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Temporal Evaluation of Spot and Landsat TM Images for Forest Mapping in Menengai Country, Kenya

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Abstract. Three multispectral (false color composite) and one panchromatic SPOT images were tested to evaluate their usefulness in forest mapping in developing countries. Simple visual interpretation techniques were utilized to plot forest maps independently from each test image. The resulting maps were compared with forestlands shown on the 1:50000 scale topographic map of the area. Results show that the highest accuracy of plotting forestlands is obtained with images taken in the rainy season where over 90% of forestlands could be identified, discerned and plotted. However, in all cases, the success rate is not less than 80%. Comparison with Landsat Thematic Mapper (TM) imagery shows that SPOT system is superior in forest mapping and interpretation.

Introduction

The management of forestlands requires timely and up-to-date information on the type, amount and availability of forest resources being produced on these lands. For almost three decades, satellite remote sensing has provided the means for collecting spectral data over large land areas in support of these resources inventory and monitoring information needs. Indeed previous experience[1] showed that Landsat

Keywords: SPOT image, forest mapping, interpretation of forestlands, accuracy.

(1) A.S. Benson and S.D. DeGloria, "Interpretation of Landsat Thematic Mapper and Multispectral Scanner Data for Forest Surveys," *Photogrammetric Engineering & Remote Sensing,* 51 (1985), 1281-1289; M.A. Karteris. "Mapping of Forest Resources from a Landsat Diazo Color Composite," *International Journal of Remote Sensing,* 6 (1985), 1797-1811; D.J. Walsh, "Conifers Tree Species Mapping Using Landsat Data," *Remote Sensing of Environment,* 9 (1980), 11-26; W.R. Hafner and W.R. Philipson, "Landsat Detection of Hardwood Clearcuts," *Photogrammetric Engineering & Remote Sensing,* 48 (1982), 779-80; A.E. Ali. "Topographic Mapping of Vegetational Features from Landsat Imagery: An Experiment from Sudan," *Sudan Silva,* 6 (1987), 78-82; Idem, "Topographic Mapping of Vegetational Features from Seasat SAR Imagery: An Experiment from the Firth of Tay," *Scottish Forestry,* 41 (1987), 273-81.

Multispectral Scanners (MSS), Return Beam Vidicon (RBV) and Thematic Mapper (TM) and Seasat (SAR) imageries were suitable for mapping large areas for the purpose of forestry. However, the spatial resolutions of these sensors, which are typically 80 m for the MSS and 30 m for the RBV TM and SAR did not allow detection of many types of forest canopies believed to be important for the forester and forest manager.

Based on the desire to enhance high resolution spectral data acquisitions from space, the French Space Agency (CNES) developed and launched in February 1986 an Earth Probatoire d'Observation de la Terre (SPOT) Satellite System. The system contains two pointable high resolution visible (HRV) multispectral pushbroom scanning sensors with ground resolutions of 10 m in the panchromatic mode and 20 m in the multispectral mode. These finer resolution figures were, of course, achieved at the cost of greater amount of data processing which would invariably lead to higher prices of SPOT data.

The purpose of this paper is to report results of a modest experiment concerned with the evaluation of multidate SPOT satellite imagery for forest mapping. It should be pointed out, however, that the expression "forest mapping" as used in this experiment, refers simply to the process of interpreting and delineating forestlands without being entangled into the very specialized aspects of forest mapping (e.g., forest type, condition, etc.) as the author does not have the necessary knowledge in this field.

The principal goals of the study are:

(i) to visually interpret and delineate small and scattered forestlands;

(ii) to find out which type of SPOT imagery is most useful for forest mapping; and

(ii) to specify the season in which SPOT imagery gives the largest percentage of forest resources information.

Description of Test Area and Materials

The test area selected for this experiment is the Menengai County in Kenya. The area is roughly 25 km in the north-south direction and 20 km in the east-west and lies between latitudes 00° 45′ S and 00° 45′ S and between longitudes 36° 00′ E and 36° 15′ E. In the extreme south of the test area lies the famous holiday resource Menengai Crater which is part of the well-known African Rift Valley (Fig. 1). The topography of the area is somewhat varied in nature with moorlands, traditionally used for grazing, a number of wooded areas and some rather extensive large scale farming

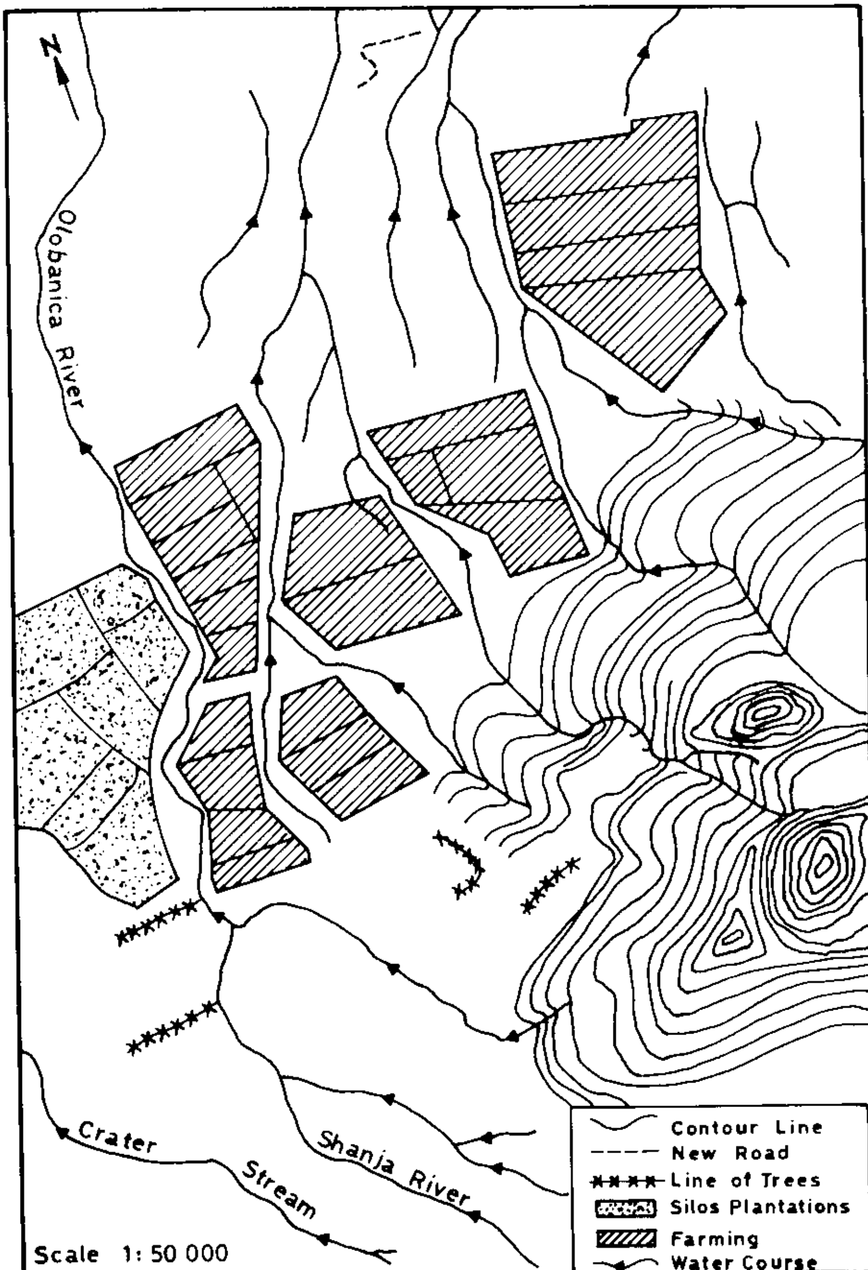

Fig. 1. Section of the Topographic Map of the Test Area.

activities with maize, coffee, silos and tea being the principal crops. Quite a number of rivers and streams exist in the area. Ground elevations range from below 1000 m above mean sea level to well above 1500 m. About 20% of the area is covered by forests and scattered woodlands of various types some of which are suitable for the production of cheap commercial timber.

For the purpose of this test, four types of SPOT imagery of the test area were made available by the Regional Centre for Services in Surveying, Mapping and Remote Sensing in Nairobi, Kenya. These are as follows:

(i) a black-and-white SPOT image (panchromatic mode) with 10 m resolution. This image was taken in September 1988. The image is virtually cloud-free and looks much like an aerial photo which means that it had been processed to a very high level (Fig. 2);

Fig. 2. SPOT Panchromatic Subimage of the Test Area (1/50000).

(ii) a multispectral image (XS1, XS2, XS3) taken on the 14th of March 1986, i.e. a few weeks after the launch of the SPOT system. The cloud cover of this image was in the order of 10% over the entire image area; but practically no clouds showed up on forest areas of the image;

(iii) A multispectral image taken on 23rd September 1986. This image was also virtually cloud-free; and

(iv) a multispectral image acquired on February the 9th 1987 with an estimated cloud cover of less than 8%.

For the sake of comparison, a Landsat Thematic Mapper (TM) image of the test area was also available for the test. The Landsat TM image was taken in July 1984 and was processed in the form of a color composite image (bands 2, 3, 4) with 30 m ground resolution.

Standard processing routines (e.g., radiometric and geometric corrections, haze removal, edge enhancement, etc.) were originally applied to the images. All test images were supplied in the form of 1:50000 scale image maps (prints). As a matter of fact, all three SPOT multispectral images were used in this experiment in the form of false color composites of the three bands, each image being used individually. The panchromatic image was exceptionally good, while the Landsat TM image suffered slightly from existence of clouds.

The primary reference data employed to evaluate the interpretation process was a topographic map of the district. This map (scale 1:50000) was supplied by the Survey of Kenya and was compiled in 1969 with revised features added in 1984. In a few cases, supplementary information was also acquired from 1:40000 scale black-and-white aerial photography flown in 1979. A 2-day field trip was made to the test area in order to solve some ambiguities in interpretation. The panchromatic image of the test area looked very much like the aerial photography and was in fact used to guide the driver through the test area during the field trip.

Method of Evaluation

Basic principles of photointerpretation were used during the process. The interpretation involved identification, location and delineation of forest boundaries without considering forest type or condition. A time lag of at least one week was allowed between the interpretation of the different images. This undertaking was believed to reduce possible interpreter biases. Forests and woodlands were plotted directly from the images onto clear good quality acetate overlays, thus producing maps of forests and woodlands at a scale of 1:50000.

The evaluation of the interpretation process of each of the five images was carried out by comparing the plot of each image with the 1:50000 scale topographic map of the area. The comparison was made by superimposing the plot of forestlands of each image on the map. Registration of a plot and the map was based on the drainage and the roads systems and on the fire-break lines deliberately made between forests.

Interpretation errors were classified into two categories:(2)

(i) Omission errors whereby forestlands were wrongly omitted on the images; and

(ii) Commission errors (i.e., additions) whereby nonforest areas were misclassified as forestlands.

The field trip to the test area allowed detection of omitted and added features. The area enclosures of correctly interpreted forestlands on the five images were then measured directly on the plots using a Sokkisha KP-90N electronic digital planimeter with an accuracy of 0.2%. The areas of omitted and committed features were also measured. Each of these entities was then compared with the total area of the plot as a percentage value.

Results and Discussions

Fig. 3 shows existing forestlands on the test area. This plot was obtained by direct tracing from the topographic map so that the resulting figure is at a scale of 1:50000. Fig. 4 shows forestlands as interpreted from the panchromatic image of the test area, while Figs. 5, 6 and 7 show the corresponding forest information as derived from the other three SPOT multispectral images (color infrared) of the test area. Table 1 shows the percentages of correctly-identified forest areas, omission errors and commission errors.

A glance at Table 1 shows that the highest percentage of correctly-identified forest information (91%) is obtained with the Sept. 1986 SPOT multispectral image. The author believes that this highest value may be due to the fact that this image was taken in September which is a rainy month in Kenya. The presence of large amounts of water on the ground causes a large increase in the amount of the chlorophyll in the plant tissues which, consequently, will increase the amount of reflected infrared radiation which is then received by the SPOT sensors. This creates sufficient contrast between forest canopies and the surrounding features. This would make a forest or woodland easy to discern and delineate on an image.(3)

(2) Karteris.

(3) A.E. Ali. "Hydrological Mapping from SPOT Imagery," *Earth Surface Process and Landforms*, 16 (1991), 173-80.

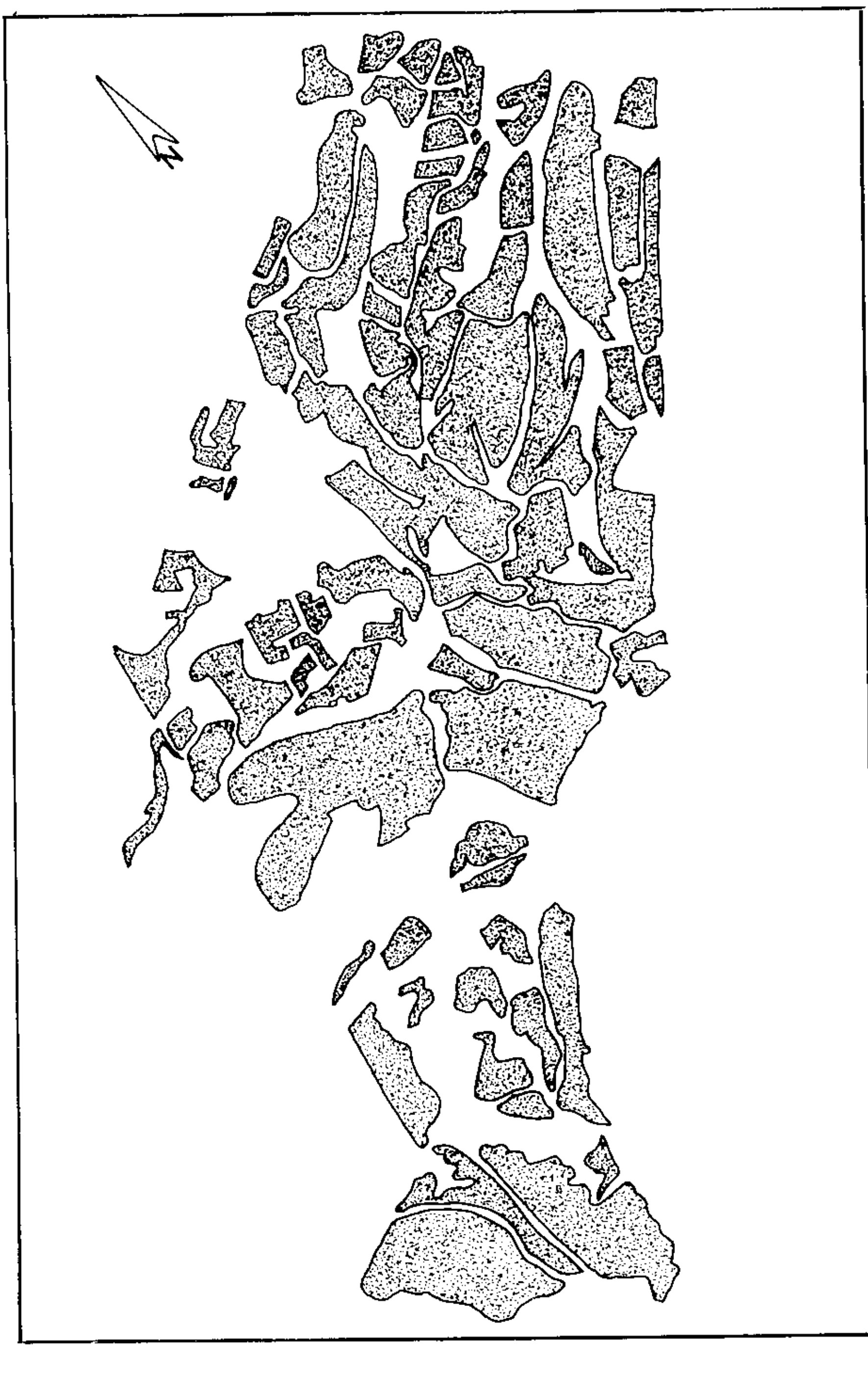

Fig. 3. Forest Map as shown on the Topographic Map of the Area (Scale 1:50000).

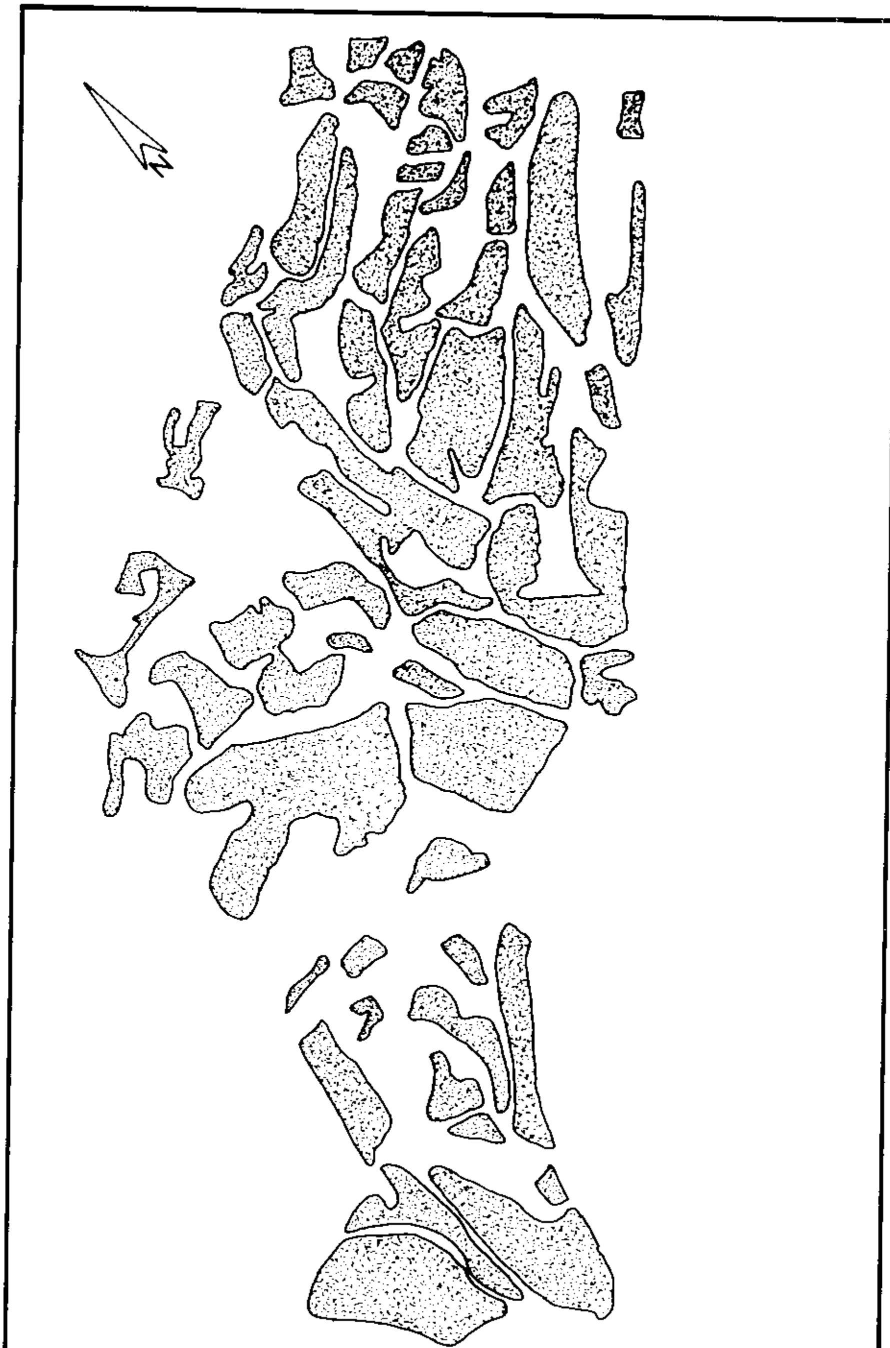

Fig. 4. Forest Map as derived from the Panchromatic Image (Scale 1:50000).

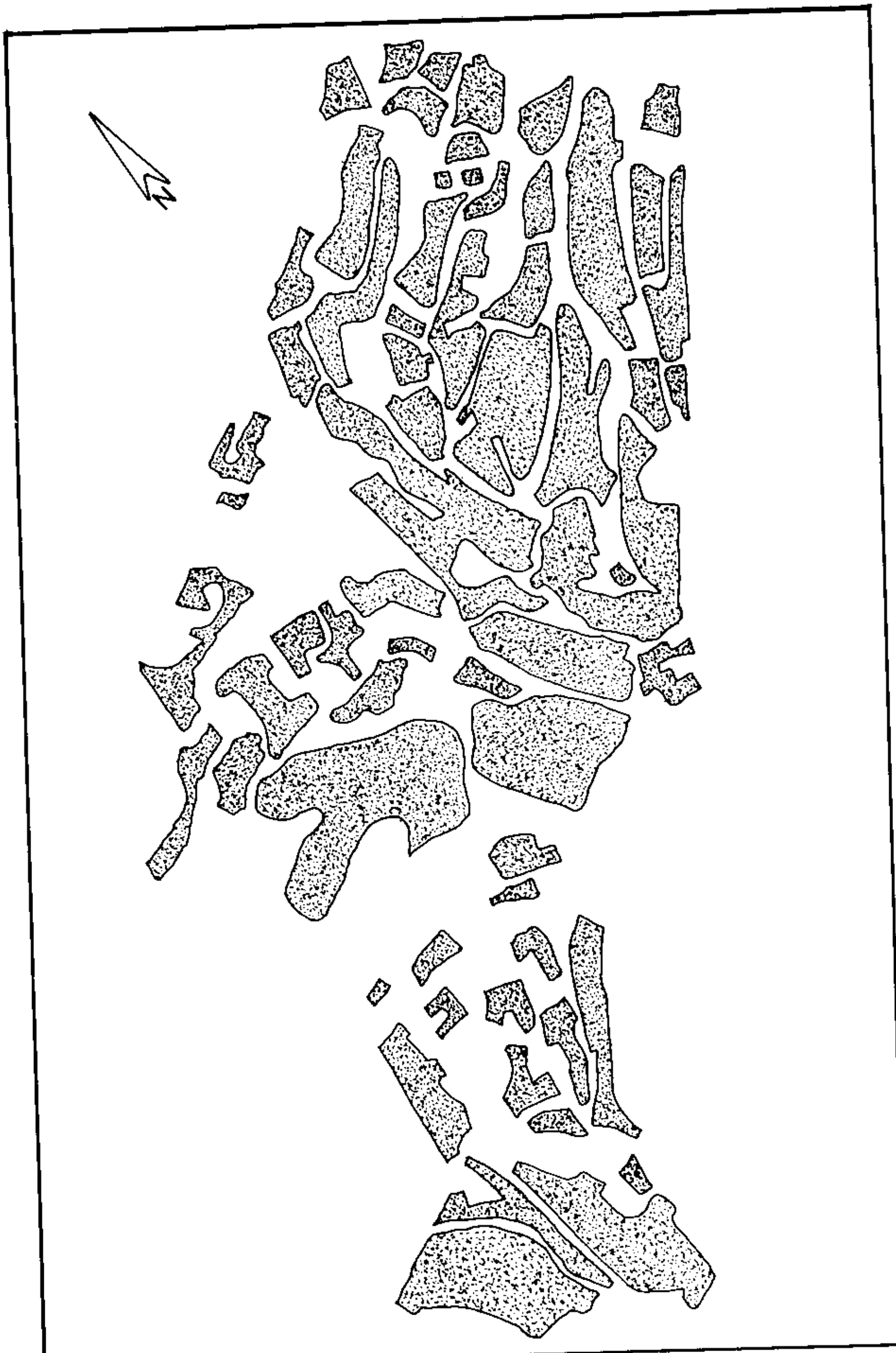

Fig. 5. Forest Map as plotted from the September 1986 Image (Scale 1:50000).

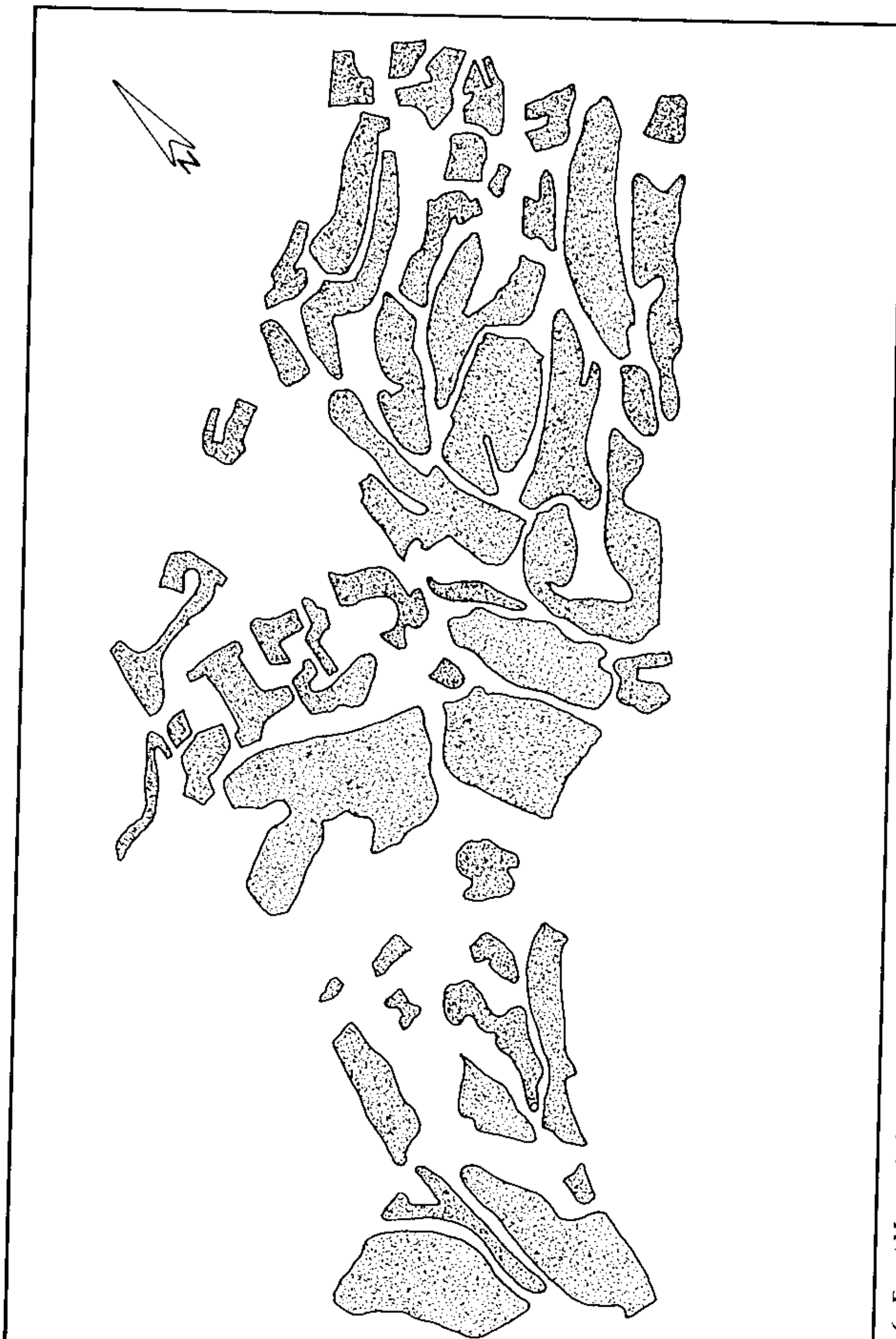

Fig. 6. Forest Map as derived from the February 1987 Image (Scale 1:50000).

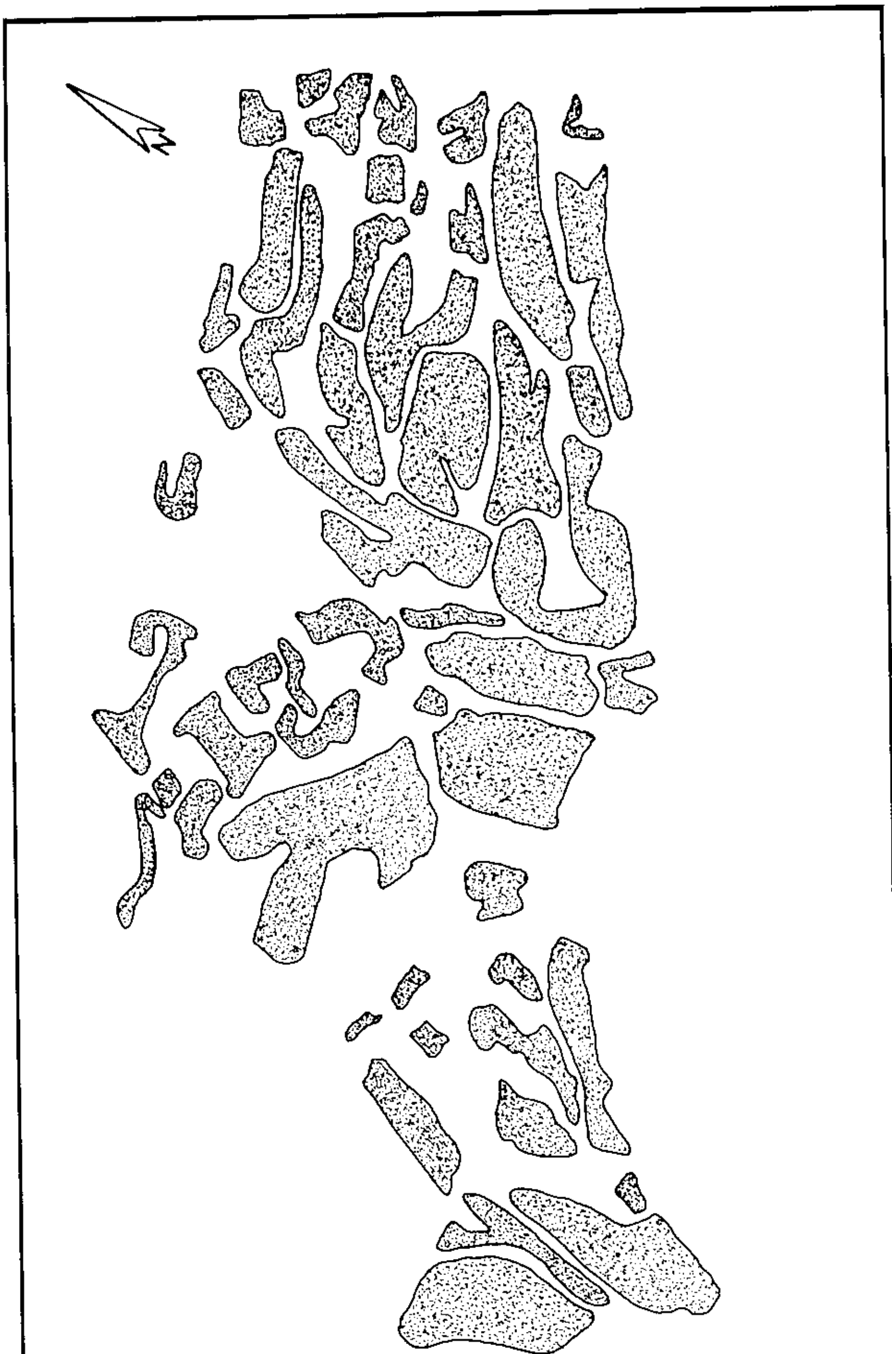

Fig. 7. Forest Map as obtained from the March 1986 Image (Scale 1:50000).

Table 1. Results of the Test.

Type of Image	Correctly identified forestlands (%)	Omission errors (%)	Commission errors (%)
(i) September 1988 (Panchromatic)	80	9	11
(ii) February 9th 1987 (Multispectral)	84	8	8
(iii) September 23rd 1986 (Multispectral)	91	3	6
(iv) March 14th 1986 (Multispectral)	85	7	8
(v) Landsat TM (July 1984) (bands 2, 3, 4)	75	12	13

Table 1 also shows that although the panchromatic image has a spatial resolution of only 10 m (compared to 20 m for the multispectral images) and was also acquired in the rainy season (September), the success rate of correctly identifying forest canopies is only 80%. This is no surprise, however, since it is well-known that panchromatic bands are not most suitable for vegetation mapping.[4] The March 1986 and the February 1987 images gave comparable accurancy and error values. Again, this is an expected result since the two images were acquired in almost the same time of the year (February and March).

On the other hand, although the percentage values of correctly identifying and interpreting forestlands from SPOT images are lower than what was initially expected, it seems that SPOT images are better in this respect when compared with the Landsat TM image of the test area where only 75% of the forestlands were correctly identified on this image. Fig. 8 shows the forest map as derived from the Landsat TM image. It is noted that, with the exception of Landsat TM image, the percentage values of omission and comission errors are comparable for all test images.

The field trip to the test area showed that most of the omission errors on all test images were due to the fact that some small and scattered woodlands were misinterpreted as agricultural land, urban trees or water-marsh. This was particularly true with the Landsat TM image of the test area thus accounting for this large percentage error (12%). Ths site visit also showed that most of the comission errors on the test

(4) E. Bryant, "Landsat for Practical Forest Type Mapping: A Test Case," *Photogrammetric Engineering & Remote Sensing*, 46 (1980), 1575-1983; P.T. Gammon and V. Carter, "Vegetation Mapping with Season Color IR Photographs," *Photogrammetric Engineering & Remote Sensing*, 45 (1979), 87-95.

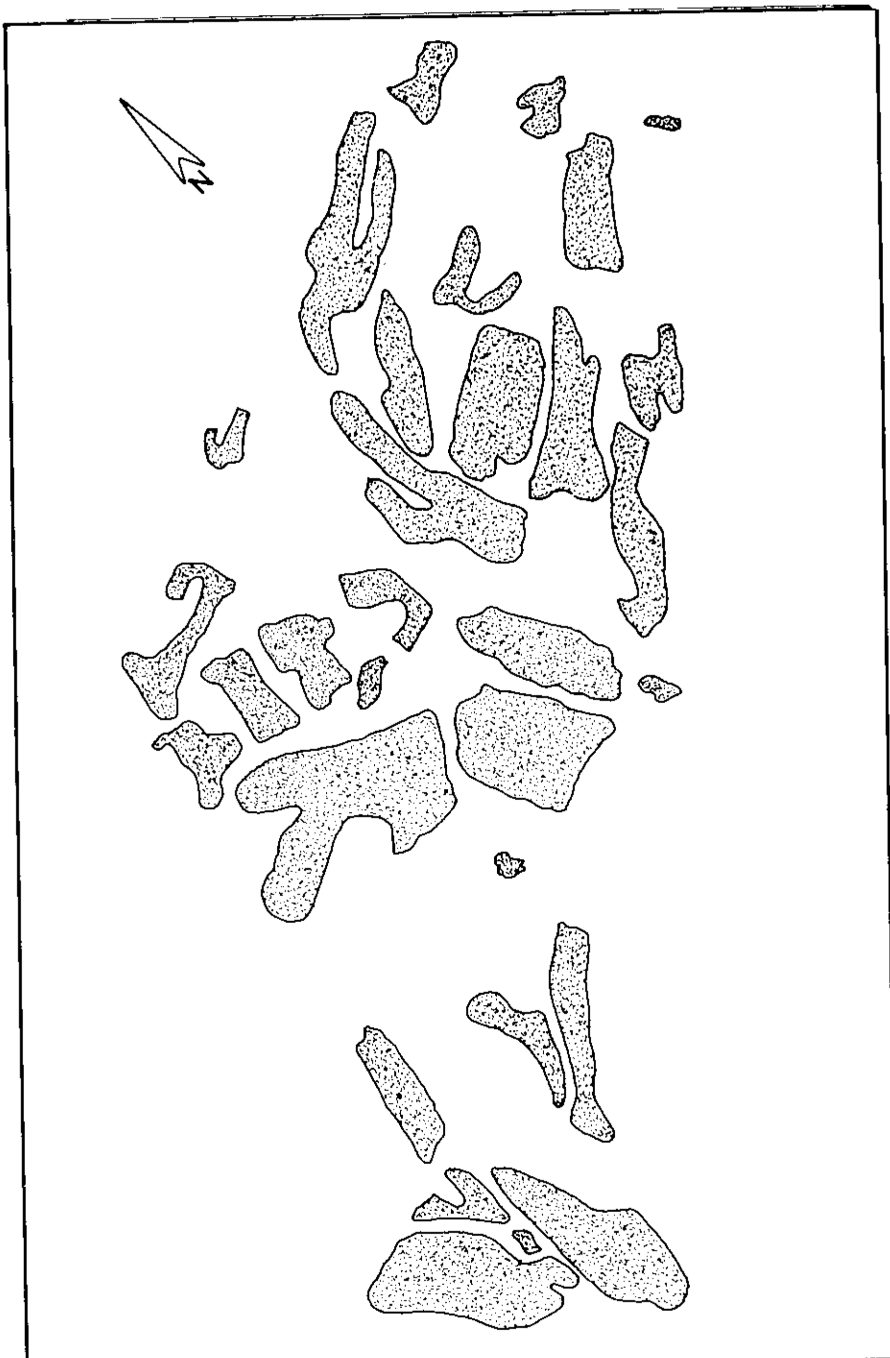

Fig. 8. Forest Map as obtained from the Landsat Image (Scale 1:50000).

images were caused by misinterpreting some agricultural lands (coffee trees in particular,) upland and lowland brush and scattered bushes as forestlands. Again, the Landsat TM image showed the largest commission error of all images test (13%).

Conclusion

This experiment was carried out in support of investigating the usefulness of temporal SPOT imagery for forest mapping at medium scales (1:50000 – 1:100000). The results show that the success of interpreting the SPOT multispectral images appears to be governed by the time of the year or season on which the imagery had been taken; with images taken in rainy seasons giving more forestland information. Thus for the 1986 image of this test area more than 90% of forestland was correctly identified and delineated. The results of this test also show that, although the SPOT panchromatic image has the highest spatial resolution (10 m), the percentage success of interpreting forestlands on it is not commensurate with this resolution value. This may be due to the fact that panchromatic bands are not most suitable for forest mapping. However, in this particular experiment the SPOT sensors seemed to have been able to map forestlands to an order of magnitude better than Landsat TM imagery.

However, a key point to be considered here is that Landsat TM imagery offers much greater spectral resolution than SPOT system (seven channels as compared to only three for SPOT). This means that if various parameters of the terrain are to be mapped, then Landsat TM images could provide much more information than SPOT's or any other sensors with less quantization levels.

Readers wishing to make use of the results published in this article are cautioned that these results may pertain only to this particular test area and possibly to areas with similar physical and environmental conditions. For other areas, different outcomes may be obtained.

On the other hand, due to the high cost involved in purchasing SPOT imagery, stereopairs were not utilized in this experiment. Surely, this could have greatly improved the accuracy of interpretation of forest features. However, it is believed that foresters and forest managers will definitely be able to use single SPOT images to an advantage for forest interpretation and forest mapping.

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استعمال صور القمر الصناعي سبوت في رسم خرائط الغابات في مقاطعة مننجي بكينيا

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ملخص البحث. استعملت ثلاث مرئيات لونية ومرئية واحدة باللونين الأبيض والأسود تغطي جزءًا من منطقة وادي الرفت بكينيا في تقويم صور القمر الصناعي الفرنسي «سبوت» في رسم خرائط الغابات لفصول السنة المختلفة. استخدمت لهذا الغرض الطرق المباشرة لتفسير الصور الجوية لرسم خرائط الغابات لكل مرئية على حدة دون الاعتماد على نتائج المرئيات الأخرى. قورنت الخرائط المرسومة من المرئيات بمحتويات الخريطة الطبوغرافية ذات مقياس الرسم ١/٥٠٠٠٠ للمنطقة المغطاة. أوضحت النتائج أن دقة رسم خرائط الغابات تصل إلى ٩٠٪ في حالة المرئيات التي أخذت في الفصول الممطرة. وفي كل الحالات لا تقل الدقة عن ٨٠٪. مقارنة نتائج مرئيات سبوت مع مرئيات القمر الصناعي الأمريكي لاندسات TM أوضحت أن مرئيات سوبت أكثر جودة ودقة في رسم خرائط الغابات.