivation was assessed as either terraced or non-terraced. All computations were presented in tabular form. A sample for Mbiuni location is given in Table 2.

Table 2: Mbiuni Location (Area = 18,000 hectares)											
1948				1961				1978			
(i+ii)	(iii)	(iv)	(v)	(i+ii)	(iii)	(iv)	(v)	(i+ii)	(iii)	(iv)	(v)
6,350	11,110	530	10	6,080	10,720	400	800	12,190	1,990	930	2,890
Percentage of area of class to study area (unclassified area subtracted)											
35.3	61.8	2.9	-	35.4	62.3	2.3	-	80.7	13.2	6.1	-
Percentage increase (+) or decrease (-) in landuse categories											
(i+ii)				(iii)				(iv)			
1948-1961	1961-1978	1948-1978		1948-1961	1961-1978	1948-1978		1948-1961	1961-1978	1948-1978	
+0.3	+128.0	+128.6		+0.8	-78.8	-78.6		-20.7	+165.2	+110.3	
Area of terraced and non-terraced land % to total cultivated land											
				1948		1961			1978		
Non-Terraced Land (i)				29.9		24.2			0		
Terraced Land (ii)				70.1		75.8			100		

ANALYSIS OF RESULTS

From the transparencies and tables, proper analysis could be done on each study area and the District as a whole. (This is briefly found in Rostom, 1991).

Assessment of precision

Interpretation

Assuming that the minimum resolving power of the camera used in producing the aerial photographs was 10 lines/mm., then the ground resolution of the 1948 photographs is 3m., 1961 photographs is 5m. and that of 1978 photographs is 2m. Based on other investigations (Aronoff, 1982; 1985), the results of similar projects, and other considerations, the accuracy of interpretation of the 1948 and 1978 photographs should be better than 95%. Due to the smaller scale of the 1961 photographs and their inferior quality, accuracy is estimated by 90%. Ordinarily, a minimum level of 85% interpretation accuracy is desired for optimal results (Anderson, 1976). Using visual techniques, this kind of accuracy is possible to achieve.

Positioning

The estimated planimetric displacement is within 1-2mm (50-100m on the ground). Although this accuracy is lower than that of the 1:50,000 base map, it is acceptable because the important task was the interpretation in which high positional accuracy does not serve an important purpose. Therefore the positional accuracy of 1-2mm of the line boundaries between landuse categories is considered acceptable.

Areas

Considering the order of the height variations on the study area the error in an individual are may be up to 5%-8%. However, as these errors vary in magnitude and sign from one place to another, the errors in any category on a map sheet should be considered of random nature. Therefore, the sum of the errors in the total area of a certain category should tend to zero. Thus the accuracy of the areas corresponds to the measuring accuracy by a planimeter or dot grid. The sums of the areas in each category were rounded to the nearest 10 hectares.

CONCLUSION

The production of transparencies was used as a manual GIS and was successful to meet the objectives of the study. It demonstrates that in the absence of computer based GIS facilities, it is possible to use available facilities and material to produce and provide useful information to satisfactorily meet certain objectives. However, the system is limited by the maximum possible number of overlaying data layers (2 or 3) and limited attributes.

RECOMMENDATION

For sustainable development, it is necessary to build and maintain a geographic framework for national spatial data infrastructure. This would take care of the present fragmented small projects, which usually have no conformity and are not compliant with any standards. It is thought that the Survey of Kenya has the capacity to develop in collaboration with academicians, experts and potential users, standards and specifications for a countrywide spatial GIS dada infrastructure founded on technical requirements and appropriate technological trends. Guided by proper direction of the development in the country and the users' needs, a suitable technology could be identified. Then GIS vendors could be invited to supply the suitable GIS tools to conform with these specifications. The need to widen and deepen the training and educational base in GIS does not need to be over emphasized.

REFERENCES

Anderson, J. R. et al. 1976, A land use and land cover classification scheme for use with remote sensor data. Geological Survey Professional Paper No. 964. Washington, D. C: Government Printing Office.

Arnoff, S. 1982, Classification accuracy: A user approach. Photogrammetric Engineering and Remote Sensing, 48(8):1309-1317

Arnoff, S. 1985, The minimum accuracy value as an index of classification accuracy. Photogrammetric Engineering and Remote Sensing 51(1):99-111

English, J., Tiffen, M., Mortimore, M. 1994. Land Resource Management in Machakos District, Kenya: 1930-1990. World Bank Environment Paper No. 5

Gichuki, F.N. 1991. Environmental Changes and Dryland management in Machakos District, Kenya: Conservation Profile, ODI working paper No. 56

Maher, C. 1937, Soil erosion and land utilization in the Ukamba Reserve (Machakos) Rhodes House Library, Oxford: Mss.Afr.S.755

Mortimore, M. (ed.), 1991a. Environmental Changes and Dryland management in Machakos District, Kenya: Environmental Profile, ODI working paper No.53

Mortimore, M. (ed.), 1991b. Environmental Changes and Dryland management in Machakos District, Kenya: Technological Changes, ODI working paper No. 57

Pratt, D. J. and Gwynne, M. D. 1977, Rangeland management and ecology in East Africa. London: Hodder and Stoughton.

Rostom, R. S., Mortimore, M. 1991, Environmental Changes and Dryland management in Machakos District, Kenya: Landuse Profile, ODI working paper No. 58

Tiffen, M. (ed.), 1991b. Environmental Changes and Dryland management in Machakos District, Kenya: Production Profile, ODI working paper No. 55

Tiffen, M. 1991a. Environmental Changes and Dryland management in Machakos District, Kenya: Population Profile, ODI working paper No. 54

Tiffen, M. 1991c. Environmental Changes and Dryland management in Machakos District, Kenya: Farming and Income Systems, ODI working paper No. 59

BIOGRAPHICAL NOTES

More than 43 years of teaching experience in surveying, photogrammetry, remote sensing and related subjects at universities in Egypt, Sudan, Nigeria, and Kenya.
Participated in more than 20 international conferences and symposia. Published more than 30 scientific papers. Executed a wide range of projects and offered several consultations. Supervised more than 15 academic theses.
Membership in several international forums including Geodetic Education and Publication Committee of the Commission of Geodesy in Africa, ISPRS and SORSA.

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