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A FIRST INTERPRETATION OF EAST AFRICAN SWIDDENING VIA COMPUTER-ASSISTED ANALYSIS OF 3 LANDSAT TAPES

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I. INTRODUCTION

This paper reports a successful preliminary application of machine processing of LANDSAT data to the identification of swidden farming in East Africa (Figure 1). Analysis of "slash and burn" or shifting cultivation via LANDSAT requires recognition of the characteristics intrinsic to swiddening: by Western standards, field sizes are small, their borders are irregularly shaped and merge with natural features of the terrain; in the area of East Africa with which we are concerned, multiple cropping of as many as 25 cultigens is common, and the small fields in which these crop complexes are grown are interspersed among land at various stages of fallow and regeneration of plant cover.

These characteristics of swidden farming combine to achieve what Geertz[1] has called a "canny imitation" of the natural landscape. This mimetic effect makes swidden fields indistinguishable from surrounding plant cover by visual inspection of standard LANDSAT imagery (Figure 2). In contrast, areas of Western-style agriculture are readily apparent. However, our analysis of the digital LANDSAT data does allow swidden areas to be differentiated.

The special problems which swidden farming pose require "a reorientation of techniques and typologies."[2] Such a reorientation is justified for two reasons. First is the number of people for whom swidden farming is the life-support system: in 1963, Conklin[3] put this number at 200 million persons in Africa, Asia, and the New World. Second, the homogeneous quality of the LANDSAT data, and the capability of making repeated observations, facilitate analysis of spatio-temporal variables intrinsic to swiddening.[4]

II. DESCRIPTION OF THE AREA

Our East African study area is West Pokot District, Rift Valley Province, Kenya. The study area lies midway between Mt. Elgon to the southwest and Lake Turkana (formerly Lake Rudolph) to the northeast. The District is about 5,000 square kilometers and includes a population of 60,000 persons, including about 45,000 swidden farmers. The balance employ a combination of farming and herding as subsistence techniques.[5]

The District's physiographic characteristics include a range of altitude from 800 meters to 4,000 meters above sea level. The probability of rainfall meeting evapo-transpiration requirements varies from .1 at lower altitudes in the north to .9 at higher altitudes in the south.[6] The soils, formed from a variety of substrates, tend to be easily exhausted. Along a cline from high to low altitude, plant cover includes "Alpine" meadow, hardwood forest, Commiphora scrub, riverine thickets, scattered Acacia, and a grassy cover which ranges from tall and dense to short and patchy (Figure 3). The preponderance of swidden farming is at mid-elevations, in association with Commiphora regrowth.

The swidden area we used for training is in a region known locally as Asar (see Figures 4 and 5), which is part of a narrow valley oriented north and south. The Asar region in general and the swidden area in particular are part of a subsistence ecozone the Pokot refer to generically as kamass, that is, mid-altitude slopes used extensively for swiddening. We use the term ecozone to mean an area sharing similar characteristics and exploited by a particular subsistence activity.[7]

The upper and lower limits of the kamass ecozone in the Asar region are approximately 2,500 meters and 1,500 meters above sea level. In the Asar region, a further characteristic of this ecozone is that the slopes are generally east-facing (B, C, and D in Figure 6). Cultivation takes place on slopes of varying degrees of steepness in plots of varying size, often less than half a hectare. A single plot may contain sorghum, millet, beans, gourds and squashes. Harvesting of different crops occurs at different times in a single plot, and at different times in different parts of the same ecozone. Throughout the ecozone, areas of mixed cultivation are interspersed among plots previously returned to fallow. The fallow period may be as

long as 20 years, by which time a mature community of secondary regrowth is established.

The decision to return a fallow area to active cultivation involves a complex set of socio-ecological factors which include population pressure, food reserves, and a need to reestablish a family's claim to the land, as well as the amount of time the land has been in fallow and the degree of regeneration of plant cover. A plot re-opened for cultivation is therefore likely to be surrounded by areas at various stages of the fallow period, from newly returned to fallow, to completely regenerated and mature regrowth. This situation is schematized in Figure 7, in which an area of active cultivation (marked AC) is surrounded by areas at different stages of fallow (marked F-1, F-5, etc., with the numbers referring to years in fallow).

The cycling of plots between active cultivation and fallow in the ecozone we studied tends to involve shorter periods of time at lower elevations than at higher elevations. That is, close to the bottom of the valley where water for cultivation is more readily available the fallow cycle is shorter, and plots are returned to active cultivation from a herbaceous stage rather than a ligneous stage of plant growth; at higher altitudes where water for cultivation is less readily available, and depends in part on the uncertain use of an irrigation technique developed by the Pokot, the fallow period is long enough that trees become established and reach maturity. Despite the many factors involved, a generalization is possible: areas of active cultivation on the upper slopes of the ecozone in the Asar region tend to be surrounded by areas of more mature regrowth, including trees, than areas of active cultivation on the lower slopes of the same ecozone. Regrowth in fallow areas on the lower slopes tends to be limited to grasses and bushes. This differentiation is evident in the 1956 aerial photography, in which there is a clear demarcation of upper and lower slopes by a band of relatively dense regrowth (see Figure 5).

III. DATA DESCRIPTION

Our knowledge of West Pokot District derives largely from data collected during anthropological fieldwork in 1961-62. In addition to these field data, there is complete aerial coverage of the District, collected in 1956. Since even recent maps of the District are relatively incomplete, the two main sources of information are the 1956 aerial photographs and the 1961-62 fieldwork. The time lapse between these data and the LANDSAT data limits the kinds of interpretation the present study can make.

The LANDSAT data consist of three tapes, each representing a different portion of the cycle of dry and wet seasons characteristic of the District, as follows: 1972, mid-dry season; 1973, late dry, and 1975, early wet. Quality ratings for these tapes were, respectively, 8888, 8888, and 5588.

IV. DATA ANALYSIS

The first step in data analysis was a pre-processing step to de-skew, rotate, and rescale the data. This geometric correction process resulted in line printer output at a nominal scale of 1:24,000. All three data sets were geometrically corrected, and gray scale printouts were produced for a region approximately equal to 1/25th of a scene. The gray scales had 16 levels or ranges of spectral response values, with one alphanumeric symbol or overprint combination assigned to each level.

To simplify correlating the aerial photography with the LANDSAT data, photographic enlargement was used. The original photography was at a nominal scale of 1:44,000; as enlarged to match the gray scales, the nominal scale was 1:24,000. For final scale adjustment, a Bausch and Lomb Zoom Transfer Scope was used to register the photographic image of the swidden area to its location on the gray scale.

By using the aerial photography to provide a framework for spatial referencing, a 32 x 40 pixel training site centered on the swidden area was selected.

The next step was to obtain spectral response values for training the classification algorithm, developed by Dr. Stephen Ungar at NASA Goddard Institute for Space Studies. The spectral responses in all four bands were tabulated for pixels falling within the previously delimited swidden area. From these tables, two methods of obtaining training data were tried: (1) the average, or mean, and (2) the most frequent, or modal response. Both methods gave similar results. The ease of determining the modal responses led us to use that method for the analysis. For all three dates, the modal response in each band for the swidden area was determined (Table 1). These modal responses were used to train the classifier. For each date, one modal spectral response was used to define the informational class swidden. The classifier then made a binary decision for each pixel: the pixel was or was not within the spectral class defined by the training spectrum and the program parameters. Program parameters were selected empirically to maximize correct classification of data points within the swidden area.

V. RESULTS

Classification results are shown superimposed on the aerial photography (Figure 8). Table 2 displays the distribution of classified points according to the areas demarcated in Figure 5.

The distribution of points is highly correlated with the ecozone comprised of lower slopes marked C, the training area marked D (also lower slope),

and upper slopes marked B. The percentage of points falling within this ecozone is, for three classifications, 77%, 82%, and 80%. This leads us to infer that the spectral class defined by our training method does represent the informational class of swiddening.

VI.   SUMMARY, DISCUSSION, AND CONCLUSIONS

This paper has reported a first attempt at interpreting swidden farming in East Africa via machine analysis of three LANDSAT scenes. Each scene represents a different portion of the seasonal cycle of alternating wet and dry periods, a characteristic of the area notably affecting food production.[9] The training area was selected because it represents a traditional system of East African swiddening, utilizing mid-altitude slopes of mountains and escarpments.[10] This training area is part of a larger ecozone defined by upper and lower altitudes and the east-facing orientation of its slopes.

Inspection of the 1956 aerial photography (Figure 5) and observations made during the 1961-62 fieldwork show only light use of the upper slopes in the kamass ecozone of the Asar region. Our classification results indicate an increase in swiddening activity over the period 1956-1975. Furthermore, within the 3 year span of our LANDSAT data, results indicate a considerable increase in swiddening activity (Table 2).

Given the necessity in the swiddening system of retiring areas of active cultivation to fallow, and opening up new areas of cultivation elsewhere, and given the shared characteristics of the ecozone, which make relocation elsewhere within the same ecozone likely, we feel this analysis resulted in (1) a successful identification of an area of swiddening in East Africa and (2) that computer analysis makes this possible. In the standard image products, the mimetic effect associated with swiddening tends to blur distinctions between the natural surround, active cultivation, and land in fallow.

We have not presented the results of our classifications in terms of an increase of so many hectares because to do so might give a false impression of accuracy. In view of our available ground information, we claim only the identification of swiddening activity within an ecozone. As for an increase in this activity over earlier levels, we recognize different possible explanations. For example, one season may be better than another for the detection of swiddening, and this alone might account for all or most of the difference in number of points classified in the three data sets. However, there is also the possibility that the changing number of points classified reflects a corresponding change in swidden activities. Only further ground truth can resolve this. The acquisition of additional information is necessary to achieve more definitive results than the preliminary ones we have presented here. The

continued importance of swidden farming in East Africa, and elsewhere in the tropical and subtropical world, warrants further investigation of this application of the LANDSAT data.

VII.   REFERENCES

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Table 1. Modal Responses Used for Training.

Scene ID	Date		Band 4	Band 5	Band 6	Band 7
1067-07221	9/28/72	count	29	22	46	24
		energy*	.566	.346	.637	1.752
1193-07230	2/1/73	count	28	26	43	24
		energy	.547	.409	.596	1.752
2063-07111	3/26/75	count	30	36	54	27
		energy	.572	.492	.636	1.859

*mw/cm^2sr

Table 2. Number and Distribution of Points Classified.* Table entries correspond to areas designated by letter in Figure 5.

Date Scene ID Season	Asar Region Ecozone			Riverine	West Facing Slopes		Elsewhere		Total
	B	C	D		E	F	A	G	
9/28/72 1067-07221 mid-dry	62	4	19	8	5	9	3	0	110
2/1/73 1193-07230 end-dry	56	13	14	7	5	4	2	0	101
3/26/75 2063-07111 early wet	93	38	22	16	8	1	14	0	192

*The convention was adopted that if a point lay along a demarcation line in Figure 5, the point was assigned to the area to the left of that line.
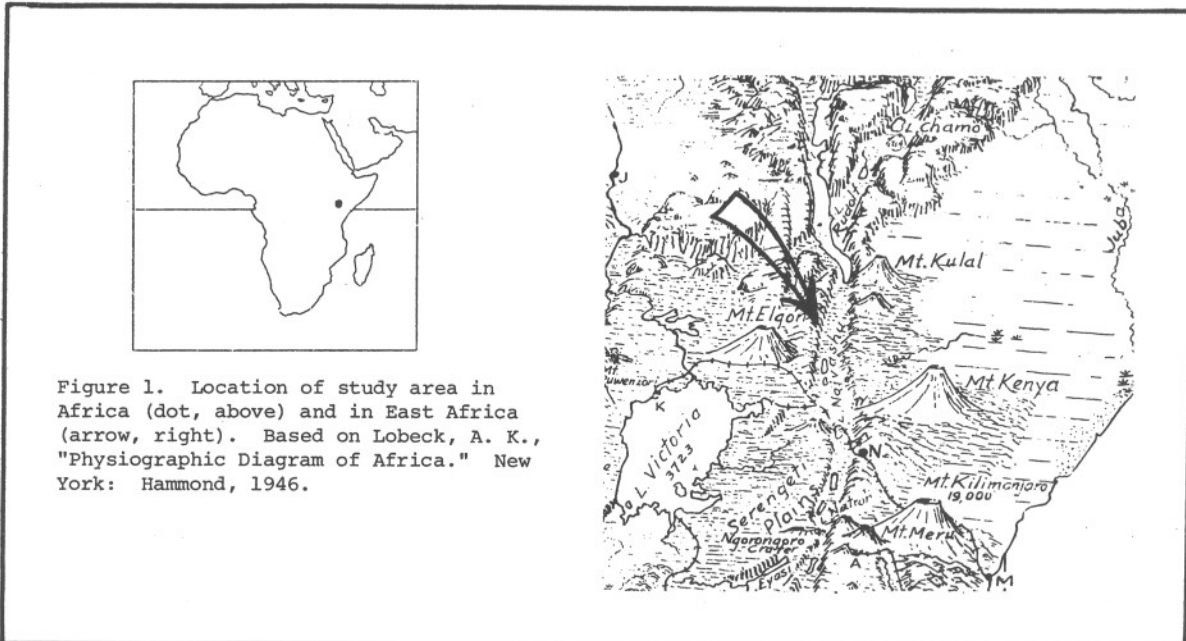
Figure 1. Location of study area in Africa (dot, above) and in East Africa (arrow, right). Based on Lobeck, A. K., "Physiographic Diagram of Africa." New York: Hammond, 1946.

Figure 2. LANDSAT scene 2063-07111, 26 March 1975, Band 7, enlarged to about 1:300,000. Large-area agriculture is visible on the left of the scene, while shifting or swidden cultivation is barely apparent on the right. Arrow indicates study area.
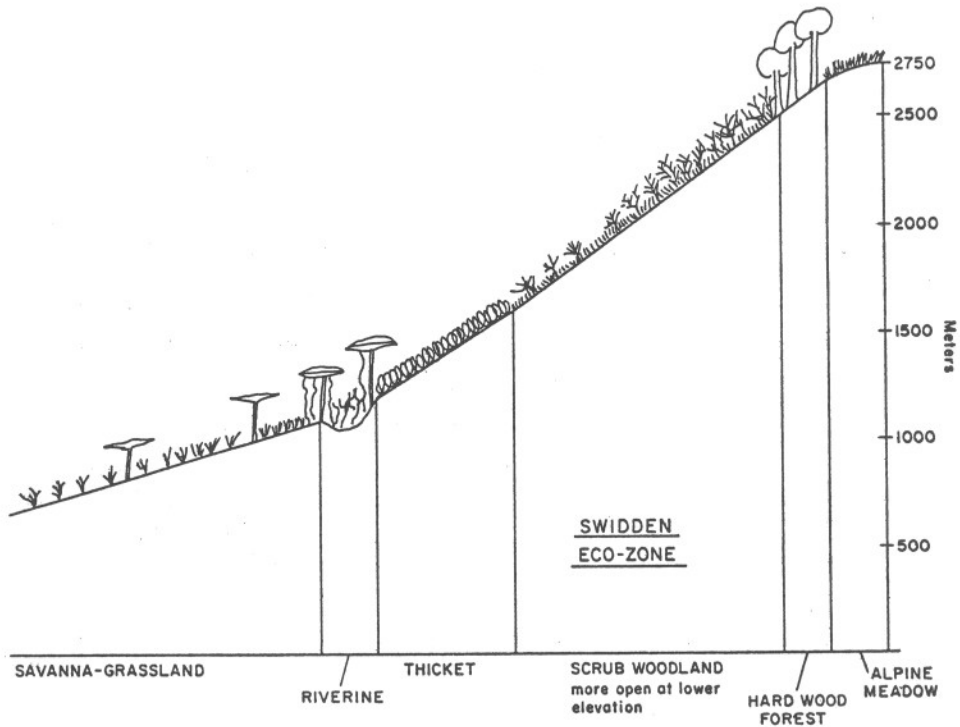
Figure 3. Schematic arrangement of plant cover, West Pokot District, Kenya, according to elevation above sea level. (Schematic courtesy of J. Coiner)
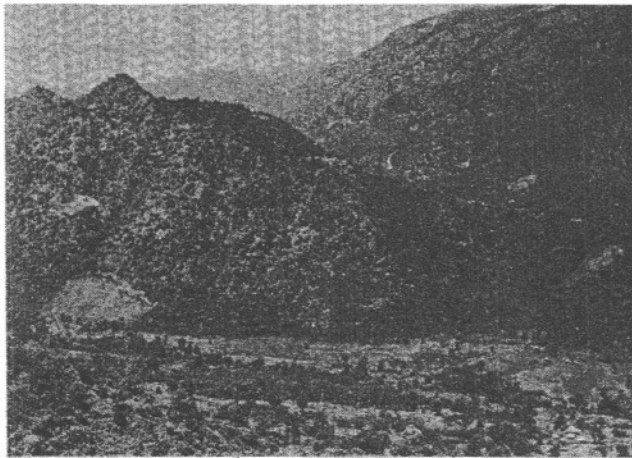
Figure 4. Field Photograph, 1961-62, of the southern portion of the Asar region swidden area used for training. North is to the right. Figure 5 is an aerial photograph of the same location.
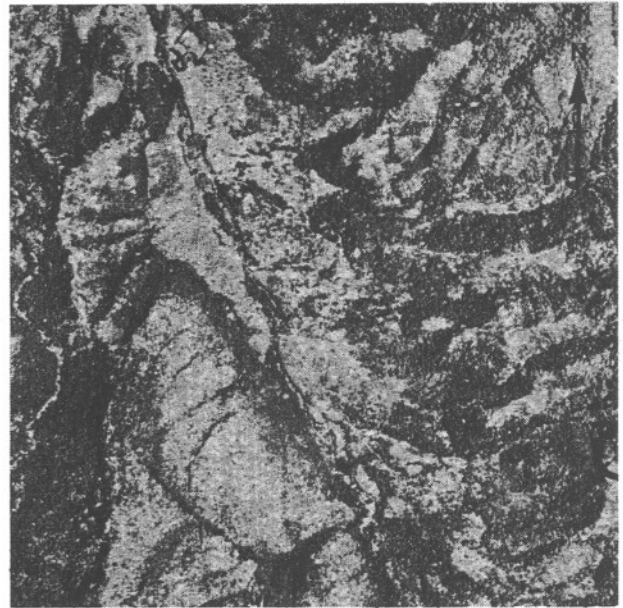
Figure 5. 1956 aerial photograph of the Asar region swidden area used for training, enlarged to a nominal scale of 1:24,000.
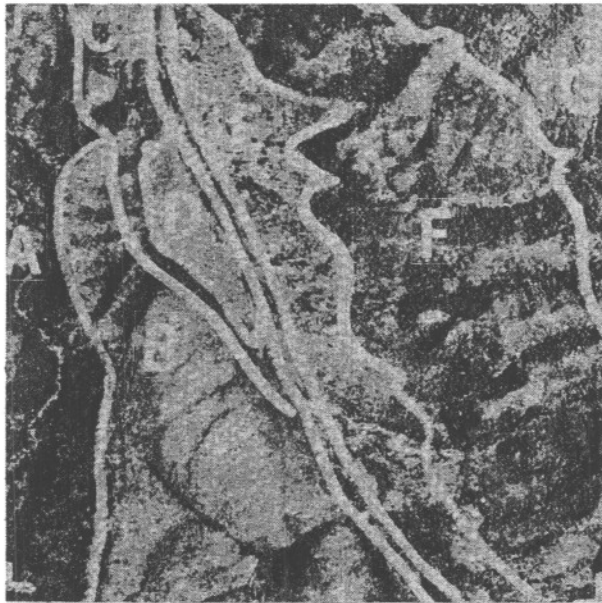
Figure 6. Ecozones superimposed on 1956 aerial photography. A = escarpment and riverine areas. B, C, and D are east-facing slopes, Asar swidden area: B = upper slopes, C = lower slopes, D = lower slope training area. E, F, and G are west-facing slopes: E = lower slopes, F = upper slopes, G = high altitude area. The narrow band separating east-facing and west-facing slopes is riverine.
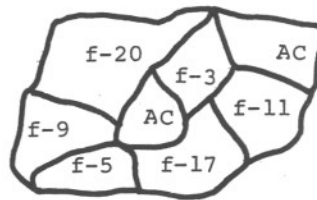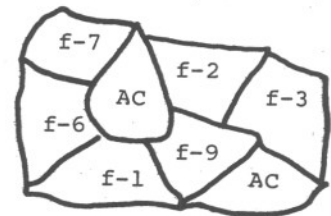
Figure 7. Schematic arrangement of actively cultivated (AC) and fallow areas, Asar region swidden area. f-1, f-17, etc., indicate years in fallow. Higher numbers correspond to ligneous regrowth, and lower numbers to herbaceous.

8a.   LANDSAT scene 1067-07221, 28 Sept. 1972.
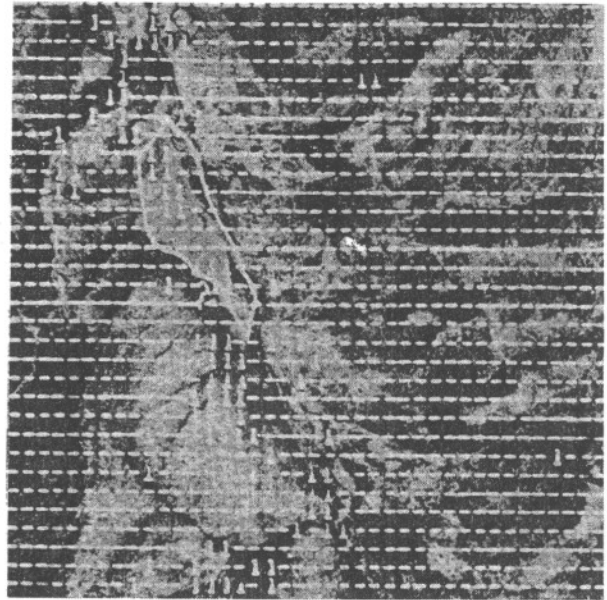
8b.   LANDSAT scene 1193-07230, 1 Feb. 1973.
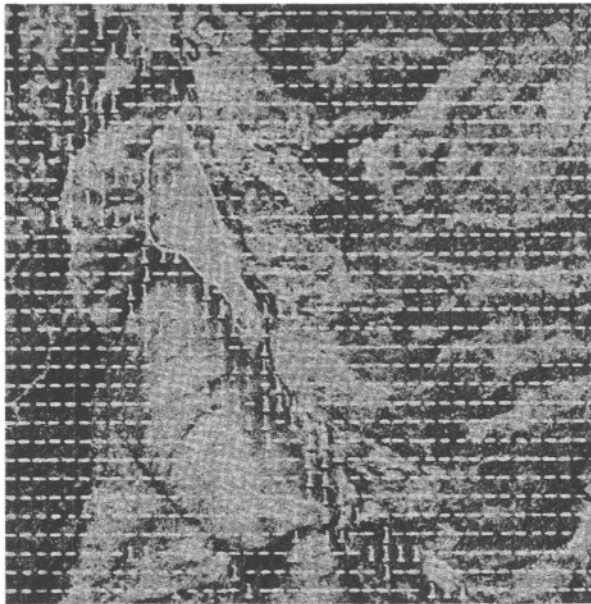
8c.   LANDSAT scene 2063-07111, 26 Mar. 1975.

Figure 8. Classification results generated by
computer-assisted analysis of digital LANDSAT data,
superimposed on 1956 aerial photography. Training
area is outlined; "1" = points classified as
swidden, "-" are points not so classified.

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