Sudan
Reforestation and Antidesertification (SRAAD) Pilot Project

Procedures Handbook

Prepared for the Forests National Corporation, Khartoum, Sudan
by the U.S. Geological Survey, U.S.D.A. Forest Service, and Sudan Survey Department,
sponsored by the United States Agency for International Development

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Introduction

A. BACKGROUND ON SRAAD PROJECT.

The Sudan Reforestation and Anti-desertification (SRAAD) Project was developed to provide assistance with the difficult problem of combating desertification in Sudan. Specifically, the agreement signed between the Government of Sudan (GOS) and the United States Agency for International Development in August 1987 is designed . . . "to reverse the process of desertification and declining soil productivity which have led to a reduction in agricultural production and income of traditional farmers in Western Sudan. This goal will be met through the achievement of two objectives:

1. The development of a sound information base for planning, managing, and monitoring forest resources through vegetation mapping and resource inventories in Western Sudan, and

2. The rehabilitation of land and forest in five rural council areas of Southern Kordofan through participatory forest management and agroforestry activities."

B. PROJECT COMPONENTS.

The project is composed of two distinct, yet interrelated components: The Resource Inventory Component and the Resource Rehabilitation Component.

The Resource Inventory Component employs innovative geographic and cartographic techniques, based on satellite imagery, to inventory the natural resources of a large part of Southern Darfur and Southern Kordofan. This effort generates base maps for the area which are used to organize and assess information on woody vegetation and a data base to devise forestry development strategies in these areas.

The Resource Rehabilitation Component of the SRAAD project operates in a smaller area corresponding to the administrative region of five Rural Councils in Southern Kordofan. This second component is based upon utilizing specific information generated by the Resource Inventory Component, combined with the results of a household survey conducted in the five Rural Council areas, to design forest management and development plans and to introduce rehabilitation activities. The rehabilitation activities utilize appropriate reforestation and agroforestry techniques.

The rehabilitation activity includes a detailed study of local conditions and the collection of baseline data from ethnobotanical and socioeconomic surveys. This component and the inventory of the SRAAD Project are designed to provide planning data for reforestation activity in parts of Darfur and Kordofan Provinces.

The area designated for study is between 10 and 16 degrees north and extends from the western border of Sudan to the White Nile. This area was chosen because destruction of Gum Arabic (*Acacia senegal*) trees (figure 1) was particularly severe during the drought and famine of 1984-85. During the famine, the vegetation was cut in an attempt to provide fodder for livestock (figure 2).

As a consequence of the drought, illicit cutting (figure 3), day to day use of the woody vegetation for fuelwood (figure 4), construction material (figures 5 and 6), overgrazing and trampling (figures 7 and 8) and as a result of land conversion to agriculture (figure 9), farmers returning to the area did not have the expected access to forest products to supplement their income including collection of gum arabic resins, firewood, fruits, foliage, etc. These items are important to the viability of the rural economy and without them the problems of re-establishing agriculture are exacerbated.

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FIGURE 1 — Hashab or *Acacia senegal* - an important source of gum arabic.

FIGURE 2 — Trees felled for forage during drought.

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FIGURE 3 — Tree illicitly cut.

FIGURE 4 — Camel ladened with fuelwood.

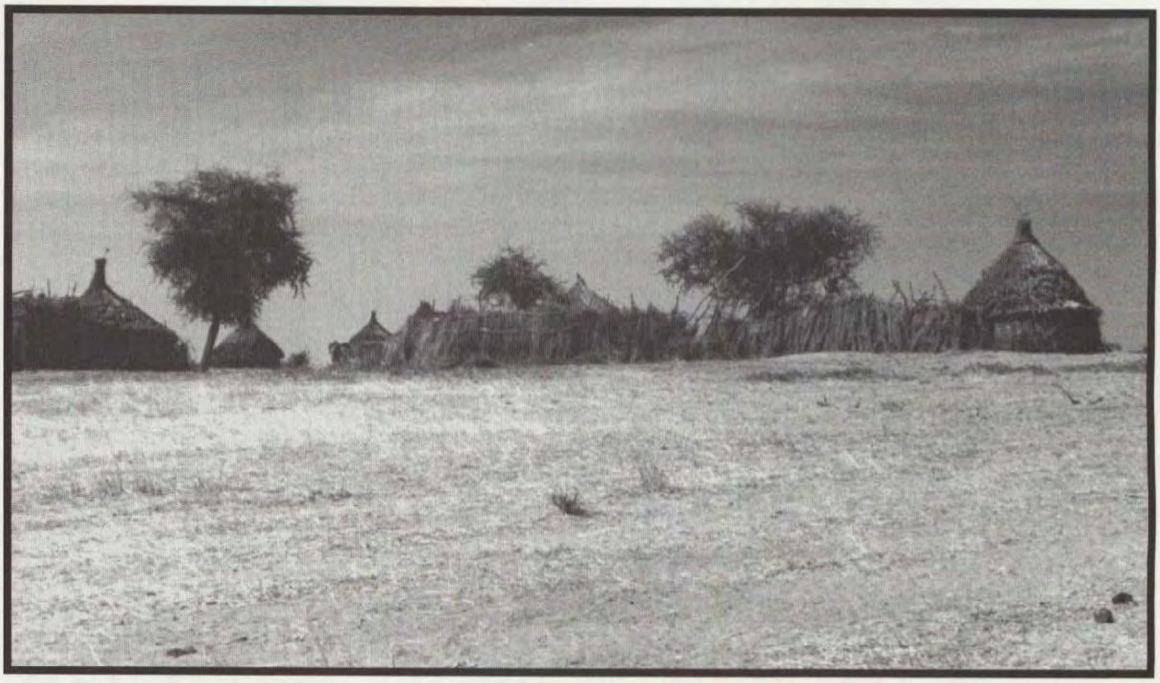

FIGURE 5 — Typical village in Kazgail area showing houses and fences made from woody vegetation.

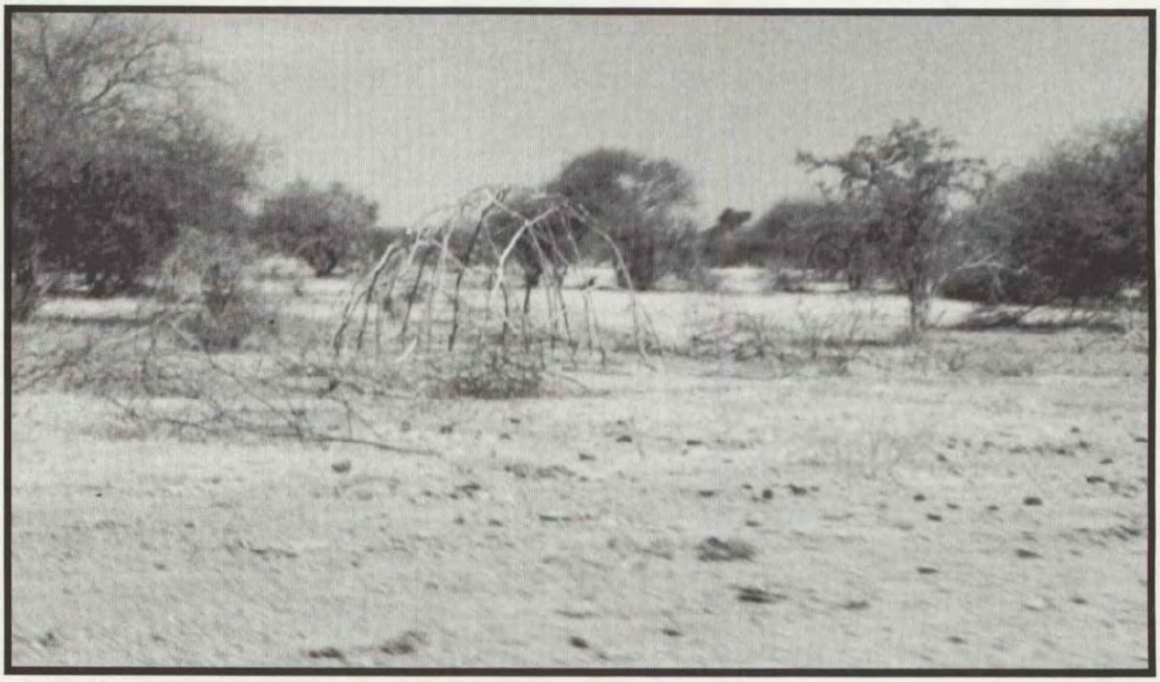

FIGURE 6 — Frame of nomad's structure made from woody vegetation.

FIGURE 7 — Goats browsing on trees.

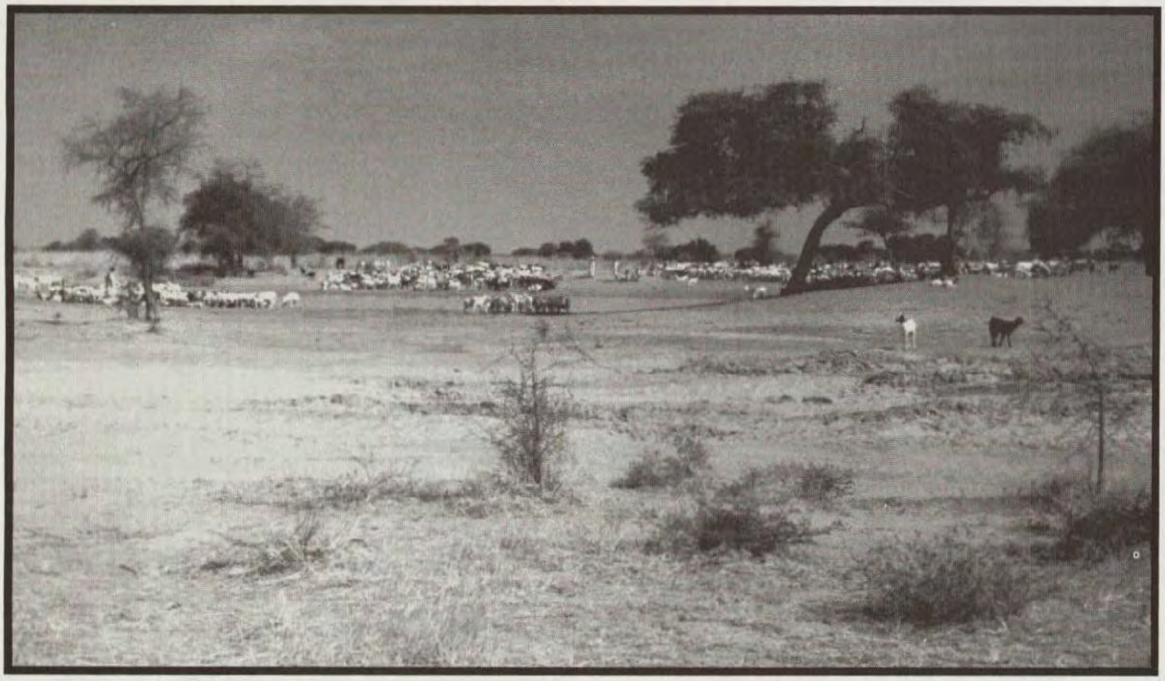

FIGURE 8 — Compaction of soil and removal of vegetation by livestock around water hole.

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FIGURE 9 — Previous forest land converted for rainfed agriculture.

One purpose of SRAAD is to re-establish woody vegetation by providing seedlings for reforestation and creating a mechanism for distribution of forest products to the community. This requires an infra-structure for establishment of tree nurseries and collecting pertinent information about the socio-economic niche occupied by the trees and the nurseries. Effective planning also requires further knowledge about the amount and distribution of the biological resources and relevant forestry data. The inventory component provides this information and creates the necessary maps and data bases to permit accurate assessment of the natural resources.

From this information, the rehabilitation component designs and implements appropriate planting schemes for the region and establishes tree nurseries as necessary. Participation by the community groups, farmers and local associations or entrepreneurs, important elements in the successful operation of this type of program are included in the implementation stages. The plans for this are based on the results of the socio-economic surveys and rely heavily upon the involvement of the community, both in the data collection and planning stages. Thus the project is geared to the creation of community driven activities based upon a knowledge of the natural resource base and the wishes of the resident population.

The detailed activity for each component was finalized in contracts signed in 1989. The rehabilitation component was contracted to a U.S. company, IRG (International Resource Group) of Washington, D.C. and the inventory component to the Regional Centre for Services for Surveying, Mapping and Remote Sensing (RCSSMRS) of Nairobi, Kenya. Activity under the IRG contract began in February 1989, and there was no activity under the RCSSMRS contract.

The imposition of Section 513 Regulations in

June, 1989, led to the cancellation of the RCSSMRS contract. Inventory activity was reprogrammed for logistics to be handled under a modified IRG contract with technical support from the U.S. Geological Survey (USGS) and the U.S. Department of Agriculture, Forest Service (USFS). Technical support was provided under Participating Agency Service Agreements (PASA's) with the U.S. Department of the Interior (USGS) and the Department of Agriculture (USFS). Rehabilitation activity was modified to focus principally on developing baseline survey methodologies and systematic data collection and analysis.

Under the 513 Regulations all project activities by the U.S. Government agencies had to be completed by 28 February 1990. In order to comply with these regulations, it was decided to restrict project activity to one area so that the techniques could be demonstrated and the results could be available for use.

Under the modified activity plan, the resource inventory focused on the Kazgail Rural Council area because rehabilitation surveys were already in progress there. In addition, large portions of the area, such as the Sheikan Battlefield, have been converted from dense forests to other uses over the past 100 years (figure 10). Today, only a few scattered trees remain.

FIGURE 10 — Marker at the Sheikan Battlefield near Kazgail. During the battle in 1883, the British reportedly lost 14,000 troops near this site because the Sudanese were able to sneak up on the enemy using the available forest cover. Today, because of livestock grazing and conversion of the land to agriculture, only a few scattered tebeldi (*Adansonia digitata*) trees remain.

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For the Kazgail area, the resource inventory component undertook the collection, tabulation, and analysis of forestry data. Also required was information about the distribution and area of the vegetation resources which was provided by the vegetation mapping activity. Base maps and vegetation maps produced for Kazgail were as follows:

1:250,000 scale "Jebel Ed Dair" sheet.

a. Image Base Map

b. Vegetation Cover Map

1:100,000 scale "Kazgail" sheet.

a. Image Base Map

b. Vegetation Cover Map

The Kazgai' Rural Council extends to the west of the standard Jebel Ed Dair 1:250,000 sheet. To ensure that the whole area was mapped an extra 10 minute segment was added to the west of the standard 1 × 1.5 degree sheet to produce the non-standard sheet with the following sides:

12 degrees north
13 degrees north
29 degrees 50 minutes east
31 degrees 30 minutes east.

In addition a non-standard 1:100,000 sheet was mapped covering the Kazgail Rural Council area with the following sides:

12 degrees 25 minutes north
13 degrees north
29 degrees 57 minutes east
30 degrees 28 minutes east.

The standard Sudan Survey 1:100,000 map sheet is a 30 minute square so the Kazgail sheet is an oversize sheet with only its northern side lying along a standard parallel used for sheet definition.

In the original project design, it was intended to produce maps of the woody vegetation of the whole project area extending from the White Nile to the western borders of Sudan between 10 and 15 degrees north. This is an area of about a quarter million square miles requiring 38 map sheets at 1:250,000 scale for full coverage. Inventory of the woody vegetation includes the need for base maps and for the collection of data by ground survey teams. Because the available maps were not adequate for natural resources inventory, the Sudan Survey Department was interested in revising the 1:250,000 base maps for the whole of the project area. The availability new global positioning systems (GPS) with a +/− 25 meter accuracy for use in the field provided an opportunity to prepare base maps and vegetation maps at a relatively low cost.

Compilation of vegetation cover maps and the field activity, field measurements, and classification work were the responsibility of the FNC staff with technical assistance from the USFS advisors as requested. Preparation of these maps for printing was to be the responsibility of SSD. All map printing was done by the USGS upon receipt of formal approval by the FNC and SSD chief executives.

C. COOPERATORS.

In implementing this project, there was a need for expertise in several areas. A first requirement was for forestry expertise to provide the advice and support in project activities including fieldwork and the associated inventory mapping. Also required was field staff, equipment and support for data collection both in the forestry activity and for the base map compilation. Much of the necessary expertise was available in the FNC and SSD. To assist with the use of new survey technology it was agreed that some external advice in the areas of both forestry and map production would be required.

The production of image maps has been pioneered by the US Geological Survey (USGS) which also has responsibility for producing the national topographic maps for the USA. The USGS has both satellite data

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processing capability and map production systems in its National Mapping Division. Accordingly, the USAID entered into an agreement with the USGS for technical assistance and support in the preparation and publication of 1:250,000 image maps.

The U.S. Forest Service (USFS), as part of the U.S. Department of Agriculture, has played a major role in the application of remote sensing to natural resource inventory and in the development of integrated inventory techniques. In addition, the USFS has an established capability in forest management and inventory has developed the appropriate field methodology and data analysis for this work. These capabilities were secured for the SRAAD project by an agreement with USFS for technical assistance and support in the vegetation mapping and inventory activities.

The USFS has experience with GPS instruments and this experience was utilized to advantage in the SRAAD project. Technical assistance provided to the SRAAD project by USFS included advice about purchase and use of GPS receivers in the field, assistance with the field sampling design, data collection design, processing and interpretation of data on micro-computers, and assistance in the preparation of an inventory report and a project handbook.

An essential link between the forest inventory activities and the image mapping work is the ability to accurately plot the field data on the map. This provides for accurate measurements of area and distribution of the major forest types from which estimates of woody volume and regeneration can be calculated for the survey area. Traditionally, the positioning of the field locations was difficult because the conventional topographic base does not show the boundaries of the major vegetation types or other natural resource information.

Field logistics and procurement were handled by IRG which also plays a major support role in the coordination of the inventory and rehabilitation activity in the SRAAD project. The technical assistance and field support for rehabilitation survey work were provided by a sub contract between IRG and Winrock International. Procurement of the necessary commodities for field and office support was also undertaken by Winrock.

These external inputs to SRAAD were financed by USAID but staff required for technical work in the field and the management and direction of the overall project were drawn from the relevant agencies of the Government of Sudan. This produced a strong team for project work which had a minimum of expatriate staff and a strong component of local knowledge.

The cooperators in this project had the following areas of responsibility:

1. Forests National Corporation (FNC), Government of Sudan.
   - Project management including the provision of the Project Director, the Co-managers of Inventory and Rehabilitation, and the supervisory field staff.
   - Provision of field staff including surveyors, inventory specialists, and mapping experts.
   - Support staff for office and field operations including drivers, field camp manager, secretarial staff and messengers.
   - Field equipment including tapes, chains, clinometers, compasses, relascopes, GPS units, etc.
   - Specifications and compilation of vegetation cover maps.
   - Supervision and approval for printing and publication of final forestry maps.
   - Inventory data entry, editing, storage, manipulation, analysis and reporting.

2. Sudan Survey Department, Government of Sudan.
    - Survey staff for field completion of base maps.
    - Field surveyors for position measurements to determine map accuracy.
    - Geodesists to calculate map graticules.
    - Cartographers to design map content and scribe linework.
    - Equipment for field work including electronic distance measurements, compasses, theodolites, and camp support.
    - Staff to work with USGS in Reston, Virginia, USA, in preparing maps for final production.
    - Specification and final approval for printing and publication.
3. National Remote Sensing Center, Government of Sudan.
    - Preparation of photo-prints and enlargements of satellite data for use in field work and in support of map preparation activity.
4. United States Agency for International Development.
    - Provide funds for project operations and monitor contractor progress.
    - Undertake contracting and formal agreements for technical assistance to the Government of Sudan under the terms of the U.S. Foreign Assistance Act.
    - Support the activities of U.S. Government Agencies involved in the SRAAD project notably the USGS and USFS activity described below.
5. USDA Forest Service.
    - Advice and consultation in project preparation phase.
    - Consultation and support in preparation and implementation of field survey activity.
    - Field training in the operation and use of GPS equipment.
    - Support with the processing and tabulation of inventory data for reports.
    - Support with the preparation of a project handbook.
6. U.S. Geological Survey.
    - Preparation of satellite images, mosaics and prints for field use, and map compilation.
    - Field support with coordination of map and inventory field work, satellite data analysis and map preparation.
    - Color separation of mosaics for printing.
    - Printing and publication of final maps.
    - Design and supply data handling system for micro-computer use, including map output and basic geographic information systems (GIS) capability and a capability to incorporate socio-economic variables.
    - Prepare and supply digitized data files of selected natural resource variables for the mapped areas.
    - Support field implementation of micro-computer system, data entry and analysis for the woody vegetation inventory.

field office operations.

- Provision of consultants and short-term specialists, support for other visitors to Khartoum and/or Washington, DC.
- Coordination of technical staff and consultants in the field and local logistical support.
- Procurement of field equipment and supplies through sub-contract with Winrock International.
- Contract support by Washington office including support of meetings in Khartoum and Washington, DC as required.
- Contract management and reporting.

Integration of the major components of the project was achieved by the use of a data base which accepted the results of the inventory and the rehabilitation work. This data base was managed in Dbase III files and linked to the graphics output program, ATLAS, which provides sketch map capability. By creating complex variables from the raw data (using standard statistical packages), it is possible to make sketch maps of areas with similar biological, physical and/or socio-economic characteristics. Both the socio-economic and physical data sets can be used together to address questions of interest to the user.

CHAPTER II

Image Map Preparation

A. Working Images

1. Introduction. Satellite image maps can be prepared by manually mosaicking individual scenes using a photomechanical procedure or a digital procedure. The procedure used at the EROS Data Center (EDC) in the SRAAD Pilot Project was to digitally mosaic satellite image data and to produce 9.5-by-9.5-inch film false-color transparencies which are used to prepare the final lithographic product.

One to four Landsat scenes may be required to produce a satellite image map of a typical 1:250,000-scale quadrangle map area. By using digital mosaicking techniques, all scenes in a project area can be geometrically and radiometrically mosaicked at one time, thus providing a match between adjacent scenes. All quadrangle areas included in the project can be extracted from the mosaic. This process allows consistent digital manipulation of image density, color, and contrast to be performed prior to film processing stages. All subsequent photographic processing and printing steps are performed under strict specifications. This provides a consistent deliverable and photographic proofing system that can be used to evaluate the mosaicking and radiometric corrections prior to final shipment.

Upon approval and authorization of the project, a search for the best possible digital data for the project area is initiated. Using computer listings of information for each path and row location in the project area and microfilm copies of the imagery to eliminate unacceptable conditions (cloud cover, season, Sun angle, etc.), the digital data for the project area is identified.

A project plan outlining project requirements, all special digital enhancements necessary to complete a project and output parameters is prepared. The project plan is important to insure requirements are met. Included in the plan are:

- Output projection and projection parameters
- Output pixel size
- Resampling algorithm
- Output scale
- Working and final product map coordinates

The digital data are acquired from the commercial supplier and working copies of the digital data are made. For this project, the digital data were acquired on behalf of the Government of Sudan and are stored at the EROS Data Center.

Photographic film transparencies are made from the acquired digital tapes for the bands of each scene to be used in the project. This imagery is evaluated to detect problems with the digital data. Any line drops or pixel drops (no image data) are compensated for using band substitution.

Black-and-white prints are made from the film transparencies and a small-scale paper print mosaic is prepared. This photo mosaic is used to check for adequate land-area coverage and to identify the placement of the mosaic seams.

The digital data are then registered to a spatial reference system. Routinely a standard 1:24,000-scale topographic quadrangle map is registered to a digitizer and used in conjunction with a full-resolution subscene of the digital data to identify a series of control points for which there are photoidentifiable locations with corresponding map locations. These control points are used to transform the digital image into a scaled and registered photo image. When 1:24,000-scale maps are not available, the largest scale source maps are used. In the SRAAD pilot project, prints of Thematic Mapper images were produced to select ground control points for field measurement of their geographic position using portable Global Positioning System (GPS) instruments.

Scenes for the quadrangle area are mosaicked using one of two methods. If four or fewer scenes are being used to produce the quadrangle area, the scenes may be mosaicked using the Image 100 geometric registration system. The Large Area Mosaicking Software (LAMS) system may be used for any number of scenes, depending on available disk storage space. All radiometric corrections and enhancements are performed as a part of this step. If there is more than one quadrangle area represented in the mosaicked digital data, each area for the quadrangle map sheets is extracted at this time.

The formatted digital mosaic data are used to produce a color film transparency that is used to produce a color photographic proof and to prepare the final-scale separates for lithographic production. A photographic proof is used to evaluate the color balance, density, and contrast of the mosaicked imagery.

2. Imagery Selection.
Once a project area is established, the search for appropriate data is started. The first step is to obtain a listing of the specific Landsat Worldwide Reference System (WRS) path-row coordinates for each image needed. The listing can be refined by specifying cloud cover or image quality parameters. This listing is used in conjunction with the appropriate microfilm or microfiche to determine specific locations of cloud cover, snow cover, or gross digital anomalies and to provide a cursory inspection of image overlap. Once the list of image candidates is refined, a more intensive check is completed using the master black-and-white transparencies located in the photographic laboratory archive. After selection, the digital data for use in the geometric registration and mosaicking processes are ordered.

Listing of satellite images can be obtained from the commercial operator, the EOSAT Corporation, or the U.S. Geological Survey (USGS) EROS Data Center. For the SRAAD project area, most of the data have been purchased and stored at the EROS Data Center.

The ideal multi-use or generic image map is one that balances image content so that no one feature or condition is overemphasized. For special-use image maps, image content must be judged on the unique requirements of the specific user.

For any image map mosaic, all parameters, such as time of year, Sun angle, and crop vigor must be as consistent as possible throughout the images. The image selection is a critical step in the development of acceptable image maps.

a. **Time of Year.** The primary consideration should be that no unique seasonal phenomenon, such as vigorous vegetation growth, drought, wet season, or burning overpowers other elements in the imagery. In the SRAAD project area the optimum time of year has been considered to be August through November.

b. **Sun Angle.** The choice of Sun angle is directly related to time of year considerations. At the mid-latitudes, the most desirable Sun angle is between 30° and 50° elevation. Sun elevations lower than 30° tend to overemphasize shadows in mountain areas and elevations higher than 50° tend to minimize the effect of terrain shadows, making it difficult to interpret terrain features in areas of low relief. In areas of low relief, Sun elevations as low as 20° may be needed.

c. **Maximum Acceptable Cloud Cover.** Cloud cover is not desirable in an image map and should be avoided if possible. In those cases where cloud cover cannot be avoided, every effort is made to limit its impact. This may involve inserting data from a number of different scenes or using data acquired at a less desirable time of year.

d. **Digital Data Quality.** While poor-quality digital data (i.e. images with missing pixels or dropped lines) may be corrected with varying degrees of success, these processes are generally time and labor intensive, and products made from these data cost more to produce and often yield less than satisfactory results. In general, the best option is the selection of good digital quality over other variables.

e. **Band Combinations.** Selection of combinations of satellite data spectral bands will markedly influence the color renditions of the final map product. There are four bands of multi-spectral system (MSS) and seven bands of Thematic Mapper (TM) data available from Landsat sensor systems. Combinations of MSS bands 4, 5 and 7 and TM bands 3, 4 and 5 in blue, green and red respectively, will produce a false-color composite that displays vigorous vegetation as red in color. Other combinations of spectral bands or color composites of spectral band ratios have been used to display specific terrain features or conditions.

In the SRAAD image mapping pilot project, thematic mapper bands 7, 4 and 2 were selected by Government of Sudan (GOS) staff such that vigorous vegetation was displayed as a green color. The compositing process combined bands 7, 4, and 2 in red, green and blue colors respectively and a falsc-color composite transparency was produced using a digital color film recorder.

3. **Project Plan.** Prior to starting the geometric registration and subsequent digital mosaicking procedures, an image map project plan should be written. The plan should describe the production procedures which are to be followed, the parameters that are to be used during production, and the output products delivered for cartographic finishing and printing. The amount of digital manipulation needed to map a specific area will depend in part on the geographic location, customer-defined parameters, and specific condition of the unregistered input data. The project plan outlines responsibility, as well as scheduled time of completion required to meet a specified delivery date.

a. **Project Overview.** An image map project is defined as any set of satellite data that need registration, mosaicking, and enhancing to prepare a specific number of quadrangle image maps. The project overview outlines the quadrangles to be extracted from the mosaicked area. Any specific digital enhancements in addition to normal processing parameters requested by the customer are explained and the responsibilities for accomplishing specific tasks are assigned. Any information that is supplied by the customer about the data's intended use is also specified in the project overview.

b. **Definition of Output Parameters.** The parameters used to prepare an image map may be unique to its geographic location or final published scale. Therefore, each of the following parameters are stated separately for each project area.

1) **Projection** — Image map data may be prepared for any of 21 projections. Normally, both 1:100,000-scale or 1:250,000-scale maps are output on the Universal Transverse Mercator (UTM) projection using the appropriate zone. In the SRAAD pilot project the Clarke, 1880 datum is suggested.

2) **Output** — The data are resampled to a specified pixel size during the geometric transformation stage. As a general rule MSS data are resampled from 57-meter pixels to 50-meter pixels, and TM data are resampled from 28.5-meter pixels to 20-meter pixels. These specifications may be changed to accommodate special-edition or special-scale maps. The color fine 240 film output size limitation is 5,322 lines by 5,322 samples, therefore, the data may be resampled to a different pixel size to provide an output product that the color fire 240 can accomodate.

3) **Quadrangle Corner Coordinates** — The upper left and lower right latitude and longitude corner coordinates for each of the quad areas are listed. These data points will then be used during the format process to place map corners into the image area.

4) **Image Corner Coordinates** — To assure that there are adequate data for the final lithographic image map product, the total image area is prepared slightly larger (0.25 inch at final scale) than the finished map area. This is accomplished by identifying latitude and longitude coordinates of an area slightly larger than the quad. These coordinates are used when a quad area is extracted from the total mosaic area.

5) **Mosaic Coordinates (LAMS only)** — The LAMS system requires the entire mosaic area to be defined. To accomplish this the upper left and lower right latitude and longitude coordinates of the entire multiple scene area are defined. In some cases, the total mosaic area may be identical to the quad image area. This will be done if a particular scene area exceeds the 6,000-sample limit of the transformation system.

6) **Resampling Algorithm** — The transformation software presently has the capability of providing nearest-neighbor, bilinear-interpolation, sinx/x, or cubic-convolution resampling. As a general rule, cubic-convolution resampling is specified for image mapping products because it better approximates the response of natural terrain conditions and results in a smoother, more acceptable image.

7) **Output Product Specifications** — The following parameters specify the film format and the enhancement to be applied:

- 38- and 57-um color fine 240 spot size
- Edge enhancement
- Look-up table
- Placement of tick marks and gray scales around image area.

4. Ordering Image Data. After identifying the scenes to be used in the project, the digital data must be ordered from the commercial supplier or ordered from the appropriate archive site. For the SRAAD project much of the digital data has been purchased by the United State Agency for International Development (USAID) on behalf of the Government of Sudan and is stored in the EDC archive. Some new TM data had to be ordered from the commercial operator, EOSAT Corporation, because clouds in existing scenes were not satisfactory for image mapping. The cost of a TM scene purchased from the EOSAT is $3,900 U.S. Scenes that exist in the GOS archive cost $80 U.S. which is the fee for copying the digital tape. Approximately eight scenes of TM data will need to be purchased to complete the coverage of the SRAAD project area.

The TM data received at EDC are in quadrant form (i.e. four quarter scenes). These data are copied to 6250 bpi working copy tapes and mosaicked into a single frame with a VAX 11/780 computer. The mosaicked frame is copied on a 1600 bpi transfer format tape for geometric registration.

At this point in the process, prints of the TM data can be made for field use or the digital data can be mosaicked, geometrically corrected and cut to coincide with the quadrangle map sheet boundaries. Ground control points are necessary during the mosaicking process to create images of the map sheets that have appropriate geometric accuracy. If uncontrolled digital mosaics are used for compilation of field information and interpretation of land cover, additional processing of the data are required to achieve positional accuracy in the final image map.

During the SRAAD project, uncorrected TM images were used to locate ground control points in the field. The geographic position of ground control points were measured with Global Positioning System instruments and will be used in follow-on activities in production of image maps in the area.

B. GROUND CONTROL.

1. Selection of Control Points.

Ground control points should be selected that are as evenly spaced over the entire TM scene area. Approximately 20 ground control points per scene are required to effectively fit the image data to the terrain and have acceptable residual geometric errors.

Maps can be used for selection of ground control when they are available. TM images can be used also to select ground control points when accurate maps are not available. In either method, terrain features, such as intersection of roads and rivers, edges of landforms, field boundaries, etc., that are recognizable on the TM images are acceptable for ground control. After image identifiable terrain features are selected, the geographic location of the points must be determined for ground control of the digital image data during the mosaicking process.

2. Field Identification.

Maps of the SRAAD study area that have acceptable geometric accuracy are not available. Therefore, the procedure to collecting ground control data involved use of TM images at a scale of 1:100,000. Image identifiable features were visited by field teams and their geographic location were measured with portable Global Positioning System (GPS) receivers. The ground control points were identified in the field and the points were marked with a pinhole on the images. The geographic coordinates for each point were recorded on the image. The TM images with the coordinates of the ground points are provided to the digital data processing system. The pixel location of each point is identified in the digital data and the data are geometrically corrected using a least-squares fit algorithm and cast in the appropriate map projection.

3. Measurements of Geographic Locations with GPS.

Use Global Positioning System (GPS) receivers to establish latitude and longitude coordinates for ground reference control points to evaluate the accuracy of the thematic mapper (TM) 1:100,000 scale image map. These points should consist of identifiable features which can be located on the ground and the same point identified on the Landsat image map. After locating the point on the ground, a GPS latitude/longitude/elevation is recorded. These points can then be plotted at 1:100,000 scale and overlain on the image map for position evaluation. The points can also be used as control during the image processing procedures creating the image map, thus increasing the accuracy of the maps. Any feature on the ground can be identified by a single GPS coordinate or a series of GPS coordinates and the location plotted and overlain on the base image map. These same GPS derived coordinates provide a direct field entry into the Geographic Information System (GIS).

4. Submitting Control Point Locations for Image Map Data Preparation.

C. IMAGE MAP DATA PREPARATION

1. Digital Mosaicking

a. **Geometric corrections** — After the TM data have been corrected for systematic errors, such as line drops, the data are ready for geometric rectification. The objectives of geometric rectification is to correct for distortions in the data and position image features to coincide with corresponding features on the ground.

CHAPTER II

1) **Control Procedures for Digital Mosaics** — The rectification of individual digital images to a common map projection is critical to the mosaicking process. Rectification normally requires the correlation of a number of points in an image with corresponding locations on large-scale topographic maps: image-to-map registration. These control points are used to develop the grid model or transformation used to rectify the image. Correlations may also be performed between previously registered images and unregistered images: image-to-image registration.

   In the SRAAD pilot project the satellite ephemerous data were used to geometrically control the TM image data. This procedure is used when adequate map control is not available. In the future, it is planned to measure the geographic position of image identifiable features in the field using GPS instruments. Once the position of features on the ground are known, the ground control points can be used to geometrically correct the TM digital image data.

2) **Number and Spacing of Control** — At least 20 control points are preferred for MSS and TM image-to-map registration. The operational characteristics of these sensors result in more cross-track distortions than along-track distortions. To correctly model these distortions more control is required in the sample direction than in the line direction. Proper control-point distribution is achieved by dividing the image into 21 regions (7×3), of approximately 1,000 samples by 2,000 lines for TM. One control point selected from each region (21 control points) will sample the image twice as frequently cross-track as along-track.

   The control points can be made using TM working images of the project area. Once image points are selected that are distributed across the image area, the position of the points are measured in the field. The control point positional data are used to geometrically rectify the TM image data.

3) **Digital Mosaicking Procedures** — Digital mosaicking is accomplished in two phases. The geometry of the component images is standardized in the first phase. Radiometric differences are balanced and the images abutted in the second phase. The Large Area Mosaicking Software (LAMS) on a VAX 11/780 computer is used for both phases of the mosaicking process.

4) **Phase 1 - Geometry** — Image-to-map registration alone will not ensure geometric consistency among component images. A close fit is achieved by collecting image-to-image tiepoints in addition to image-to-map control points. These tie points are handpicked in the overlapping areas of the images; top-to-bottom and side-to-side. Tiepoint selection is performed on an image analysis computer system by viewing the overlap area of two images in a split screen mode. One image is designated the reference image: the second is the test image. Four common points are selected from each image and a rough transformation (image-to-image) is run. Tiepoints are obtained by enlarging selected windows in the reference image and identifying a specific pixel with the display cursor. A console command causes the corresponding area of the test image to be displayed. The operator then identifies the pixel in the test image that most closely matches the pixel

selected in the reference image. As tiepoint pairs are identified each control-point file is updated to contain the line/sample location of its respective input image pixel. Ten to thirty evenly distributed tiepoints are selected depending on the amount of overlap.

The coefficients for equating input line/sample to mosaic space line/sample are applied to the tiepoint pairs following the selection process. This correlation yields a single averaged mosaic space line/sample for each tiepoint pair. Both control files are updated to contain these tiepoint line/sample locations. At this point the control files contain both edited control points and unedited tiepoints. Tiepoint editing is accomplished by running the control files through the GCTP program, residual errors are reported and tiepoints showing large errors are discarded. The GCTP program is re-run after each edit until the residuals are reduced to an acceptable level.

The process of running the GCTP program creates a transformation grid derived from a least-squares fit of a second-order polynomial. User specified parameters such as pixel size, projection, and output image framing (mosaic space) define the grid. Transformation grid files and the image data are processed during rectification.

5) **Transformation** — This process uses the grid tape to map the input line/sample coordinates to output map register line/sample coordinates using a "rubber sheet" geometric transformation.

Output pixel size is dependent upon user requirements, data type (original pixel size), system requirements and limitations, and the size and scale of the image map. Pixel size is specified in the transformation program.

The resampling algorithm most often used for image maps is cubic convolution, although the program can provide nearest-neighbor, bilinear, or sinx/x interpolation.

Component images are assessed for image-to-map and image-to-image accuracy following rectification. This verification is accomplished in the same manner as control-point selection and tiepoint selection. Reports are produced that list the pixel errors associated with selected verification points (figure 11).

PIXEL RESIDUALS

CONTROL POINT	LAT DD	LAT MM	LAT SS	LON DD	LON MM	LON SS	SELECTED LINE	SELECTED SAMPLE	ACTUAL LINE	ACTUAL SAMPLE	OFFSET LINE	OFFSET SAMPLE	PIXEL ERROR
2	39	29	59	-94	17	26	935	3145	936	3144	1	1	1.41
3	39	20	8	-94	19	40	1013	2984	1014	2983	1	1	1.41
4	39	11	17	-94	32	42	1816	2034	1815	2036	1	2	2.24
5	39	9	7	-94	35	39	2012	1817	2012	1817	0	0	0.00
6	39	2	21	-94	27	28	2648	2397	2649	2396	1	1	1.41

SELECT ANOTHER CONTROL POINT? (Y OR N)

Figure 11. — Sample control-point verification listing.

6) **Control Data Required for Map Production**

- A list of the ground control points with residual position errors is supplied for each scene (figure 12).
- A plot showing selected (true) ground control points and interpolated points relative to the input image is supplied for each scene (figure 13).
- A list of image-to-map verification points is furnished (figure 11).

7) **Phase 2 - Radiometry and Image Abutment** — Assembling a digital mosaic is much like assembling a photomosaic. In both processes the component images are cut or trimmed to achieve the best possible cosmetic match. Cut lines for digital mosaics are initially determined on photomosaics. Carefully chosen cuts are used to hide the mosaic seams and to eliminate undesirable conditions like clouds or snow.

Digital cutting is performed on the PDP 11/60. The display cursor is used to pick vertices in the rectified image that define the cut lines marked on the photomosaic. These vertices are stored in "cut" files that are used by a routine that performs the cut on the image data. Cut images show data outside of the cut lines as white fill (digital value 255).

Radiometric matching is performed on the component images after the cut lines are determined. The component image comprising the majority of the mosaic space is normally selected as the brightness reference. The contrast of the other image(s) is adjusted to match the brightness reference. This matching can be accomplished in two ways.

NUMBER OF UNITS OF MEASURE/OUTPUT 20.000
NUMBER OF LINES IN OUTPUT GRID = 9928 NUMBER OF SAMPLES IN OUTPUT GRID = 10300 SCALE = 20.00
MINIMUM AND MAXIMUM X PROJECTION COORDINATES = 0.3156200000E+06 0.5377600000E+06
MINIMUM AND MAXIMUM Y PROJECTION COORDINATES = 0.4206700000E+06 0.4405240000E+07

POINT	INLINE	INSAMP	LAT	LONG	OUTLINE	OUTSAMP
1	5115.0	5927.0	38.2384	-93 2004	8659 0	8343 2
3	3972 0	6203 0	38.5128	-93.0409	7137.8	9041 7
5	2227 0	6059 0	38 9595	-92 9769	4659.2	9320.2
7	5021.0	4115.0	38.3490	-93 7745	8032 0	5836.1
10	3216 0	3986.0	38.8108	-93.7068	5472.5	6151 6
11	2092 0	3968.0	39.0949	-93 6443	3898.2	6433.9
14	5487.0	680 0	38 3884	-94 9034	7742.1	908.0
16	3871.0	1234 0	38.7723	-94 6332	5634.3	2126.0
18	2078.0	1246 0	39 2249	-94 5258	3131.0	2634.6
19	626 0	6393.0	39.3460	-92.7665	2513.2	10225.9
21	688 0	4036 0	39.4447	-93 5270	1960.7	6952.7
23	609.0	908.0	39.6112	-94 5504	985.8	2565.4

TRANSFORMATION COEFFICIENTS RESIDUAL ERRORS

POINT	1LINE	1SAMP	TLINE	TSAMP	OLINE	OSAMP	OIFFLINE	DIFFSAMP	RES ERR
1	5115.0	5927.0	5114.6	5927 2	8659 0	8343 2	-0.4	0.2	0.4
3	3972 0	6203.0	3972.3	6202 6	7137.8	9041 7	0 3	-0.4	0.5
5	2227 0	6059.0	2227.0	6059.3	4659.2	9320.2	0 0	0 3	0 3
7	5021 0	4115.0	5021.2	4115.0	8032.0	5836.1	0 2	0 0	0 2
10	3216.0	3986.0	3215 5	3986 2	5472.5	6151.6	-0.5	0.2	0.5
11	2092.0	3968.0	2092.8	3967.7	3898.2	6433.9	0.8	-0.3	0.8
14	5487 0	680.0	5487.1	679.9	7742.1	908 0	0 1	-0.1	0.1
16	3871 0	1234 0	3870.9	1234.2	5634.3	2126.0	-0 1	0 2	0 2
18	2078.0	1246.0	2007.7	1245 9	3131.0	2634.6	-0.3	-0.1	0.3
19	626.0	6393.0	625.9	6393 0	2513 2	10225 9	-0 1	0.0	0.1
21	688 0	4036.0	687.7	4063.1	1960.7	6952 7	-0.3	0.1	0.3
23	609 0	908 0	609.2	908.0	985.8	2565.4	0 2	0 0	0 2

AVERAGE LINE RESIDUAL =0.3 AVERAGE SAMPLE RESIDUAL =0.1 PMS ERROS =0.4

FIGURE 12. — Sample list of control-point residual positional errors

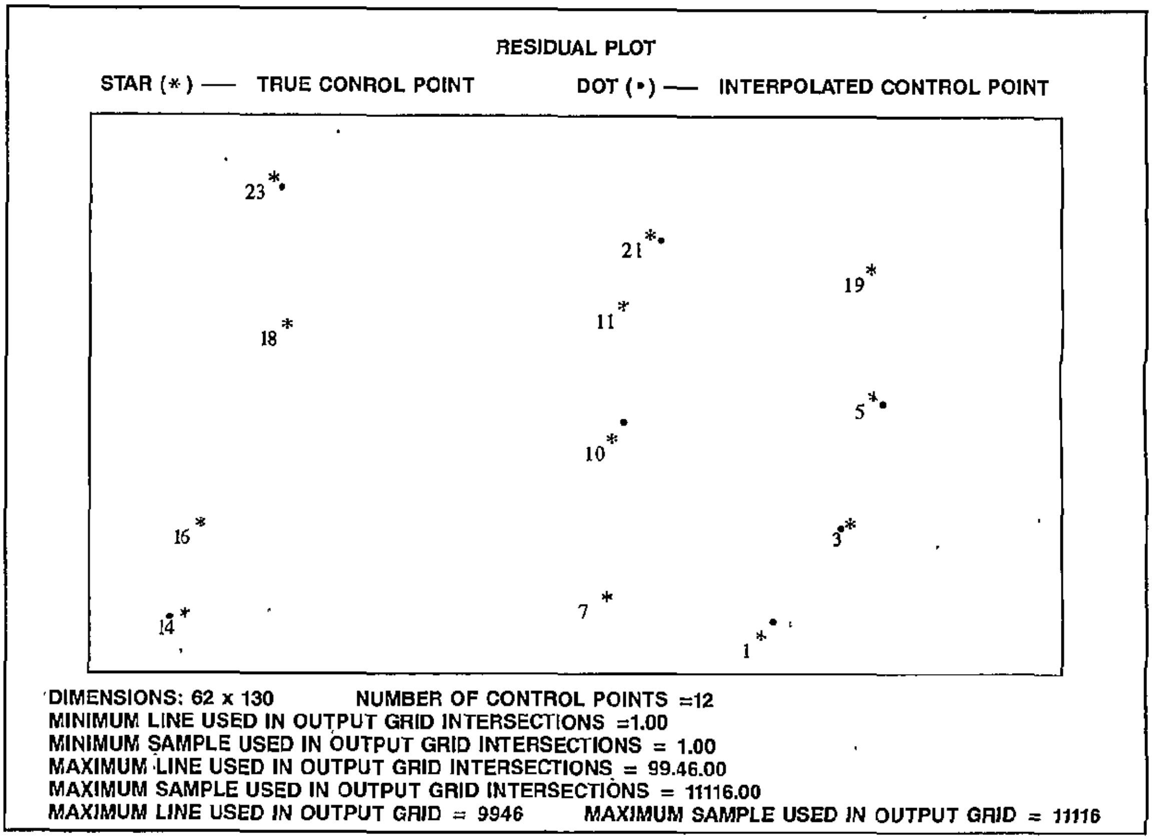


FIGURE 13 — Sample control-point residual plot

The method performed most often is the piecewise linear mapping that standardizes the brightness value (BV) distribution of the component images. This procedure is initiated by producing histograms of the overlapping portions of the images. The histograms of the brightness reference and adjacent images are compared. Selected BV's in an image are relocated in the mapping function so that its BV distribution matches the brightness reference. Visual comparisons are made on the display and mapping are adjusted and re-run until an acceptable match is produced. A second more localized adjustment is produced by defining a reference line in the overlap. A systematic linear regression is performed along the line and a two-point linear matching stretch is applied to the data. Radiometric matching is performed for each band of image data used in the mosaic.

The final procedure in the digital mosaicking process is the abutment of the component images. When abutting images the order in which they are assembled determines what image data are used when there is overlap between two or more scenes. The first image specified will be used in its entirety. The second will only be used where there is no data from the first, and so on. Histograms are produced for each band of the assembled mosaic and the image data copied to the library CCT's completing the mosaicking process.

The Large Area Mosaicking Software (LAMS) system is used to mosaic any number of scenes, limited only by the amount of disk storage space available. The LAMS system provides better geometric control between neighboring scenes by selecting tiepoints along a predefined mosaic contour or cut line and uses a finite element method of generating the transformation grid that forces control points to a specified output location. Radiometric matching is accomplished by collecting brightness value information at the geometric tiepoints between neighboring scenes and a "rubber sheet" correction is applied, automatically matching an image to its neighboring scenes. The software has the ability to hold the control information for all images of a mosaic in a single file, providing better data management capabilities.

b. Radiometric Corrections — The brightness values from the adjacent scenes are subtracted and the difference is divided by two, so the same amount of correction is applied to each image. The grids are applied to the images on a band-by-band basis and the cuts are applied at the specified vertices. The images are then mosaicked and visually checked for radiometric and geometric problems. If problems exist, any of the previous steps can be repeated; if the data are correct, a transfer format tape is created for final contrast-stretch limit determination.

1) Spatial Filtering — Following the mosaicking procedure, the data may be enhanced using a boxcar spatial filtering technique. This is an optional step, dependent on subject detail and the product's intended use. The boxcar filter may be used to modify either low-frequency spatial data to increase the effectiveness of the contrast enhancement process or high-frequency spatial data to provide edge enhancement. It can also be used for preprocessing and noise removal in addition to post-processing for contrast enhancement.

The use of the boxcar filter for low-frequency modification will balance regional variations in spatial frequency content. For instance, if an image consists of a very dark homogeneous region in one part of an image and a very bright homogeneous region in another area of the image, the filter will bring out local information in the dark and the bright areas.

The boxcar filter contains both low-pass and high pass filtering techniques to modify the distribution of spatial frequencies in image data in order to increase the effectiveness of the contrast enhancement process. It is not used as a replacement for contrast enhancement. It is still necessary to modify the contrast in some way in order to achieve the desired density range and color rendition by using a contrast-stretch technique.

The algorithm requires that a large kernel (typically 101 by 101 pixels or larger) is passed across an image, moving one pixel location at a time. The mean of all pixel values falling inside the kernel is calculated and an output value is assigned to the center pixel using the following equation:

$$2Yij = AXij + (Xij - \underline{X}ij)$$

where:

X_{ij} = input (original) pixel value at line i and sample j

Y_{ij} = output (enhanced) pixel value at line i and sample j

A = an addback factor (0.0 to 1.0) which controls the amount of enhancement

$\underline{X}_{ij}$ = mean value of all pixels inside the kernel centered on X_{ij}

The addback factor and the kernel size are both specified by the user. Increasing the kernel size causes the filter to respond to lower spatial frequencies in the image. The addback factor affects the magnitude of change resulting from the filter.

The algorithm contains optional parameters which may be used to identify specific brightness value ranges to be filtered. These options are termed "high" and "low" and are used to threshold a brightness value range above and below which the image data are filtered.

2) **Edge Enhancement** — To increase high-frequency components, an edge enhancement is applied to the data. This is accomplished by applying the boxcar filter with a small kernel size after the mosaic process or by utilizing the edge enhancement algorithm of the EROS Digital Image Processing System (EDIPS) just prior to film production. Both are comparable providing the addback constants are at 1.0 (which is usually the case). The object of this enhancement process is to proportionally boost the high-frequency spatial variation in the final image. There are several combinations of edge enhancements (1 by 3, 3 by 3, 5 by 5, 9 by 9, etc.) that could be applied. For image mapping, a 3 by 3 enhancement is presently being used.

The EDIPS algorithm is defined as follows:

$$Y_{ij} = X_{ij} + C\,(\underline{X}_{ij} - X_{ij})$$

where:

X_{ij} = input (original) pixel value at line i and sample j

Y_{ij} = output (enhanced) pixel value at line i and sample j

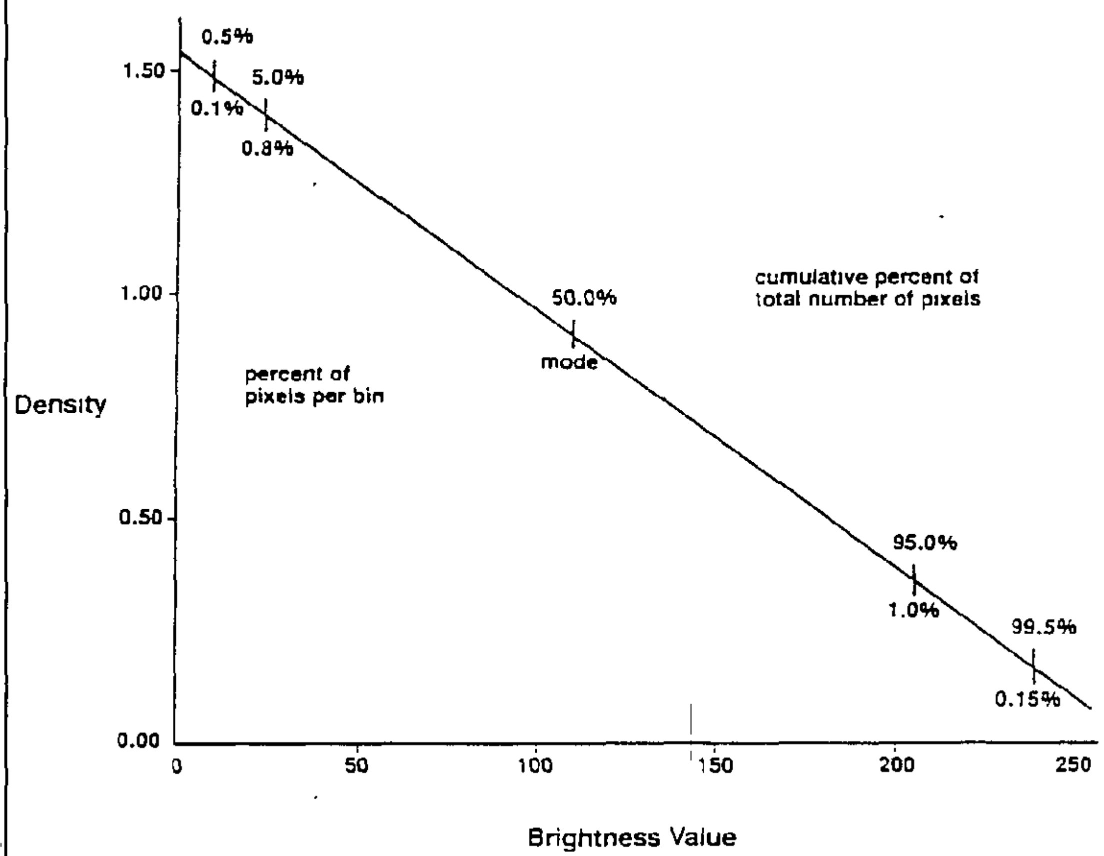
C = a constant which controls the amount of enhancement. Default value is one but may be set on any percentage, that is, 0.40, 0.60, 0.80, etc.

$\underline{X}_{ij}$ = a local average value at location (i, j) obtained by using a boxcar filter of size M (line) and N (sample) pixels. The range of N and M is odd integers between 1 and 9, that is, 1, 3, 5, 7, and 9.

3) **Contrast Stretch** — To provide adequate contrast and maximum tonal differentiation in each film separate, the data are contrast stretched prior to film production. A multi-point linear stretch is performed using an interactive procedure with the help of a display. This procedure is performed using the Raster Technology display system on the PDP 11/60 computer.

The histogram of each band is initially evaluated to determine the number and position of the break points which provides proper data distribution. Figure 14 represents guidelines which may be used. The histogram mode (land detail) is stretched to the 120- to 130-brightness-value range to provide a proper output density for lithographic reproduction. The exact placement of the mode will be changed slightly for each band to provide a subjectively pleasing color product. This is an interactive process using a display system. Figures 15 and 16 show a Gaussian-distributed histogram and its result after stretching. A larger number of break points are used with a bimodal distributed histogram in order to concentrate the majority of the stretch among the brightness values containing the majority of data.

TWO SETS OF TARGET BREAKPOINT VALUES FOR MULTIPLE-POINT LINEAR CONTRAST STRETCH
(SCENE W/O WATER)



95% of total number of pixels are reproduced within the density range of 0.35-1.35 D.

FIGURE 14 — Stretch target breakpoint values.

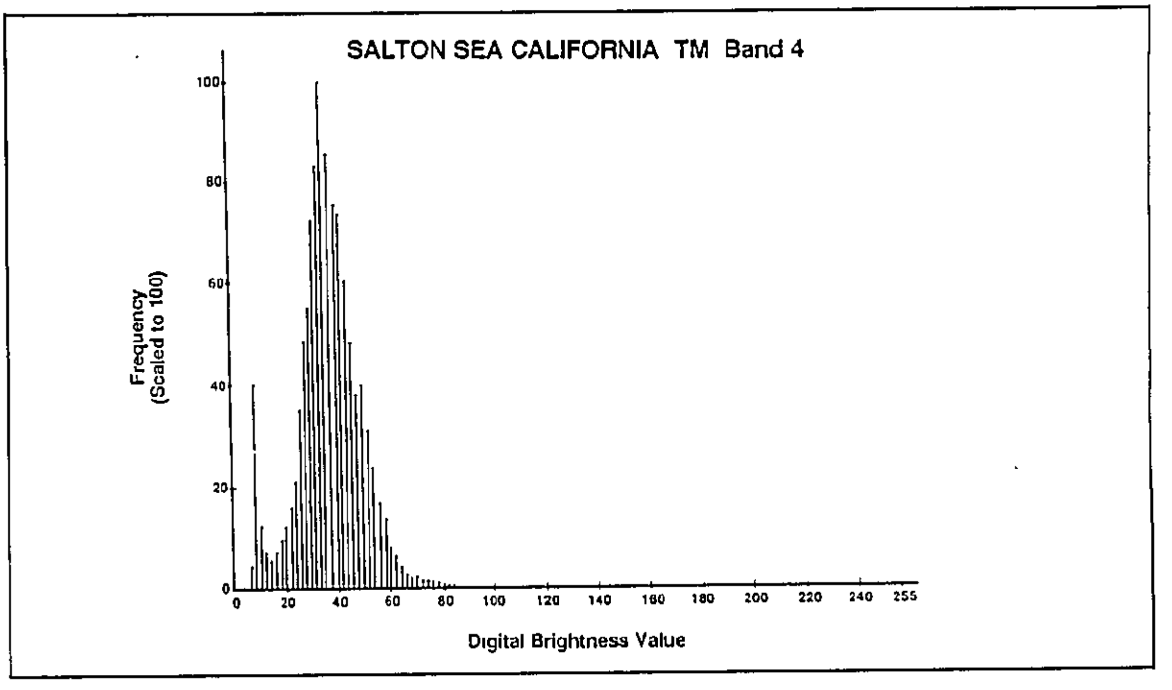


FIGURE 15 — Sample normal histogram.

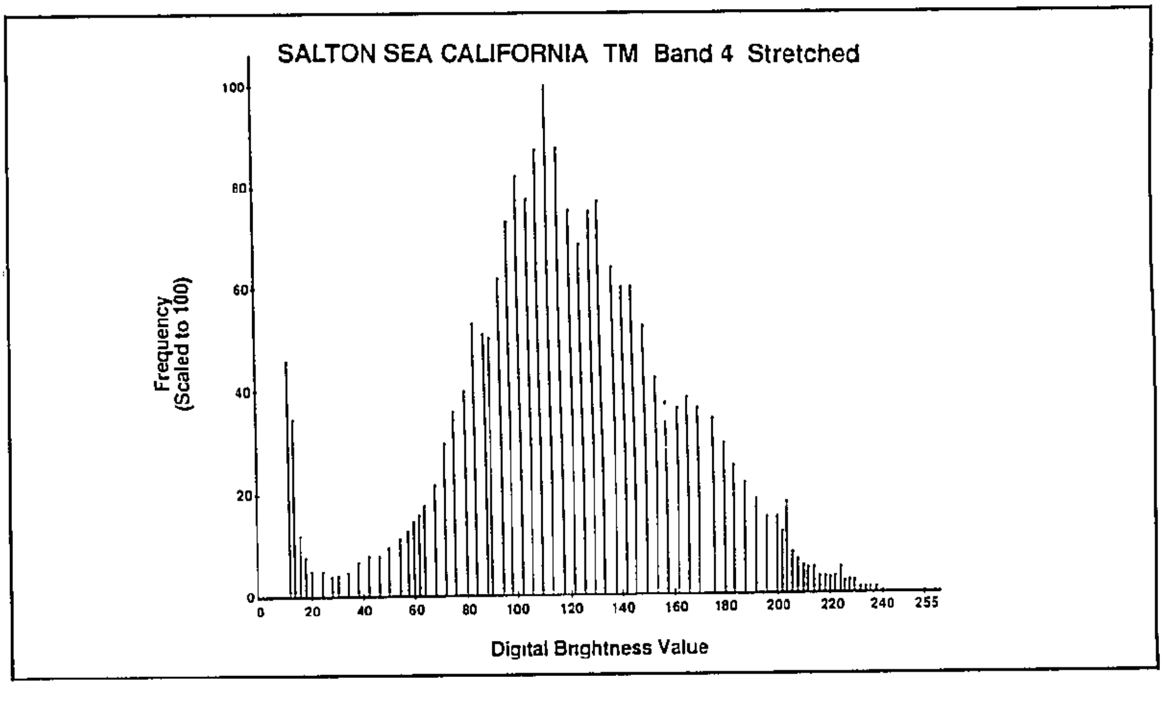


FIGURE 16 — Sample histogram after stretch.

The LAMS system allows multiple quad areas to be contrast stretched identically. This is accomplished by contrast stretching the data prior to quadrangle extraction. This will provide output products that have an excellent color and contrast match. However, experience has indicated that this may not always be feasible. In extremely large areas, the variation in geography may generate a histogram having a large standard deviation, which will not allow proper data distribution at the quadrangle level. If this is the case, the quadrangle will have to be extracted from the mosaic area and contrast stretched on an individual basis.

4) **Image Format** — The format used for the output film products combines the hard-coded parameters of the color film recorder, additional gray scales and ticks, and the original image map data. The hard-coded format of the film recorder provides a method of annotating the image data. The gray scales and ticks are inserted (buttered) into the image space at specific locations around the original image map data. Figure 17 shows the general relationships among all added features. The overall size of the image data and adjoining scales, ticks, and annotation should be kept as small as possible to reduce the cost of subsequent lithographic proof preparation. Following the format procedure, EDIPS format tapes are generated and entered into the image production system.

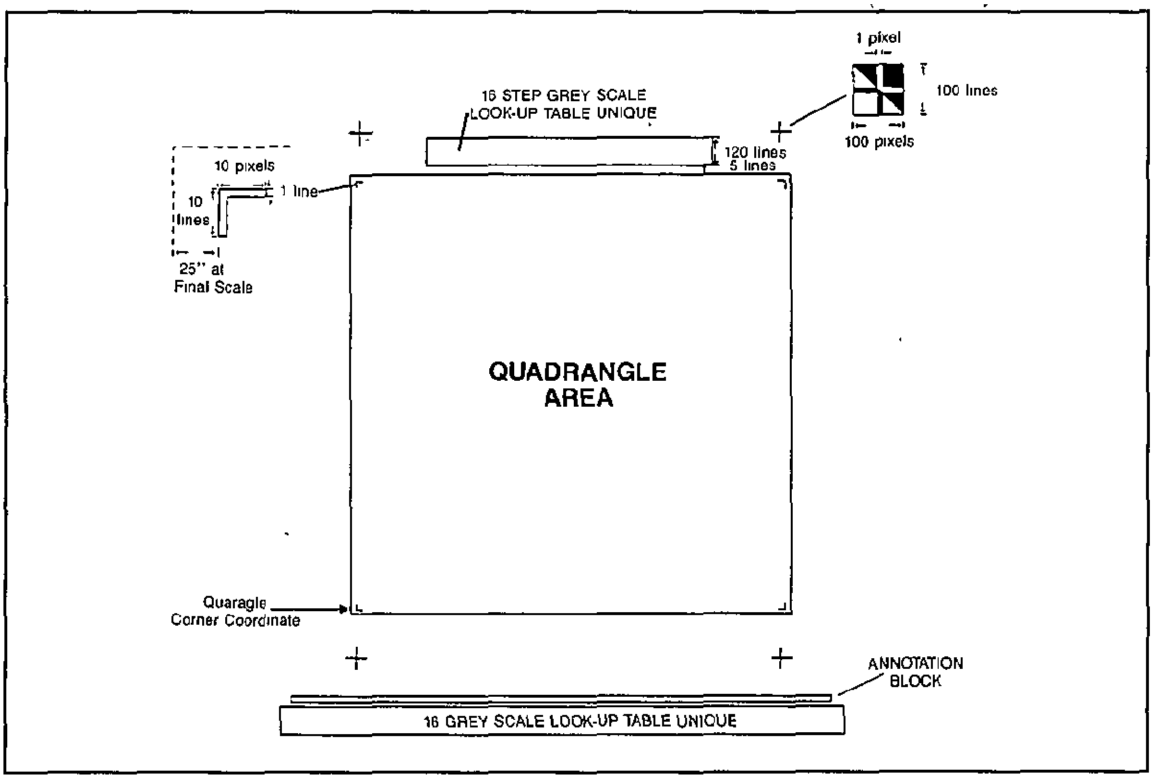


FIGURE 17 — Image map film format.

5) **Registration Marks** — Registration marks are added to the image space above and below the image map data. They are used for the registration procedure during the color photographic print preparation and the lithographic proof preparation. The tick is contrasting black-and-white with a 1-pixel-wide fiducial.

6) **Map Corners** — Map corners are added within the image map data to mark the quadrangle corner. Approximately 0.25 inches of additional image data (at final scale) is supplied outside the map corner. The map corner is "L" shaped and contains 10 pixels on a side and is 1-pixel thick.

7) **Annotation** — An annotation block is provided at the bottom of each image and is located just below the cumulative percentage gray scale. This portion of the image is prepared using the EDIPS-formatted annotation area, which allows operators to easily change alphanumeric characters in specific locations.

2. Image Map Design and Final Preparation

a. General. There are two procedures for producing final-scale halftone separates and prepress color proofs from satellite imagery. They are the photographic and electronic scanning methods and in both procedures a high level of skill and experience is required to achieve the best results. In the SRAAD pilot project, the electronic scanning procedure was used and involved a graphic arts scanner and plotter.

The following are provided for each 1:250,000-scale quadrangle to be produced on a graphic arts scanner/plotter:

1) A digitally mosaicked false-color composite transparency in quadrangle format with density scales, annotation, register marks and 1x10-pixel quad corners within the image area.

2) Scale measurements and magnification correction parameters for precise enlargement to 1:250,000 scale.

3) Brightness histograms before and after contrast stretch.

4) Photographic color proof at 1:250,000 scale with a linear density scale representing the imagery.

5) Plot of control points and table of residuals for each scene used in the mosaic.

6) Densities and a copy of the look-up table used to generate positive transparencies.

b. Scanning, Color Separation and Scaling

1) **Evaluation of Photographic Color Proof** — The photographic color proof of the quadrangle to be scanned is evaluated by visually comparing lithographic color values from a standard color chart to selected areas on the proof. This is done by punching holes in the centers of color samples from the control color chart and overlaying them on the color proof for direct comparison of the image area without the influence of surrounding colors.

Integrated halftone dot density values can then be assigned to aimpoints for three-color printing to match important image areas. The control color samples are used primarily as a guide for overall density shifts to aid in selecting density aimpoints for the cyan halftone separation. The cyan separate carries the shape and contrast of the features in the imagery. Gray balance adjustments will shift yellow and magenta values appropriately. If a specific color must be matched exactly, aimpoints will be selected for the yellow and magenta halftone separates as well, using the color chart, and gray balance will not be considered (the overprinting of yellow, magenta, and cyan will produce shades of gray). Generally, if the 16-step density scale on the photographic color proof ranges between step 2 (light gray tone) and step 14 (darkest gray tone), the colors on the proof will approximate the colors in lithographic printing except for ink/dye color differences; photographic dyes are different from pigments in printing inks.

The most useful guideline for achieving pleasing color relationships in the final printed image map is to start with a cyan separation that shows good detail and tonal contrast, then electronically adjust the yellow and magenta separations in gray balance with the cyan. In the printed map, spectral highlights and white clouds should be free of color. The darkest shadows should be black, and the midtones should exhibit good contrast.

2) **Gray Balance** — A basic requirement in color lithography is to achieve gray balance when overprinting ink colors. If halftone dot sizes are equal for the yellow, magenta, and cyan overprinting inks, the combined ink color will appear brown rather than black, because of ink pigment deficiencies. Depending on inks, paper, and press, the amount of imbalance in dot size to correct for gray balance ranges between and 8- and 12-percent reduction from the cyan separation in midtones for the yellow and magenta separations, with highlight and shadow endpoints reduced approximately 4 and 7 percent respectively.

For example, the EDC midtone aimpoint for the cyan separation — step 8 in the 16-step linear density scale — may be assigned a 60-percent dot area to achieve required image contrast and detail definition. In step 8 of the yellow and magenta separations, a density of 50 percent would be assigned to achieve gray balance.

Gray balance is based on first establishing the reproduction tone curve for cyan and then adjusting the yellow and magenta separations; this adjustment primarily reduces excess yellow in the cyan and magenta separations to correct for ink pigment deficiencies. When gray balance is achieved, the yellow, magenta, and cyan inks should overprint correctly to reproduce color image areas, and appear gray or black in areas where halftone dots are of equal value for each of the three colors. To control these adjustments, a linear density scale in steps of 0.05 to 0.10 is required on the imagery.

3) **Selecting Halftone Density Aimpoints** — Generally, three aimpoints are selected and submitted to the scanner operator for stretching the continuous-tone imagery to fit the halftone reproduction tone curve (Figure 18). These aimpoints are noted on the Cronapaque print on the 16-step density scale. One aimpoint is the highlight assignment of a 3- to 5-percent dot value in an area of interest, usually step 2 (about 0.20 transmission density) on the 16-step linear control scale. The shadow aimpoint at step 14 (density about 1.35) is selected for the 95- to 97-percent dot.

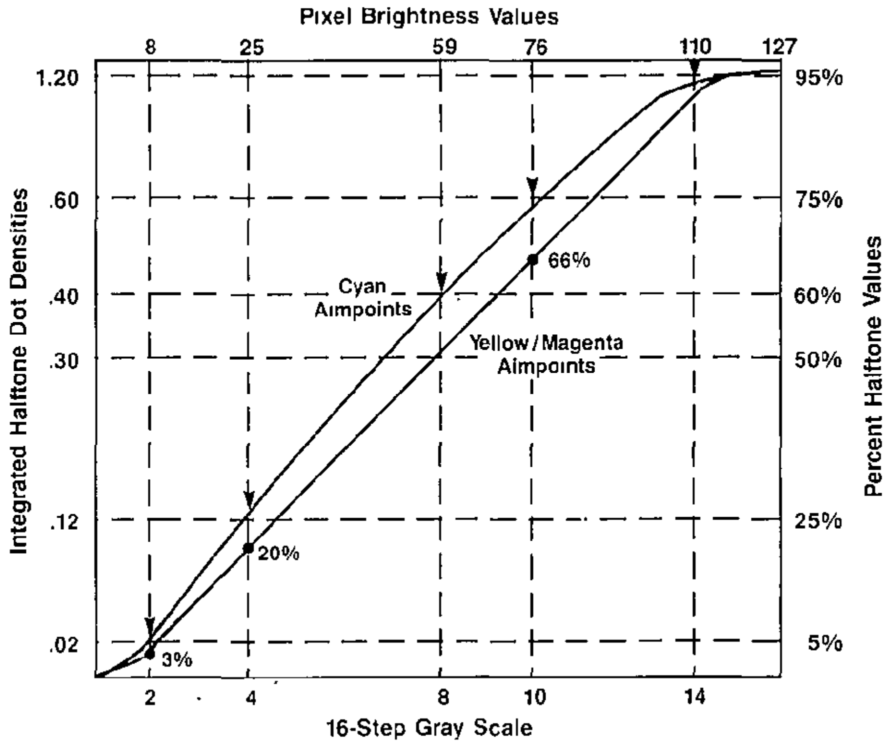


FIGURE 18 —Typical aimpoints and tone curves.

The midpoint aimpoint at step 8 (density about 0.80) is assigned a 60-percent dot. In cases where quarter-tones at 25 and 75 percent must also be specified, they are generally assigned closer to the end-points than to the midpoint, because image data in the middle values should be stretched further than data near the endpoints. Yellow and magenta separations generally follow the cyan tone curve with a 10-percent drop at the midtone and a 5-percent drop in quarter tones. Reduction in the yellow/magenta tone curves is made to correct for deficiencies in the printing inks; if the ink pigments were pure, equal densities of ink in each of the separations would combine to make tints of gray.

Whenever two aimpoints such as a quarter-tone and midtone are brought closer together, image detail will increase; if separated, detail will be subdued or lost. The midtone is very important because if is where the imagery changes in its tone representation from solid dots in the highlight area to open dots or holes in the shadow area. The elliptical dot used in halftone printing of image maps smooths the transition in midtone areas to improve tone reproduction. Although histograms of the image data before and after contrast stretch aid in selecting aimpoints, the final aimpoints are determined by personal preference, requirements to match adjoining maps, or a need to increase detail in highlight or shadow areas.

4) **Check for Correct Quadrangle Corners** — Quadrangle corners are added by EDC within the image area, with approximately 0.25 inches (at 1:250,000 scale) of additional image data supplied beyond the quadrangle corners. The corners are "L" shaped, one pixel thick, and 10 pixels on a side. A film positive of the map projection, which will subsequently be provided to the scanning operator as a guide for scaling, should be used to check for correct placement of quadrangle corners before materials are shipped for scanning.

5) **Scale Factors for Enlargement** — Images output on film recorders generally exhibit slight scale differences in both the x and y directions. Therefore, it is necessary to supply the scanner operator with final enlargement correction factors in both directions for scaling.

   Each image should be measured in the x direction (along scan), y direction (across scan), and diagonally between the registration marks. These measurements are compared with theoretical aim values and the percentage difference is used to calculate final enlargement scales in x and y. Scale readings and final enlargement correction factors are supplied to the scanner operator for the color transparency.

6) **Submitting Materials for Scanning** — The following materials are submitted to the scanner operator:
   - A chart of density aim points for all colors.
   - A positive film color transparency composite of bands 2, 4, and 7 (yellow, magenta, and cyan separates, respectively).
   - Final x and y enlargement factors.
   - Film positive of the map projection with quadrangle corner marks circled in grease pencil.

7) **Scanner Calibration** — The graphic arts scanner/plotter is designed for color separation of photographic color positive images on paper or film.

   To calibrate the scanner, the color film transparency is scanned a few centimeters on both x and y image lengths for the cyan density scale. This technique provides a quick check plot of the x and y map dimensions to calibrate the equipment for both register and reproduction density scale aimpoints for the cyan separation. This technique also avoids the extra expense of scanning and plotting of an entire scene for calibration purposes.

8) **Registering to the Projection** — After calibration, the entire cyan separation is scanned and enlarged to achieve the best fit to the four map projection corners (Figure 19) to within a tolerance of 0.002 inches or one pixel. The yellow, magenta and black separations are scanned next.

9) **Image Register** — Register between image separates must be precise to avoid distorted color and blurred image definition in the final map. Good register is assured by maintaining the original EDC image register marks on the image separates throughout the scanning, proofing, and plate-making processes. If the register marks cannot be retained

because of sheet size or are inadvertently removed, it is best to duplicate the halftone image positive which contains the greatest detail onto a 0.007-inch polyester base magenta color foil. The foil then serves as a guide for punch-registering the remaining image separates. It is extremely difficult to visually register screened Landsat image data by overlaying separates on a light table. The final set of punch-registered separates should be proofed with the map projection before platemaking to check registration; misregistered imagery destroys all other efforts to produce an acceptable image map.

10) **Production of Halftones and Color Proof** — As the cyan separation is scanned, elliptical screen dots (175 lines per inch) are electronically generated and aligned. The image is scanned at 500 lines per inch and plotted at 1,000 lines per inch, with halftone dots formed by six microdots across the plotting path. When the cyan separation meets the density aimpoints the magenta and yellow separations are scanned and plotted in gray balance with the cyan separation. The elliptical screen dots are rotated 30 degrees for cyan and magenta and 15 degrees for yellow to minimize moire patterns in the final image map. The routine scanner

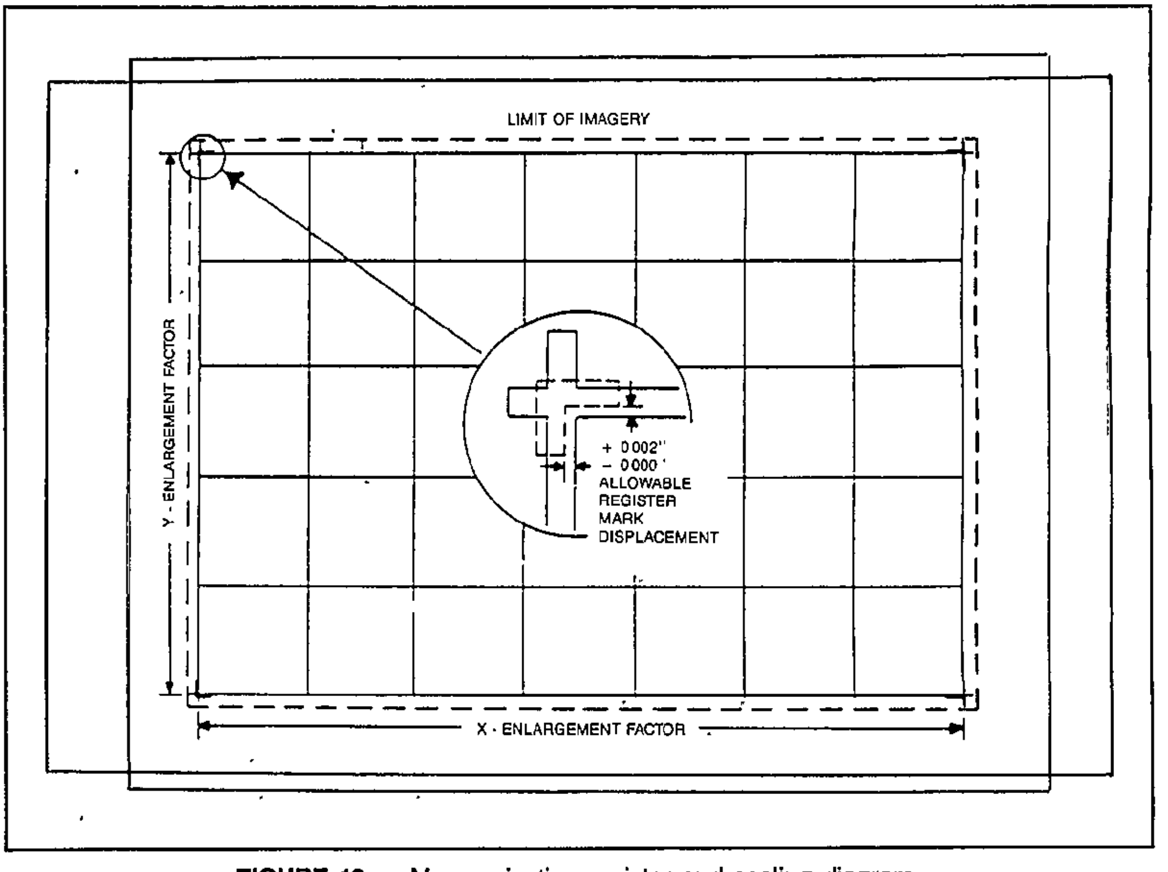


FIGURE 19 — Map projection register and scaling diagram.

alignments are 0 degrees for yellow, +15 degrees for magenta, and −15 degrees for cyan (if there is a black image separate, it is aligned at 45 degrees). A wrong-reading halftone film positive is produced for each of the separations, and a Cromalin color proof is prepared.

c. **Cartographic Overlays.** When cartographic information is to be added to the image map (such as roads, cities, place names, etc.) the overlays should be prepared using one of the monochrome separates to insure good registration with the image detail. Line and lettering detail are scribed using standard cartographic procedures.

Preparation of thematic overlays, such as forestry classes, requires scribing the boundaries on scribing film. The scribing film is used to expose a peel-coat film and a separate layer is made for each class of forest type. The peel coat layers are used to make halftone images for color printing.

d. **Map Collar Design.** The map collar must be carefully designed to provide necessary information on source materials, name of quadrangle, preparing agency name, insignia, scale, projection, date, geographic grid, credits, etc. Layout of the map collar can be made to the agency requirements and is very important for intended use.

e. **Preparation of Color Proofs.**

1) **Preparation of Halftone Negatives for Printing** — The halftone positives of the imagery are punch-registered with all line/lettering separates before halftone negatives are prepared. The USGS uses negative-working pressplates, requiring conversion of the halftone image positives to negatives. During the conversion to negatives, a sharpening of 5 percent in the 50-percent halftone dot area is required to compensate for dot gain in negative-working plate printing.

When tint screens or halftone negatives are made from screened positives, the resulting percent-dot value of the negative is not exactly reciprocal, except at the ends of the density range (0.0 and 2.00). That is, a 0.30-integrated-density 50-percent-dot-area positive that theoretically should yield a 50-percent dot area on the negative actually produces a negative with a 0.35 integrated density, or 55-percent dot area.

2) **Halftone Dot or Line Thickness Change**— Negative-working pressplates are imaged by emulsion-to-emulsion contact with a film negative. The clear areas in the negative permit an exposing light to penetrate to the pressplate. The exposure time must be long enough to firmly fix the image. Routinely, this exposure results in some light spread and thereby a dot or line thickness change. For example, a 175-lines-per-inch halftone dot in the 50-percent dot area is increased in size by about 5 percent. The normal printing of ink on paper may add 5 or 10 percent more spread or increased thickness to the dot size from a combination of pressplate-to-blanket-to-paper pressure and paper absorption of ink. A photographic procedure to change/spread halftone dots to lighten or darken the imagery can adjust for a maximum of 10-percent dot gain in halftone printing. Any change in halftone dot size in the 50-percent area will also affect the highlight and shadow dots. At the extremes, or the 3-percent and 97-percent areas, dots will disappear. Therefore, a density change requiring more than a

10-percent dot adjustment requires remaking the halftones from the continuous-tone film.

The photographic procedure to spread halftone dots is to place the halftone film positive image in contact with unexposed film, emulsion to non-emulsion. Exposure of diffused light through the halftone positive will cause the dots to spread and thereby reduce the negative film's printing dot size (the clear area is the dot size on the negative). The amount of exposure is determined by test exposure using a 16-step halftone positive/negative scale, emulsion up. The film thickness of the scale must be the same as that of the halftone negative (usually 0.004 or 0.007 mils). The midtone, or 0.30 integrated dot density scale step of the halftone positive as read by a densitometer, is used to measure the exposure required to change the 50-percent dot size.

3) **Preparation of Halo Mask** — The spread-film technique is also used in exposing halftone image separates onto metal pressplates to provide a white or black paper halo effect for increased readability of line/lettering data within the image area. For a white halo effect, a spread-image film positive is made from a line/lettering negative by overexposing the negative, emulsion up, with the base in contact with the emulsion of the unexposed film. A sheet of Cronaflex (matte-coated plastic film) is placed on top of the glass frame to diffuse the light. The amount of spread is governed by the length of exposure. The resulting spread-film positive, or halo mask, is exposed with each halftone image separate onto the pressplates. To provide a black halo effect, a contact negative is made from the spread-film positive.

   Register is extremely critical, because the line/lettering data must be centered within the halo mask. The best register can be achieved by the following procedure:

   a) Make a combination negative from each set of line/lettering negatives. Figure 20 illustrates the preparation of a halo mask for line/lettering data to be printed in three colors.

   b) Expose a single combined negative from the combination negatives made in step 1. Also make duplicate negatives of each combination negative. Develop the single combined negative and the duplicate combined negatives at the same time.

   c) Make a spread positive halo mask from the single combined negative made in step 2.

   d) Expose the halo mask with each image separate to make the color proof and pressplates.

4) **Preparation of Color Proof** — A second color proof (negative Cromalin or other proofing system) must be made from the halftone image negatives and line/lettering negatives for the press operator to use as a guide for checking register, completeness of linework and color.

   Proofs must be made emulsion-to-emulsion from the same film separates that will be used for platemaking. They must include a 16-step screen tint scale and a 21-step x 0.15 continuous-tone density scale in addition to the linear density scale

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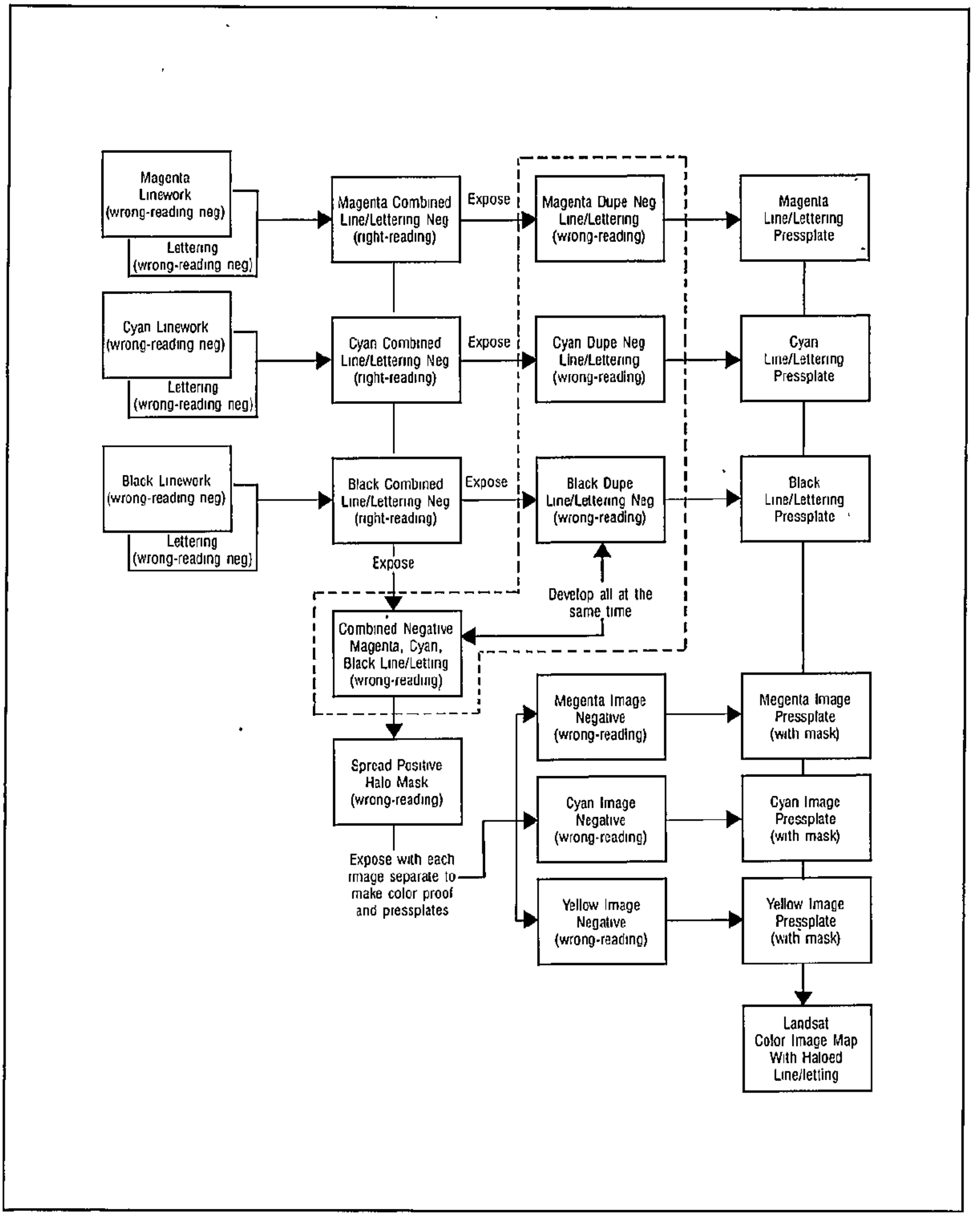

FIGURE 20 — Preparation of halo mask for Landsat image map.

generated by EDC and retained on the halftone image separates. The screen tint scale assures that the halftone dots are reproduced correctly, and the continuous-tone scale provides exposure control.

D. FINAL PRINTING

1. Submitting Materials for Printing

The negatives and the color proof made from the image and line/lettering negatives must satisfy the following requirements before they are submitted for printing.

a. All prepunched negatives must be in register.

b. The 16-step × 0.10 density scale (or equivalent) on each of the image negatives must be positioned to print outside the map trim area.

c. Under 10X magnification the halftone dots on the color proof must be of equal size and shape to those on the image negatives in the 16 steps of the density scale.

d. The images must be wrong-reading when viewed from the emulsion side of the film negatives.

e. Each negative must be properly identified with: name, top of sheet, printing color, and item number.

f. If there are multiple sheets of film to be printed in the same ink color, one sheet must contain a set of register marks.

2. Preparation of Pressplates

Using a light table and a straightedge, the neatline and type on the black negative are aligned horizontally. The center of the map and trim limits are precisely located and scribed on the negative. The scribed marks are then transferred to a plate template.

Adhesive pins are transferred from punch-registered holes in the black negative and subsequent Landsat MSS halftone image negatives to the plate template. A Graphic Arts Technical Foundation (GATF) or equivalent color test strip (color bar) and a 21-step x 0.15 Stouffer or equivalent continuous-tone density scale are also pinregistered on each halftone image negative.

Press plates are exposed through the halftone image negatives emulsion-to-emulsion and processed to a solid step 6 on the 21-step x 0.15 density scale to assure uniform processing. The original Landsat image register marks should also be exposed on the pressplate to provide the press operator with the best possible register guide. Each plate is labeled as to ink color. If the map collar contains information to be printed in color, then other negatives (in addition to the image negative) of the same color will be exposed on the same pressplate.

3. Printing Sequence

Image maps are usually printed on coated stock. The standard printing sequence is black, cyan, magenta, and yellow. Printing the black line/lettering plate first aids good register. Cyan is printed next because it is the best ink trap for the remaining colors and controls most density contrast.

If the cyan area coverage is heavy (i.e., where most of the image area is open water), the cyan may not trap the other ink colors well if printed first. Therefore, a change in the printing sequence with magenta or yellow may be required to improve ink transfer to paper. However, because inks are manufactured with high to low tack (adhesion) levels to match the printing sequence, any change in sequence will also affect the tack required, resulting in a need to request reformulated ink from the manufacturer.

4. Quality Control and Printing

The Cromalin color proof of the halftone image positives is used as a guide to acceptable halftone printing color. The second color proof of the image and line/lettering negatives is used to check register and completeness of linework. The press is operated in a makeready stage until each color ink is in register and uniformly distributed across the sheet. The initial press color runs are checked against the proofs to insure that color and register are satisfactory, that there is no broken or weak type or linework, and that there is adequate color match with adjacent printed map sheets (if any).

Before beginning the actual press run, makeready printed sheets are brought to the Quality Control section for evaluation. The sheets are viewed under 5,000oK light. A reflection densitometer is used on color bars to measure and monitor solid ink densities, dot gain or loss in screened tint areas, trapping in areas of overprinting, and dot deformation caused by poor press performance.

5. Printing
After registration and color approval, the press is run at approximately 6,400 sheets per hour.

6. Finishing
The image maps are trimmed and folded (if required) according to instructions on the printing requisition order. An accurate count of the maps must be made if there are special instructions for packaging, shipment, or distribution.

CHAPTER III

Woody Vegetation Mapping and Resource Inventory

A. OBJECTIVES

The objective of the mapping is to show the extent and distribution of the natural woody vegetation. The purpose of the inventory is to quantify the amount and condition of the vegetation resource base. The objective of all efforts are to develop a scientifically valid data base for use by the Sudan Forests National Corporation for the management of the natural vegetation and to provide baseline information for rehabilitation.

B. IDENTIFY INVENTORY UNIT AND INFORMATION NEEDS

The inventory unit may be a Rural Council Area, a 1:100,000 map quad or other geographic area for which the statistics are desired. Delineate the unit boundaries on image maps of the area.

Determine what information is required about the inventory unit. Assemble existing information from the study area or from similar areas, such as vegetation and soils maps, previous reports, volume equations, aerial photography, imagery, and determine what additional information is required. Use this process to define the objectives for the data collection effort. List the objectives and the desired products in writing including draft examples of tables (with title, row and column headings), maps with draft legends, and reports with chapter and section headings.

C. PREPARATION FOR THE FIELD

Preliminary planning is essential to the success of any resource mapping and inventory project. Visitations to the site to be inventoried and mapped before the project begins are essential to gain understandings of access, terrain, the variation in the vegetation, and working conditions that exist in the area.

1. Mapping and Inventory Plan.
Develop a written plan for the vegetation mapping and data collection. Include a description of the inventory unit, the objectives of the mapping and data collection, the expected results including draft tables, graphs, etc. For the mapping portion, include classification scheme, scale of final product, legend and description of delineators, proofing and publication processes.

For the inventory include a description of the sample design, sample intensity, personnel and equipment needed, field instructions, data collection forms, quality standards, and edit checks. Also develop a coding sheet that can be taped on to the back of a clipboard for easy field reference.

Include in the plan, the listing of field plots and their latitude and longitude and an overlay showing their location.

The SRAAD Project Manager approves this plan before the mapping and data collection phase is implemented.

2. Personnel and Equipment Requirements.
The objectives of the project and the amount of time available to do the vegetation mapping and resource inventory significantly influences the sample design, the size of crew, equipment and support facilities needed to produce the final products. Anticipated weather conditions (i.e. rainy seasons) and their affect on accessibility must be anticipated in determining personnel and equipment needs.

a. **Personnel.** Field staff and a central office staff are required to complete the vegetation mapping and resource inventory of Sudan.

A **Project Manager** is responsible for the overall project performance and administration. The Manager prepares requested progress reports and provides liaison with the Sudan Survey Department and other groups or personnel connected to the project.

The **Field Supervisor** is directly responsible for the training and supervision of all mapping and inventory crews and as such is in charge of all field sampling activities. Each evening, the Supervisor reviews the accomplishments and problems encountered and provides the Mapping Crew Chief and Inventory Crew Leaders with instructions for work for the following day.

The **Mapping Crew Chief** is responsible for all activities involving the development and production of the vegetation map. The Chief ensures that all products are complete and to the specified standards. A one person crew, trained in image interpretation and familiar with vegetation classification and the types in the study area, plus driver is the minimum recommended crew size for vegetation mapping.

The **Inventory Crew Leader** is responsible for the performance of an individual inventory crew. The Leader ensures that daily work schedule is undertaken accurately and efficiently. Before leaving camp each morning, the Leader checks to see that the crew has all the necessary equipment, forms, supplies to accomplish the day's work. At the end of the day, the Leader ensures that all field forms are accurately completed, edited, and submitted to the Field Supervisor.

The **Inventory Crew** should consist of people trained in image interpretation, familiar with the local vegetation and its uses, and having previous inventory experience. For the inventory work, a two to three person crew is the minimum recommended. One person serves as crew leader and recorder and the other two serve as measurers. The size of the field crew can be estimated by the relation of the average crew productivity to the total number of samples required and the time in which they must be established. The number of individual sampling crews (C) needed may be determined by (Poulin and Ltee 1984):

C = [N/(P x E)]/D

where:
N = Total number of samples required.
P = Average daily production in number of samples per crew.
E = Efficiency factor which considers number of days actually spent establishing field samples with respect to time lost travelling, training, sickness, days off, etc.
D = Total number of days available.

Example:
In Kazgail area, we determined we needed to establish 74 plots (N).
We determined that, given the distance between plots, that a crew could establish 2 plots per day (P).
For an efficiency factor we used 80% or 0.80 (E).
We estimated that we had 30 days in which to complete the inventory.
C = [74(2 x 0.80)/30] = 1.54 or 2 crews.

b. Equipment. Vehicles, fuel, spare parts, camping equipment, etc. In addition to adequate personal clothing and footwear, the following are needed for each inventory crew:

Field record sheets
Global Positioning System
1 Clip board or tatum

CHAPTER III

3 pencils with erasers
2 metric diameter tapes
1 100 meter topographic chaining tape
1 30 or 50 meter topographic tape
2 compasses graduated in azimuths
2 clinometers
2 back packs water bottles or canteens
1 metric engineers scale or photo scale
1 clear plastic protractor graduated in azimuths
2 grease pencils plastic flagging
1 pocket stereoscope
1 magnifying glass
1 axe or machete
1 first aid kit
3 pairs of chaps (1 for each crew member) when working in thorn country.
1 pin prick
1 measuring rod 6 mm in diameter, 1 meter loug graduated in decimeters
Metal stakes to mark beginning and end of transect.
Aerial photographs of the area if available and image maps.

D. WOODY VEGETATION MAPPING.

If reliable maps of vegetation cover are available, they should be utilized in subsequent inventory designs. Use only maps that are sufficiently accurate to allow field survey personnel to correlate ground and vegetation mapping with a reasonable degree of confidence. If the available maps are not sufficiently accurate or if they do not meet the objectives of the project, new maps must be produced.

If a pre-stratification sample design is to be used, complete the mapping before the sample selection and inventory data collection begin. If a systematic sample with post-stratification is to be used, then the mapping may be done at the same time as the inventory data collection.

1. National Vegetation Classification and Mapping Scheme.

A scheme for Sudan outlined below can be found in Anonymous (1980) or in Badi, et al (1989):

Desert Zone
Semi-Desert
Acacia tortilis-leptadenia
Acacia mellifera

Low Rainfall Woodland Savannah on Sand
Acacia senegal
Combretum cordofanum
Dalbergia melanoxylon
Albizzia amarc
Terminalia
Sclerocarya birrea

Low Rainfall Woodland Savannah on Clay

2. Cover Types

Cover Type — Left justify.

SA	= Sahab
TT	= Tartar
TE	= Tebeldi
DU	= Dom
MSA	= Mixed Sahab
MTT	= Mixed Tartar
TYSA	= Taraya-Sahab
TYGA	= Taraya-Gafal
GASA	= Gafal-Sahab
TH	= Talh Mixed
HA	= Habil Mixed
HS	= Hashab
TA	= Talh
LA	= Lalot
SL	= Selam
HR	= Haraz
SR	= Sarah
SU	= Sunt
DA	= Daleb
GI	= Gimbil
HU	= Humid
MA	= Mahgria
AG	= Abu Gawi
B	= Bare Soil*
C	= Cultivated*
CHA	= Cultivated/Hashab
MKT	= Mixed Kitir*
KTAS	= Kitir and Talh*
MKAS	= Mixed Kitir and Talh*

SUAADR	= Sunt, Haraz, and Arad*
KTAR	= Kitir and Arad
TBAR	= Terminalia brownnii and Arad
MMK	= Mixed Mukhiet*
HACG	= Hashab and Habil*
W	= Water*

* = Found in Kazgail area.

3. Procedures.
Vegetation maps must be developed in the field. Boundaries of the extent of the vegetation conditions can be derived from conventional aerial photography (see Caylor 1988), from the interpretation of the image maps or from both sources. Generally speaking, aerial photography (or aerial observations) provides the best medium from which to produce vegetation maps but current coverage of high quality is often lacking in Sudan. Therefore mapping using the advantages of Landsat imagery is recommended. For selection of images, the best time of the year, sun angle acceptable, cloud cover etc. should be considered, see Chapter II.

Because Landsat data is recorded at a high altitude, distortion caused by the ground elevation changes is insignificant. Maps traced on overlay material or directly on the 1:100,000 image maps are reasonably accurate as far as visible details are concerned.

If overlay material is used, use a stable base such as acetate or tracing cloth. Pinprick and label the corners of the image map and use a suitable pen for delineating polygon boundaries. While mapping, check to make sure that all polygons are closed properly and legibly labeled.

In addition to the visual interpretation of satellite imagery, computer-aided analysis methods do exist. This needs digital image processing equipment aud the acquisition of the appropriate computer compatible tapes. The decision on which methods to use, i.e. either a manual or automated classification method, depends on the purpose of the study and resources available. Though automated procedures provide results which can be entered directly into a data file they require long and expensive processing to obtain an acceptable precision.

4. Map Production.
After the overlays have been thoroughly checked and edited in the field, turn them over to the Sudan Survey Department for scribing and digitizing. Use the same procedures for production of the Vegetation Maps as outlined for the Image Map production in Chapter II. To the extent practical, use a color scheme that follows the natural appearance of the vegetation on the imagery.

The General Manager, Sudan Forest National Corporation, approves the final vegetation maps for printing and distribution.

E. RESOURCE INVENTORY

The purpose of the inventory is to determine the type, amount and condition of vegetation (grasses, forbs, shrubs and trees) in the survey unit and to provide a base for monitoring changes and predicting trends. The sample design, plot configuration, and this section of the manual have been arranged so that either all the vegetation can be measured or only the components that are of immediate interest or as funds permit.

1. Sample Design.
Use a systematic sample scheme with a random start with poststratification of sample plots based on the vegetation map and other ancillary information.

- **a. Advantages:** The systematic sample scheme is easy to understand, design, and implement. It provides a sample across all classes of land. This is particularly important in Sudan where land uses such as agriculture and livestock grazing are interspersed with the natural vegetation. The systematic location of plots provides a sampling of strata proportional to their size. It permits field work to begin before mapping is complete. As all plots have nearly the same weight even with post-stratification, errors are not magnified as much as with other designs.

b. Disadvantages: The design is not as efficient as other designs when inventorying for a specific resource or when thematic mapping is complete. Depending on the sample intensity and the detail of the mapping, there is some possibility that some strata may not be sampled. If this does occur, then the non-sampled stratum should be either collapsed with another similar stratum or be considered a separate inventory unit.

2. Sample Intensity.
For most inventories of woody vegetation, sample intensities are usually determined to achieve an allowable error based on total volume. The number of plots to be established should be determined by the equations given in Section 3.3.1 of the Field Sampling Manual for the Blue Nile Province (Poulin and Ltee 1984) or other sampling text.

However, often time and funding are more of a constraint than allowable errors. This was the situation in the Kazgail area where the inventory had to be completed in two months time. In this case, the number of plots (N) was determined as follows:

N = P x C x D

where:

P = Average production in number of plots a crew can establish in one working day. In the Kazgail area, we estimated that we should get a least two plots per day per crew.

C = Number of crews that will be working on the inventory. For Kazgail, we anticipated we would have two inventory crews.

D = Number of working days available (excluding time lost to travelling, training, sickness, etc.). We estimated we would have at least 18 to 19 working days as a minimum in the Kazgail Area.

Therefore:

N = 2 x 2 x 18.5 = 74 plots.

If using pre-stratification, at least two field plots per stratum are needed to compute sampling errors and all stratum must be sampled.

3. Sample Selection.
Once the number of samples required are known, compute the interval between plots (I) in km. This is determined by the following:

I = SQRT (A / N)

where:

SQRT = Square root

A = Area of the inventory unit in square kilometers

N = number of plots to be established.

The interval (I) may be rounded down to nearest half kilometer.

Example:

A = 2890 Square kilometers

N = 58 plots

I = SQRT(2890/58) = 7 km.

4. Locating Sample Plots on Image Map.
Using the image map, randomly select a latitude and longitude within the inventory area. This point will be the location of one of the sample plots. Next select a random azimuth in which to orient the grid of plots. This will give the direction one plot will be away from the other. Given this information, plus the interval between plots, the Survey Department can construct a grid overlay showing the location of all other sample locations and at the same time provide the latitude and longitude of each plot.

Locate the sample plots on overlay material such as acetate or tracing cloth. Pinprick the corners of the image map on the overlay material and clearly mark and label. Pinprick the plot locations through the overlay material and the image map. Circle and number the plot locations on the overlay and on the back of the image map.

5. Locating Plots in the Field.
If aerial photographs are available, transfer the plot locations from the image map grid to the aerial photos. Pinprick the plot locations on the aerial photos and annotate with grease pencil on the front and circle and number the plot location on the back of the photo.

Use ground navigation to get to the plot (see figures 23-26). Locate features identifiable both on the ground and on the imagery or photos. Determine the azimuth and ground distance from this identifiable feature to the desired location and chain into the plot.

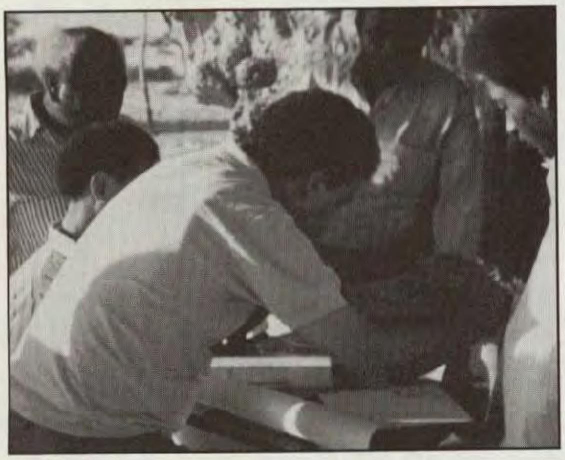

FIGURE 23 — Transferring plot locations from image map to aerial photos.

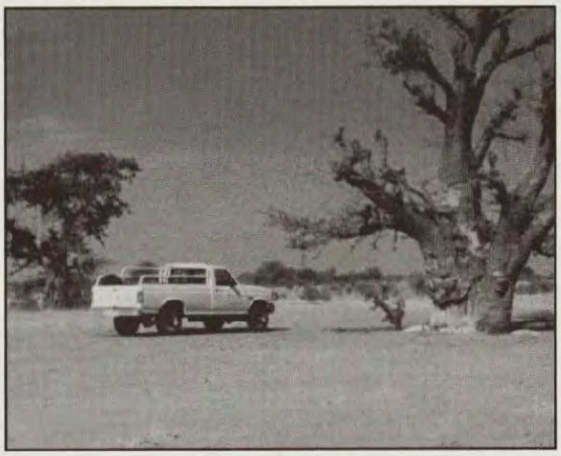

FIGURE 24 — Maneuvering to field plot.

FIGURE 25 — Determining distance from road reference point to plot location.

FIGURE 26 — Chaining into plot.

An alternative is to use Global Positioning Systems (GPS). GPS receivers can be used to locate and establish field plot locations based upon the latitude and longitude coordinates provided by the Survey Department. Enter the coordinates of the plot locations into the GPS as waypoints. Drive to a location closest to the sample plot to be visited (figure 27). Using the GPS determine the coordinates at which you are located and use the GPS navigation function to determine the azimuth and distance you must go to reach your sample location. The GPS unit now has the capability to provide navigational data from your existing position to the waypoint (field plot location). The unit displays the bearing, azimuth, and distance to the field point and indicates if you are right or left of the azimuth to the point. Repeat the process of using the GPS to determine your location and the distance and azimuth still needed to go as you work your way to the plot. The final field location is established on the ground when the GPS unit indicates the correct coordinates for the plot location.

Verify the plot location by comparing the surroundings with the imagery or aerial photography. Once satisfied that you are at the correct location drive a stake into the ground to mark the beginning of the plot and reference its location for remeasurements. Buried metal stakes are preferred as they will not be noticed by the casual passer-by and can be relocated with metal detectors.

6. Plot Configuration and Layout.
The plot configuration (figure 28) is nearly the same as that used in the Blue Nile inventory (Poulin and Ltee 1984) and is similar to that used by the U.S. Army in their Land Condition Trend Analysis (Anonymous 1989b). The basic plot is 20 meters wide by 100 meters long and is 0.2 ha in size and is used to tally woody vegetation that meet specific minimum standards. There is also a 1 m by 10 m, 0.001 ha regeneration plot. If data on the non-woody vegetation are desired for determining forage utilization or production, a line transect, established within the center of the plot and along its long axis, also 100 m in length and having 100 observation points, at 1 m intervals, along its length may also be established. The latter is used for monitoring changes in the ground cover.

Run the long axis and center line due east (magnetic) from the initial plot location (figure 29). Keep the 100 m tape horizontal and close

FIGURE 27 — Driving directly to plot using ground navigation or global positioning systems.

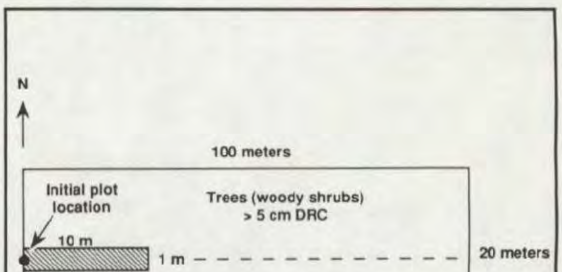

FIGURE 28 — Sample plot layout.

to the ground. Drive a stake into the ground at the 100 m mark. This 100 m center line is used as a line transect for measuring vegetation cover. Flag the corners of the plot by measuring out 10 m at right angles to the centerline at each end of the 100 m tape (figure 30). This establishes the woody vegetation plot.

FIGURE 29 — Running centerline of plot.

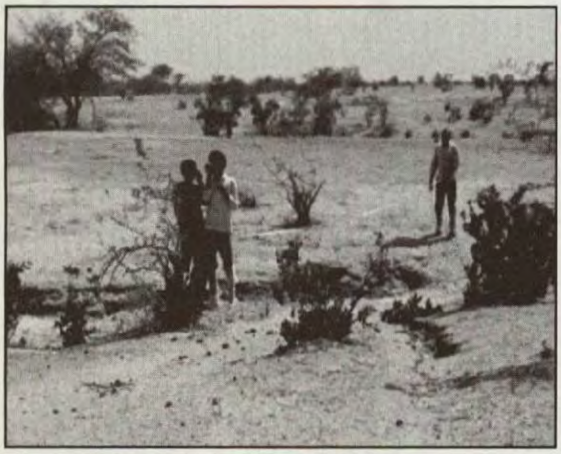

FIGURE 30 — Establishing corners of plot.

7. Data Collection.

a. Woody Vegetation Plot. Complete the **Vegetation Inventory Form** (See Appendix 2) for each plot.

Plot Header Information.

Plot Number — Enter the assigned plot number.

Photo Stratum — Enter the photo or map stratum (note this may be entered after the inventory if the mapping is not completed).

Land Cover — Enter one of the following codes:

- T = Tree is on the plot
- S = Shrubs on plot, no trees
- G = Grass/forbs on plot, no trees or shrubs
- B = Barren - no live plants on plot
- W = Water - plot falls entirely in water.

Land Use — Enter one of the following codes for primary use of area:

- F = Forestry/fuelwood
- G = Grazing
- C = Cultivation and agriculture
- P = Populated
- U = Unknown

Land Condition — Enter one of the following codes for primary condition of plot.

- N = No damage
- E = Eroded
- F = Subject to flooding
- D = Drifting due to wind erosion
- S = Scouring due to wind erosion
- R = Rill/Sheet erosion due to water
- G = Active gully due to water erosion
- P = Pedestaled plants due to wind or water erosion

Cover Type — Extract from vegetation map or use same codes found in Vegetation Mapping Section.

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Tree Density — Record percent of ground covered by tree crowns. Leave blank if no trees occur on plot.

0 = 1 – 10% of ground covered by tree crowns
1 = 11 – 20% of ground covered by tree crowns
2 = 21 – 30% of ground covered by tree crowns
3 = 31 – 40% of ground covered by tree crowns
4 = 41 – 50% of ground covered by tree crowns
5 = 51 – 60% of ground covered by tree crowns
6 = 61 – 70% of ground covered by tree crowns
7 = 71 – 80% of ground covered by tree crowns
8 = 81 – 90% of ground covered by tree crowns
9 = 91 + % of ground covered by tree crowns

Soil Type — Record dominant soil on plot. Left justify.

D = Dune
S = Sand (Goz)
SC = Sandy Clay (Gardul)
L = Loam
C = Clay
R = Rock
A = River Alluvium (Khor)
= Moglad

Plot Weight — This is the plot expansion factor determined by dividing the stratum area by number of plots falling within that stratum.

Crew — Enter the one-digit code for identifying crew.

Date — Enter the day (2 digits), month (2 digits), and year (last two digits) that the plot is established.

Tree tally. Tally all live trees, 5 cm and larger at 20 cm above the ground (Diameter at root collar - drc) whose germination point lies within the sample plot boundaries (figure 31).

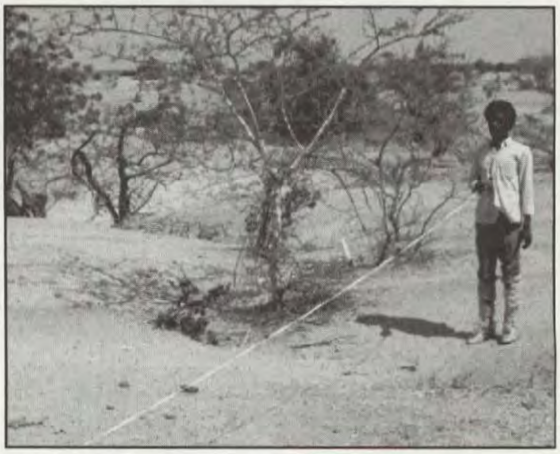

FIGURE 31 — Measuring from plot centerline to determine if tree is on the plot. Tree must have it's germination point located within the plot boundaries to qualify as a tally tree.

This activity is undertaken by the two Tree Identifiers who proceed in an orderly manner, one on each side of the plot center line, from tree to tree until all qualifying trees within the plot boundaries have been identified, measured, evaluated, and recorded. Record the following information:

Tree Number — Assign a unique tree number to each qualifying tree on the plot.

Species Name — Write in the common or botanic name of the tree being tallied only if the species is not included in list of codes.

Species Code — Enter the appropriate code as follows:

001 = Millet
002 = Sesame

003	= Zunari	
004	= Ground nut	
005	= Watermelon	
006	= Lubia	
007	= Okra	
008	= Karkadi	
009	= Fruits	
010	= Vegetables	
102	= Taraya	Pterocarpus lucens
103	= Darot	Terminalia brownii
105	= Hashab	Acacia senegal
106	= Sunt	Acacia nilotica v neabra
107	= Gumbil	Cordia africana
201	= Sahab	Anogeissus leiocarpus
202	= Leyun	Lannea fruticosa
206	= Aradieb	Tamarindus indica
208	= Talh	Acacia seyal
209	= Heglig	Balanites aegyptiaca
301	= Habil	Combretum glutinosum
305	= Kakamut	Acacia cumblicantha
306	= Kuk	Acacia sebriyana
308	= Dom	Hyphaene thebaica
310	= Gafal	Boswellia papyrifera
311	= Homeid	Sclerocarya birrea
313	= Tartar	Sterculia setigera
314	= Tebeldi	Adansonia digitata
315	= Dalieb	Borassus aethiopium
316	= Kitir	Acacia mellifera
317	= Arad	Albizzia amara
318	= Bauhinia	Bauhinia rufescens
319	= Sidir	Ziziphus spina-christi
321	= Abnous	Dalbergia melanoxylon
326	= Godiem	Grewia tenax
328	= Kadad	Acacia
329	= Gerf El	Albizzia anthetminthica

Diameter at Root Collar (DRC) — Measure at 20 cm above ground. Record to last tenth cm (figure 32).

Diameter at Breast Height (DBH) — If tree has one main bole, measure at 1.3 m above ground. Record to last tenth cm (figure 33).

Bole Height — If tree has one main bole, measure that portion of the tree between the stump and the crown that may be recovered as merchantable logs. Record to last tenth m.

Total Height — Record the length from the stump of the tree to its very top (figure 34). Record to the last tenth m.

FIGURE 32 — Measuring diameter at root collar (DRC).

FIGURE 33 — Measuring tree dbh.

FIGURE 34 — Measuring tree height.

Crown Diameter (CD) — Measure and record the average crown diameter of the tally tree. Record to the nearest meter.

Percent Cull — Record the percent of the tally tree that is missing due to fuelwood or forage removal that would reduce the total volume of the tree.

b. Regeneration Plot. The regeneration plot is nested within the 0.2 ha tree tally plot. It is 1 m x 10 m located at the start of the tree tally plot and along the center line and long axis of the plot (see figure 28). For each one meter block record whether tree regeneration (any live tree less than 5 cm DRC) is present or not (A for tree regeneration absent; P for tree regeneration present) and the tree species code if regeneration is present.

c. Line transect. Data derived from the line transect are used to estimate soil erosion and to develop vegetation profiles for livestock and wildlife factors.

With the measuring rod vertically positioned, take readings at one meter intervals along the 100 m line transect starting at the 0.5 m point and at each meter thereafter (0.5 m, 1.5 m, 2.5 m, etc.). There is a total of 100 observations for each transect.

The tip of the measuring rod touching the ground at each observation point identifies the ground cover and the vertical intervals along the rod the canopy cover. Place the tip of the rod on the ground along the measurement point. Record the ground cover contacted by tip on the **Line Transect Form** (to be developed). After recording the type of ground cover, identify and record the vertical intervals along the rod that are in contact with live vegetation in the canopy cover. Record the species and plant height encountered. Collect samples of unknown plants for later identification. Where more than one species contacts the rod, record only the species and height of the plant that touches the highest point.

Ground Cover. Any material on the surface of the soil. Categories are:

LV = Live vegetation including parts of the plant where the leaves and stems meet the roots at the soil surface, exposed roots, non-basal, attached plant cover such as decumbent leaves, stems, stolons, etc. Record also species.

DW = Deadwood cover including single woody plant part 2 cm or more in at least two dimensions.

LT = Litter cover including any dead plant part or parts less than 2 cm in at least two dimensions and at less than 2.5 cm in accumulated depth. Includes animal feces and other rapidly degradable material.

DF = Duff cover including any plant part or parts, usually partially decomposed, 2.5 cm or more in depth.

RK = Rock cover including consolidated mineral matter or other slowly degradable material 7.5 cm or larger in any dimension.

GR = Gravel cover including consolidated mineral matter more than 2 mm in some dimension and less than 7.5 cm in all dimensions.

BG = Bare ground. Any area not meeting any of the above conditions.

8. Volume Estimation Study.
The objective of the volume estimation study is to derive reliable relationships of gross tree volume to easily measured variables such as drc, crown diameter, and total height. These variables have been found significant in similar areas (Lund 1983). If acceptable volume equations are already available, this study may not be necessary.

Proceed to areas in the inventory unit where the species and size of tree desired are to be found. Once at the site, a selection of trees to be examined, measured and recorded is made. Care must be taken that a range of tree qualities are chosen. If selections tend towards the poorer or better quality trees, the results will be biased in a like manner.

Destructive sampling is recommended, but visual segmentation is acceptable where time is limited, trees are scarce, and owners object. If destructive sampling is to be used, look for areas where land clearing operations are going on or where they are anticipated to make the most of available labor and to mitigate the unnecessary destruction of vegetation. Measure at least 10 trees per species or species group within the inventory unit and covering as wide a range of tree sizes as possible (figures 35 & 36). Complete the ***Woodland Tree Segmentation Record*** (see Appendix 2) as per instructions by Born and Chojnacky (1985). Segments are in half meter classes and 2 cm mid-point diameter classes. Keep a record of species and diameters measured and check daily to ensure enough samples are obtained to develop regression equations.

FIGURE 35 — Small tree for volume segmentation.

FIGURE 36 — Ocular volume segmentation on a tebldi tree.

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When destructive sampling is not being used, trees tallied on the inventory plots may be used. This can save time and reduce the number of people needed for the study. In such instances, record the plot number and tree number if sample tree occurs on plot.

9. Quality Control.
Constant care and checking is required to maintain a high degree of precision on all direct measurements. If it is not possible to supervise to the extent required to ensure quality work, a verification sample must be undertaken.

At least 10 percent of the plots should be verified. Remeasure the selected plots taking increased time and care to perform the tasks to ensure accuracy of measurements. Do not take the completed forms to the field. Use new forms and compare the results after the verification is completed.

Establish maximum allowable errors both for the inventory as a whole and for individual tree measurements. Evaluate the verification plots and the recently completed plots against these standards. Check more plots at the beginning of the inventory as this is when most errors will be made.

F. DATA ENTRY, EDITING, AND PROCESSING.

1. Data entry.
Edit field forms before leaving plot making sure all data are collected and properly coded (figure 37). Check for legibility, missing information, and inconsistent data. In office, make copy of plot forms and store in a safe place. Use originals for data entry. If time permits, the person who recorded the data should have experience in entering data into the computer. This provides the individuals with additional training and alerts them to problems with recording data in the field. Often times, problems will arise in data entry that only the person that was on the plot can resolve.

FIGURE 37 — Checking forms.

2. Data editing.
Once data are entered into computer, edit the data to insure that:

- **a.** there are no blank spaces - all data called for are provided.
- **b.** only legal codes are used.
- **c.** ranges of data are logical. For example, species 105 may have a drc between 5 cm and 30 cm, but a drc of 140 cm would be illogical.
- **d.** cross checks of data are made and are logical. For example, a tree that has a drc of 140 cm should have a height greater then 3 m.

3. Processing.

- **a.** Volume Equation Development.
  - **1)** Input ***Woodland Tree Segmentation Record*** and edit.
  - **2)** Compute segment volumes (sv) in cubic meters by equation

    sv = [(md/100/2)SQ × 3.1416 × sl]

    where:

    SQ = previous quantity squared

    md = midpoint diameter of segment in cm

sl = segment length in meters

Example:

md = 6 cm

sl = 2 m

sv = [(6/100/2)SQ x 3.1416 x 2]
= 0.00565488 cubic meters.

3) Total segment volumes per sample tree and develop regression equations for volume prediction testing DRC, DRC(SQ), Crown Diameter, and Total Height as independent variables.

b. Plot and Tree Tally.

1) Input ***Vegetation Inventory Form*** and edit.

2) Using volume equations, compute and assign tree volume per tally tree

3) Sum tree volumes on plot and multiply by 5 to get tree volume per ha.

4) Multiply results of Step 3 by plot weight to get volume per stratum.

5) Sum volumes per stratum to get total volume for the inventory unit.

c. Repeat process in b. for other estimates as necessary.

d. Determine sampling errors according to equations and examples given on pages 37-38 of Lund and Thomas (1989).

4. Data Base Maintenance.

G. REPORTING.

The results of the Kazgail inventory will be published as a separate report.

Minimum reports to be generated for each inventory unit.

1. Land Cover Area Summary.
Area by land cover class, including cover type, by mapping unit or photo stratum and for inventory unit as a whole. Includes estimates of sampling errors.

2. Land Cover Volume Summary.
Volume (cubic meters) by land cover class, including cover type, by mapping unit or photo stratum and for inventory unit as a whole. Includes estimates of sampling errors.

3. Stand Tables.
Number of trees by species and DRC classes. One for each mapping unit or photo stratum and one for the inventory unit as a whole including estimates of sampling errors.

4. Stock Tables.
Woody volume (cubic meters) by species and DRC classes. One for each mapping unit or photo stratum and one for the inventory unit as a whole including estimate of sampling errors.

5. Regeneration Summary.
Area having regeneration by species presence and mapping unit and for inventory area as a whole. Includes estimates of sampling errors.

6. Land Use Area Summary.
Area by land use and class by mapping unit or photo stratum and for inventory area as a whole). Includes estimates of sampling errors.

7. Land Use Woody Volume Summary.
Woody volume (cubic meters) by land use class and by mapping unit or photo stratum and for inventory area as a whole. Includes estimates of sampling errors.

8. Ground Cover Summary.
Area by ground cover type and forest type. Produced from line transect data.

9. Vegetation Profile.
Graphic display of vegetation height in 0.1 meter classes by percent of ground covered for species classes or groups.

10. Statistical Summaries.

In a post-stratification design, plots are simply grouped by the same vegetation map characteristics and the variance is computed for each stratum and then pooled for the inventory unit as a whole. As the number of samples in a given stratum is not predetermined, there is a random component to the estimates of standard error and confidence limits. Some strata may have been poorly represented in the sample and estimates for these strata may be highly variable. Procedures for calculating estimators for a systematic sample with post-stratification are given in Lund and Thomas (1989) pages 37-38.

F. APPROVAL AND DISTRIBUTION OF RESULTS

The General Manager, Sudan Forests National Corporation, approves the final Vegetation Maps and the Resource Inventory results.

CHAPTER IV

Combining Data Through Computer Techniques

A. OBJECTIVE.

Create a digital and spatial data base that can be used on microcomputers to display and analyze resource inventory and rehabilitation information.

B. EQUIPMENT AND SOFTWARE.

1. Equipment.
The following equipment is needed to process the woody vegetation inventory data and for geographic information system (GIS) demonstration.

- **a:** Compac Deskpro 286 with an Intel 80287-10 Math CoProcessor.
- **b:** 40 megabyte hard drives.
- **c:** One high density 5.25 floppy drive.
- **d:** One high density 3.5 floppy drive.
- **e:** Compac VGA color graphics monitor with a graphics board.
- **f:** One EPSON LQ-850 24 pin dot matrix printer.

2. Software.
The following software are available.

- **a:** DBASE III+ — This organizes data into specific databases so forest inventory calculations can be made. The calculations are carried out in DBASE programming language.
- **b:** LOTUS 123, Ver. 2.2 — This particular software package is a spreadsheet program and is used for regression analysis, such as that needed to develop volume equations, and other statistical analyses.
- **c:** Atlas Graphics, Ver. 3.0—Atlas Graphics is a mapping software package that display maps created in a GIS system (such as ARC/INFO, ERDAS, etc.).
- **d:** Word Perfect — A word processing package to create simple data files as well as for documentation of procedures and report preparation.

C. DATA ENTRY AND ANALYSIS.

Both DBASE III+ and LOTUS software are used.

The following are procedures need to be followed to generate outputs for the Woody Vegetation Inventory.

1. Session set-up.
From the *c:/* prompt, move to the DBASE subdirectory by typing ***cd DBASE***. From the DBASE3 directory, move to the DATA sub-directory by typing ***cd DATA***. The DOS prompt should look like this.

C:/DBASE/DATA

From here, one can run the data entry and analysis program by typing ***DBASE MAIN***. In a moment or two a menu will appear giving different choices from which either data entry or analysis can be performed.

2. Data Entry.
To enter data from the field sheets into the computer enter a code 1 for plot data and a code 2 for tree segmentation data. A table will appear on the screen nearly identical to the field forms (see Appendix 2).

Enter the field data at each appropriate location within each table using the keyboard. Press the escape key Esc when complete. A command or a table will appear on the screen giving the user a variety of options. The user can select a new plot, continue with the same plot or quit. Choices 3 and 4 on the main table will allow the user to modify existing plot and segmentation data after entry into the database. The commands to enter and exit the tables are identical to the commands for choices listed above.

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3. Data analysis.
After all data have been entered, an analysis can be performed on the data by choosing 5 on the main menu. A new menu will appear giving the user 8 choices. The creation of each output is handled separately below.

a. **Creation of Land Cover and Land Use Tables** — the same procedure is used for the creation of both the Land Cover and Land Use tables.

   First, make sure the printer is on.

   Next, enter a 1 for Land Cover or 2 for the Land Use table.

   Next a table will be automatically generated and outputted to the printer. The table will show either total area in either land cover or land use classes by vegetation mapping strata within the inventory unit.

   This can process can be repeated as often as desired.

   When completed, press escape ESC to return to the analysis menu.

b. **Creation of a Stand Table** — To create a stand table from the forest inventory data, choose 3 on the analysis menu. The program will run for about five minutes and will save the results in a file named ***sttables.dbf.*** To print the information, make sure the printer is on and choose 4 on the analysis menu. The program need only run once (choice 3) but the printout of the data (choice 4) may be run as often as needed.

c. **Creation of a Stock Table** — The creation of a stock table requires a number of different steps including moving completely out of DBASE and doing a regression analysis of the data in LOTUS. The first step is the calculation of volumes from the segmentation data gathered in the field.

Choose option 5 in the analysis menu, to calculate volumes for every tree that has a segmentation record. This program will also create a LOTUS table for each species within the forest inventory showing volume in cubic meters, diameter of root crown (DRC) in centimeters, crown diameter (CD) and total height in meters for every tree that has a segmentation record. It will take almost 10 minutes for this program to run.

After this program has completed the volume calculations, exit out of DBASE by choosing 8 on the analysis menu and 6 on the main menu. The C:/DBASE3/DATA prompt should now appear on the screen.

Move into LOTUS by typing ***123*** (it might be necessary to type ***LOTUS*** first and choose 123 from a menu within LOTUS). A spreadsheet will now appear. Type the slash (/) to show the 1-2-3 main menu. Retrieve each file for each species within the forest inventory be choosing ***FILE***, then ***RETRIEVE***. Press the escape key Esc to interactively choose the directory where the species files are located. Type in ***C:/DBASE3/DATA/*.WKS*** to show all LOTUS files in the DBASE/DATA directory. Move the arrow to the proper file (e.g. 105.wks) and press ENTER. Refer to pages 2-69 through 2-73 in the LOTUS Manual for a description of regression analysis. The file will be displayed in the spreadsheet on the screen. Press the slash key (/) again to return to the main menu. Calculate a regression equation for the particular species by choosing ***DATA*** then ***REGRESSION***. A new table will now appear. Move to ***X-RANGE*** and specify the independent variables by moving the cursor to the upper left independent variable and anchor it with a dot (.). Then move the arrow down and to the right until the highlighting includes all independent values and press ENTER. Do the same for the dependent variable by moving to ***Y-RANGE*** and defining the field to analyze with the procedure used to set the X-RANGE. Specify an output location of the regression analysis by moving to ***OUTPUT-RANGE*** and press ENTER. Move the cursor to a clear part of the spreadsheet and hit ENTER. Move to ***INTERCEPT*** and choose ***YES*** for calculating an intercept. After all of this entry is completed, choose ***GO*** and hit ENTER.

Record the results of the regression by pressing slash (/), select file, press enter. Select save, press enter. Select replace, press enter.

Move to the next species by reading in a new file using the procedures described above and repeating the regression analysis.

Note: It might be necessary to combine species if there are a short supply of volume data for a particular species. Consult a qualified forester for proper groupings. To combine files first position the cursor in the exact position the file needs to go before going through the following procedures. Choose ***FILE***, ***COMBINE***, ***COPY***, and ***ENTIRE-FILE***. Hit the escape key <Esc> to interactively choose the proper location for the file and press ENTER. Arrow over to the proper file and press enter. The files should now be on the same spreadsheet ready for the regression analysis. Be sure to delete any unnecessary characters in the data field before preforming the regression analysis.

Exit LOTUS by choosing ***QUIT*** in the LOTUS menu. When the C:/DBASE3/DATA prompt appears, type ***DBASE***. When the next prompt appears type ***assist***. This will bring up the DBASE menu. Select ***Database File*** in the SETUP menu by hitting ENTER. Choose the C drive by hitting ENTER and choose the data base file ***regress.dbf***. The file is not indexed so choose NO when that question is asked. Move over to the UPDATE menu and select ***append***. Change each of the data coefficients in each field for each particular species, delete species that don't exist and create new fields for new species. When that is accomplished, push <Ctrl><End>. This will save any changes made to the data file.

Next, move out of the menu for DBASE by returning to the SETUP menu. Select ***Quit dBASE III Plus*** and the C:/DBASE3/DATA prompt will return to the screen. Type in ***DBASE MAIN***, enter 5 on the main menu, and then enter 6 on the analysis menu. This program calculates the volnme for each tree in the study area based upon the regression equations calculated in LOTUS. This will take about 4 or 5 minutes to run. The program will save the results to a file called ***sktables.dbf***. After this is complete, choose 7 to print the stock data out on the printer. The tables will give the volume per species per each vegetation type and the volume per species for the entire forest inventory area. The program need only run once (choices 5 and 6) but the printout can be run as many times as necessary (choice 7).

After the analysis is complete, choose 8 on the analysis menu and 6 on the main menu to exit the forest inventory program.

D. GIS PREPARATION.

Digitize the base map information (vegetation, soils, geology, land use, etc.) using the best sources of information available. Download the digital data to an ASCII file for reading by ATLAS GRAPHICS.

E. MAP CREATION AND DISPLAY USING ATLAS GRAPHICS.

To display the vegetation, soils, terrain units, and city locations with buffers (Table 1), use the ATLAS GRAPHICS software. Refer to the

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ATLAS GRAPHICS Manual for detailed procedures.

1. Session set-up.
To start up ATLAS GRAPHICS, at the C: prompt type ***cd AG***. The prompt should now appear as C:\AG . Type in ***AG*** at this prompt to start ATLAS GRAPHICS. A screen will appear identifying Atlas Graphics software. Hit ENTER to continue.

2. Reading Data into ATLAS GRAPHICS.
A second screen will appear presenting a choice of several different procedures. Each of these serves a different function within ATLAS GRAPHICS, such as data entry and editing, map boundary manipulation and joining, and importing files from other software packages, including DBASE and LOTUS. For now, we are only interested in the display function within ATLAS GRAPHICS. Use the arrow key to highlight ATLAS and push ENTER.

The display directory within ATLAS GRAPHICS will appear on the screen. It is within this directory that the map, data, and legend to be shown on the plot is specified. The plotting of the map on the screen will be done from this directory as well.

Normally, within ATLAS a boundary file (a file which contains coordinates of the map boundaries), a data file, and a legend file (the title, subtitle, and legend used for the map) would have to be specified to create a complete plot. To make displays easier for this project, the boundary file and data file have been saved into a map file. This file can be identified by a ***.MAP EXTENSION*** and can be read into ATLAS in place of the boundary and data files.

To display a map, first insert the Atlas file disk into drive A (the ATLAS display files are also on the C drive in the AG/DATA subdirectory). Arrow over to ***MAPFILE***, select ***MAPFILE*** by pushing ENTER. In the MAPFILE subdirectory, select ***LOAD***. A screen will then appear showing the disk drive to use to read the mapfile. If this is correct, hit ENTER. A list of mapfiles stored on the disk that was specified will now appear on the screen. Select one of these files by highlighting it with the up and down arrow keys (e.g. SUSTEX refers to SUSTEX.MAP - a mapfile which contains the boundary and data files for soil texture in the Kazgail region, refer to Table 1). Push ENTER to read in the boundary and data files stored in the mapfile. When this is accomplished, ATLAS will return to the display directory.

Next, load in the legend file by arrowing over to ***LEGEND*** and hit ENTER. Highlight ***LOAD*** and push ENTER. A screen will appear showing the disk drive to read the legend file from. If this is correct, push ENTER. A list of legend files will now appear which are stored on the disk that was specified. Select one of the files by highlighting it using the up and down arrow keys (ex. SUSTEX refers to SUSTEX.LEG—a legend file that contains the title, subtitle, and legend title for the soil texture map of the Kazgail region, refer to Table 1). Push ENTER to read in the legend file. When this is accomplished, ATLAS will return to the display directory.

3. Displaying Data Through Mapping in ATLAS GRAPHICS.

All of the files are now entered and ready for display. Highlight ***PLOT*** in the ATLAS directory and push ENTER. Highlight ***DISPLAY*** to direct the plotting to the screen. Push ENTER. The map will now be plotted on the screen. After the map is complete, the ATLAS display directory will appear in black and white above the map. From here another map can be displayed by choosing a different mapfile and legend file, the current map can be redisplayed, or quit. To produce a new map or plot the current map, repeat the procedures above. To quit, highlight ***QUIT*** in the display directory and in the ATLAS GRAPHICS main directory. This will return the display to the C:\AG prompt.

F. ANALYSIS EXAMPLES.
Tables II through V give examples of the output from the forest inventory analysis performed

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in DBASE. Some other useful tables that might be generated from the data analysis would be a table showing the number of trees sampled per tree species and plot. Another might be the total volume each of the plots have in the forest inventory compared with the total number of trees per plot. The addition of these tables would assist in the calculation of standard errors for the forest inventory giving some indication of the accuracy of the inventory study.

Other maps could be created for display with ATLAS GRAPHICS. One might be comparing erosion potential (derived from the soils map) with the vegetation within the Kazgail inventory area. This might give an indication as to what types of forest stands fair better in rough terrain. Another possibility might be to overlay other socioeconomic data (such as anthropogenic consumption of woody biomass) with the vegetation data within the Kazgail inventory area. This might give some indication as to what types of forests stand the worst chance of survival due to human interaction. Although both of these might be useful, they would have to first be created in a GIS system and then downloaded to ATLAS GRAPHICS for display purposes.

G. Training In-Country.

Extensive training was carried out in the country of Sudan at the SRAAD office from approximately Feb 6, 1990 to Feb 15, 1990. Within that time period, two Sudanese were trained to run the DBASE, LOTUS, and ATLAS GRAPHICS software associated with the forest inventory. With the skills they have acquired, they should be able to run the forest inventory analysis with little difficulty.

TABLE 1

FILES USED FOR ATLAS GRAPHICS DISPLAY

Vegetation 1:100,000	SUVEG.MAP SUVEG.ABF SUVEG.DAT	Village Locations	SUREHB.ABF SUREHB.DAT
Soils 1:250,000	SUSOIL.ABF SUSOIL.DAT	Village Locations with buffer zones	SUREHBUF.ABF SUREHBUF.DAT

TERRAIN UNITS BASED UPON SOILS 1:250,000

Erosion Potential	SUEROP.MAP SUEROP.LEG	Tree Survival Chances	SUTSC.MAP SUTSC.LEG
Herbage Yield	SUHY.MAP SUHY.LEG	Slope	SUSLP.MAP SUSLP.LEG
Suitability for Traditional Agriculture	SUSTA.MAP SUSTA.LEG	Soil Moisture Regimes	SUSMR.MAP SUSMR.LEG
Suitability for Mechanized Agriculture	SUSMA.MAP SUSMA.LEG	Land Use	SULU.MAP SULU.LEG
Soil Texture	SUSTEX.MAP SUSTEX.LEG		

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TABLE 2

KAZGAIL AREA SUMMARY REPORT
Hectares by Land Cover and Vegetation Mapping Classes

Land Cover	Bare Soil	Cult'd	Hashab & Comb	Mixed Mikhiet	Sunt,Arad &Haraz	Kitir & Tahl	Mixed Kitir	Mixed Kit & Tal	Water	Totals
	VEGETATION CLASSES									
Tree	2897.6	13768.3	28450.5	49322.4	10600.7	0.0	71283.8	12418.1	0.0	188741.5
Shrub	0.0	9178.9	14225.2	5480.2	0.0	0.0	0.0	0.0	0.0	28884.4
Grass	0.0	22947.3	9483.5	0.0	0.0	0.0	10183.4	6209.0	0.0	48823.2
Barren	2897.6	0.0	8483.5	0.0	0.0	0.0	10183.4	0.0	0.0	22564.5
Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	5795.2	45894.6	61642.7	54802.7	10600.7	0.0	91650.6	18627.2	0.0	289013.7

TABLE 3

KAZGAIL AREA SUMMARY REPORT
Hectares by Land Use and Vegetation Mapping Classes

Land Use	Bare Soil	Cult'd	Hashab & Comb	Mixed Mikhiet	Sunt,Arad &Haraz	Kitir & Tahl	Mixed Kitir	Mixed Kit & Tal	Water	Totals
	VEGETATION CLASSES									
Forest	2897.6	13768.3	28450.5	38361.8	10600.7	0.0	71283.8	12418.1	0.0	177781.0
Grazing	0.0	13768.3	9483.5	10960.5	0.0	0.0	5091.7	0.0	0.0	39304.1
Agriculture	2897.6	18357.8	23708.7	5480.2	0.0	0.0	15275.1	6209.0	0.0	71928.6
Populated	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unknown	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	5795.2	45894.6	61642.7	54802.7	10600.7	0.0	91650.6	18627.2	0.0	289013.7

TABLE 4

KAZGAIL AREA STAND TABLE
Total Number of Trees by Species & DRC Class
TOTALS FOR ALL FOREST TYPES

Species Code	Diameter of Root Crown								
	10	20	30	40	50	60	70	70	Total
105	1,620,126.5	109,606.0	23,709.0	0.0	0.0	0.0	0.0	0.0	1,753,441.5
106	174,759.0	154,642.5	62,091.0	85,038.5	0.0	0.0	0.0	0.0	476,531.0
107	310,719.5	26,502.0	0.0	0.0	0.0	0.0	0.0	0.0	337,221.5
208	514,530.0	262,852.0	85,800.0	0.0	0.0	0.0	0.0	0.0	863,182.0
209	0.0	27,401.5	27,401.5	0.0	62,091.0	0.0	0.0	0.0	116,894.0
301	22,947.5	47,418.0	0.0	47,418.0	0.0	0.0	0.0	0.0	117,783.5
305	93,136.5	155,227.5	62,091.0	0.0	0.0	0.0	0.0	0.0	310,455.0
310	50,917.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50,917.0
314	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23,709.0	23,709.0
316	7,372,604.0	1,970,410.5	289,660.5	23,709.0	0.0	0.0	0.0	50,917.0	9,707,301.0
317	157,024.0	51,110.5	133,218.0	54,754.5	31,045.5	0.0	0.0	31,045.5	458,198.0
318	0.0	27,401.5	0.0	27,401.5	0.0	0.0	0.0	0.0	54,803.0
319	27,401.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27,401.5
321	454,354.5	189,383.5	23,709.0	0.0	0.0	0.0	0.0	0.0	667,447.0
326	203,668.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	203,668.0
328	25,458.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25,458.5
329	25,458.5	133,218.0	54,754.5	31,045.5	0.0	0.0	0.0	0.0	244,476.5
Total	11,053,105.0	3,155,173.5	762,434.5	269,367.0	93,136.5	0.0	0.0	105,671.5	15,438,88.0

TABLE 5

KAZGAIL AREA STOCK TABLE
Volume in 100s of Cubic Meters by Species & DRC Class
TOTALS FOR ALL FOREST TYPES

Species Code	Diameter of Root Crown								
	10	20	30	40	50	60	70	70	Total
105	829.4	67.8	32.4	0.0	0.0	0.0	0.0	0.0	929.7
106	60.5	133.1	25.6	85.8	0.0	0.0	0.0	0.0	305.1
107	214.3	17.1	0.0	0.0	0.0	0.0	0.0	0.0	231.5
208	156.5	59.5	28.7	0.0	0.0	0.0	0.0	0.0	244.7
209	0.0	28.8	20.4	0.0	43.8	0.0	0.0	0.0	93.2
301	10.1	29.9	0.0	69.3	0.0	0.0	0.0	0.0	109.4
305	35.1	30.7	9.9	0.0	0.0	0.0	0.0	0.0	43.2
310	43.20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	43.2
314	0.0	0.0	0.0	0.0	0.0	0.0	0.0	172.3	172.3
316	2,866.8	1,303.5	313.7	27.5	0.0	0.0	0.0	530.2	5,041.8
317	147.2	54.9	102.0	56.5	19.6	0.0	0.0	61.4	441.8
318	0.0	22.4	0.0	64.6	0.0	0.0	0.0	0.0	87.0
319	16.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.1
321	274.2	198.9	22.4	0.0	0.0	0.0	0.0	0.0	495.6
326	109.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	109.1
328	9.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.5
329	17.5	92.8	104.8	71.9	0.0	0.0	0.0	0.0	287.2
Total	4,790.0	2,039.9	660.1	375.9	63.5	0.0	0.0	764.0	8,693.6

APPENDIX 1 - GLOSSARY

Accuracy — A measure of the variability of an estimate of a characteristic from the true value of the estimate.

Allowable error — Also called the allowable sampling error or tolerance specification. The largest acceptable size of the standard error of the estimate usually specified before a sample is drawn to determine the sample size.

Arithmetic mean — An average of a series of values determined by dividing their sum by the number of individual values.

Attribute (properties) — The differentiating characteristics that must be discovered, measured, described, delineated, or derived to fulfill the objectives of the inventory.

Bearers — Rings of steel at the ends of the plate cylinder, the blanket cylinder, and sometimes the impression cylinder. On American offset presses the bearers make rolling contact for proper meshing of the driving gears. On all presses, bearers provide a fixed base for determining the packing behind the plates and blankets.

Bias — Generally a systematic deviation between a statistical result and a parameter that is being estimated.

Blanket — A fabric coated with natural or synthetic rubber which is clamped around the blanket (offset) cylinder of an offset lithographic press which transfers the ink from the pressplate to the paper.

Bole — Portion of tree between stump and crown that may be recovered as merchantable logs.

Borderline tree — A tree or shrub sufficiently close to the boundary of a sample plot that more measurements are required to establish whether the tree or shrub is inside or outside the plot.

Breast height — A standard height, 1.3 m above mean ground level, at which the diameter of a tree is measured.

Brightness value — A number, typically in a range of 0-63, 0-127, or 0-255 for Landsat data, that is related to the amount of radiance in watts per square centimeter striking a detector on either the multi-spectral scanner or Thematic Mapper or as recorded subsequent to some transformation of the data set.

Butter — The function of adding or replacing existing data in a digital image.

Canopy — The cover of branches and foliage formed by tree or shrub crowns.

Classification — The process of describing categories from mapped or sampled objects.

Coefficient of variation — The ration of the standard deviation to the mean.

Continuous tone — An image in positive or negative form which has not been broken into discrete dots by screening or dot generation and contains unbroken gradient tones from black to white.

Contrast stretch — A digital transformation technique which increases local contrast of digital imagery. Input digital values are assigned new output brightness values by a transformation function which changes their digital range, mean, and standard deviation values.

Control point — A feature of know location, recognizable on the imagery, used to determine geometric correction to these images.

Cromalin color proof — A DuPont pre-press color proofing system that uses colored powdered tones that adheres to an image area. A separate film layer is used for each toner.

APPENDIX 1 - GLOSSARY

Cronapaque — A white, semi-opaque photographic film used for making prints that can be viewed by either reflected or transmitted light. This film has a high-speed, variable-contrast emulsion on a DuPont polyester film base.

Crown width — The average span of the crown of a tree or shrub.

Cubic convolution — A high-order resampling technique in which the brightness value of a pixel in a corrected image is interpolated from the brightness values contained in a 4-by-4 pixel window centered on the corrected pixel.

Dampening solution — A solution of alcohol, water, and etchant for wetting the lithographic press plate.

Delineators — Attributes used to locate or define an inventory unit or polygon boundary on a map on imagery.

Densitometer — A sensitive photoelectric instrument which measures image intensity. A transmission densitometer measures the density range of transparent negatives or positives. A reflection densitometer measures the reflectivity range of opaque copy, and is used in color printing to determine whether color is consistent throughout the run.

Density, image — A measure of the degree of blackening of an exposed film, plate, or paper after development, or of the intensity of the direct image. It is the logarithm of the optical opacity, where the opacity is the ratio of the incident to the transmitted (or reflected) light.

Diameter at root collar (drc) — The straight line passing through the center of a cross section of a bole measured at the root collar of a shrub or tree.

Diameter breast height (dbh) — The cross sectional diameter of a tree measured 1.3 m above mean ground level.

Diameter tape — A specially graduated tape by which the diameter may be read directly when the tape is placed around the tree stem.

Distribution — The relative frequency with which different values of a variable occur.

Dodging — The process of shielding a portion of the surface being photographically exposed from the light source during part of the exposure time.

Edge enhancement — A type of digital filter commonly applied to digital imagery to enhance the high frequency components of the imagery. Typically the high frequency components are edges.

Established seedling — Immature woody plants which are expected to survive and continue to grow over the next several years.

Estimate — The particular value yielded by an estimator in a given set of circumstances.

Estimator — The rule or method of estimating a constant of a parent population.

Forage — All browse and herbage that is available and acceptable to grazing animals.

Forage production — Annual production of herbage, shrubs, woody vines, and trees which may provide food for grazing animals or harvested for feeding.

Forage utilization — That proportion of current year's forage production that is consumed or destroyed by grazing animals.

Ground control points — Control points, established by ground surveys, used to fix the altitude and/or positions of one or more images for mapping purposes.

Gummiug — Protecting the printing plate with a cum solution to prevent oxidation in the non-image area between the time the plate is made and when it is used for printing.

APPENDIX 1 - GLOSSARY

Halftone — Any photomechanical printing surface and impression therefrom in which detail and tone values are represented by a series of evenly spaced dotes of varying size and shape. The dot areas vary in direct proportion to the intensity of the tones they represent.

Histogram — A graphic representation of frequency distribution. For Landsat image data, the histograms indicate pixel brightness values along the x-axis and the corresponding number of pixels occurring at each brightness value along the y-axis.

Image base map — A map using digital imagery as a background displaying basic planimetric information (drainage and cultural features) and which is used as a base for subsequent maps, overlays and studies.

Integrated inventory — An inventory or group of inventories designed to meet multi-location, multi-decision level, multiresource, or monitoring needs.

Inventory — To account quantitatively for goods on hand or provide a descriptive list of articles giving, at a minimum, the quantity or quality of each.

Inventory (survey) unit — The land unit containing the population for which information will be summarized and analyzed.

Land cover — That which overlays or currently covers the ground, especially vegetation, water bodies, or structures. Barren land is also considered a "land cover" although technically it is lack of cover. The term land cover can be thought of as applying to the setting in which action (one or more different land uses) takes place.

Land use — The predominant purpose for which an area is employed.

Landsat imagery — Images of the Earth's surface prepared from data sensed and transmitted to earth receiving stations by the Landsat satellite.

Laser beam recorder — A film recording device that produces a photographic image on 9.5 inch film rolls from a digital data source. The recorder assigns density levels to each of the 0 to 127 brightness values according to a look-up table and outputs the resulting data through a laser scanner.

Litho tape — A red, opaque adhesive film used to attach film and/or to mask film during photographic exposures.

Look-up table, film density — A table which specifies the actual output film density for each of the 128 integer brightness values from the digital data input. Sometimes referred to as a control curve.

Magenta contact screen — A photographically-made halftone screen on a film base, having magenta dots, each grading in density from light to dark. Continuous-tone images exposed through the screen produce halftones.

Mapping — The identification of selected features, the determination of their boundaries or locations, and the delineation of those boundaries or locations on a suitable base using predefined criteria.

Mean — The arithmetic average of a group of values.

Method of least squares — A technique of fitting a regression equation to observed data. The least squares criterion requires that a curve be chosen to fit observed data so that the sum of the squares of the differences of measured values from curve values will be minimal.

Monitoring — The process of observing and measuring over time to detect changes or to predict trends.

Mosaic — An assembly of overlapping images that have been marginally cut or torn and then fitted together to form a continuous representation of a portion of the Earth's surface.

APPENDIX 1 - GLOSSARY

MSS (multi-spectral scanner) — As used in the Landsat program, a scanner system that uses an oscillating mirror and an array of six fiber-optic detectors in each of four spectral bands from 0.5 to 1.1 um. The mirror sweeps from side to side in 185-km swaths, transmitting incoming energy to the detector array, which sequentially outputs brightness values (signal strengths) for successive pixels. Image resolution is approximately 80 meters (ground dimension of a pixel).

Normal distribution — That distribution of frequencies found within a population when sampled for a particular parameter, i.e. volume.

Offset lithography — A method of printing that transfers an ink image from the pressplate to the surface of an intermediate rubber blanket, then from the rubber blanket to the paper or other printing stock.

Overprinting — Double printing; printing over an area that has already been printed.

Packing — The paper and stable-based coated material used to underlay both the pressplate and the blanket to bring their surfaces to the desired height above the cylinder surfaces; the method of adjusting squeeze pressure between plate and blanket.

Parameter — A characteristic of a population.

Permanent plot — A sampling unit established and documented so as to permit repeated measurements of the same variables at the same exact places but at different times.

Pixel — Contraction for picture element. A spatial data element having spectral aspects. The spatial variable defines the apparent size of the resolution cell (i.e., the area on the ground represented by the data values) and the spectral variable defines the intensity of the spectral response for that cell in a particular sensor channel.

Planimetric map — A map showing correct horizontal positions of features represented.

Plot configuration — The size and shape of the sampling unit (plot) and the spatial arrangement of any subsequent subplots.

Population — An aggregate or collection of unit values.

Post-stratification — A process by which sample units are assigned to a specific stratum after the plots have been established in the field.

Pressplate — A thin, metal plastic, or paper sheet that carries the printing image.

Pre-stratification — A process by which sample units are assigned to a specific stratum before samples are drawn.

Precision — The variability of a series of sample estimates. The precision of a sampling exercise is usually expressed as the sampling error in percent.

Register punch — A device that punches holes in film, color proofing material, or pressplates along one or more sides of the sheet. Precision-made pins are placed in the holes to perfectly register the appropriate materials.

Regression analysis — An analysis which indicates how one variable is related to another by providing an equation that allows the sue of the known value of one or more variables to estimate the unknown value of the remaining variables.

Resolution — The ability of an imaging system to distinguish closely spaced objects in the subject area. Expressed as the spacing measured on the image in line-pairs per unit distance, of the most closely spaced lines that can be distinguished. The term is also used to coincide with the dimension of a square pixel.

APPENDIX 1 - GLOSSARY

Resource inventory — The collection of data for description and analysis of the status, quantity, quality, or productivity of a resource. Such inventories usually include descriptive data, numeric data and at times, maps showing the extend to the inventory unit, the resources, and location of sample units.

Return beam vidicon (RBV) — A camera system on Landsats 1 and 2, and employing three independent cameras operated simultaneously, each sensing a different spectral band in the range of 0.48 to 0.83 um with a resolution of about 70 m. The RBV system on Landsat 3 contained two identical cameras which operated in the spectral band from 0.50 to 0.75 um with a resolution of about 30 m. The cameras were aligned to view adjacent nominal 99- by 99-km ground scenes with 15-km side-lap yielding 183- by 99-km scene pairs. Tow successive scene pairs nominally cover one MSS scene.

Right-reading — A descriptive term for a photographic reproduction, which, when viewed through the base, appears the same as the original exposure.

Sample — A sub-set of one or more of the sample units into which the population is divided that is selected to represent the population and examined to obtain estimates of population characteristics.

Sample plot — A sampling unit or element of know area and shape such as a 0.2 ha rectangular plot.

Sample unit — One of the specified parts into which the population has been divided for sampling purposes. Each sample unit commonly consists of only one sample element which may be a sample plot, tree, or shrub.

Sample size — The number of sampling units that are to be included in the sample.

Sampling — The selection of sample units from a population and the measurements and/or recording of information contained therein, to obtain estimates of population characteristics.

Sampling (inventory) design — The specification of a configuration of sampling units and the method used to determine which sampling units will be measured.

Sampling error — That part of the difference between a population value and an estimate thereof, derived from a random sample.

Sampling frame — See also population. The complete aggregate or list of sampling units from which the samples will be drawn.

Sampling intensity — The number of sampling units established per unit area.

Scale — The relationship between a distance on a map or image and the corresponding distance on the ground.

Scanner/Plotter — A graphic arts scanner/plotter used for color separation by electronically recording the original image for manipulating and plotting each halftone film separation at publication scale.

Stand table — A summary table showing the number of trees pere unit area by species and diameter class.

Standard deviation — A measure of the dispersion of population represented by the value range from the mean within which 68 percent of the units sampled will fall.

Standard error — The positive square root of the variance of the sampling distribution of a statistic.

Statistically valid design — A design that permits inferences based on logical analysis, the premises, and the data to a well defined population.

Stock table — A summary table showing the volume of trees and/or shrubs per unit area by species and diameter class.

APPENDIX 1 - GLOSSARY

Stouffer scale — A density scale on paper or film, with gradient tones from black to white, placed on the original copy during photographic reproduction to measure the tonal ranges obtained; also used on color separation negatives for determining color balance or uniformity of the separation films.

Stratification — The division of an inventory unit into more homogeneous sub-units to improve the efficiency of the inventory.

Stratum — Any division of the population for which a separate estimate is desired.

Systematic sample — A sample obtained by making observation at equally spaced intervals, such as taking a sample every 7 kilometers.

Tack — The resistance to splitting of an ink film between two separating surfaces, i.e., stickiness.

Tally — A record of the number of units counted or measured.

Tiepoint — An identifiable point with specific geometric coordinates located in an overlap area between two adjacent scenes used for geometric or radiometric alignment or an identification point recognizable on the ground and on covering imagery to which survey lines or sample plots are referenced.

TM (Thematic Mapper) — A 7-band mechanical scanner orbited on Landsats 4 and 5. The TM uses an oscillating mirror and seven arrays of detectors which sense electromagnetic radiation in spectral bands ranging from 0.45 to 2.35 um at a ground resolution of 30 m.

Tone — Each distinguishable shade variation from black to white in an image.

Tone reproduction — Retaining the original image tones throughout all the intermediate steps to the final reproduction.

Transmittance — The ability of a substance to transmit energy, expressed as the ratio of the energy transmitted through a body to that incident upon it.

Trapping — The ability of an already printed ink film to accept an overprinted ink film to yield a print of satisfactory optical density and uniform coverage.

Tree length (height) — The total span of a tree from ground level along bole to tip of tree.

Trend — The direction of change in ecological status observed over time.

Universal Transverse Mercator (UTM) — A widely used map projection employing a series of identical zones, each covering 6 degrees of longitude and oriented to a specific central meridian. The UTM projection is characterized by its property of conformity, the preservation of constant scale along lines approximately parallel to the central meridian, and a maximum scale distortion of 1 part to 1,000. The UTM is one of the projection options offered by NASA for Landsat data and is the most common projection used for Landsat image maps.

Update — A method used to make current inventory estimates by manipulation of the data base through accounting procedures, projection models, or by adjustment of a base by subsampled data.

Variable — A characteristic that may vary from unit to unit, i.e. tree height, diameter, etc.

Variance — The measure of dispersion of individual unit values about their mean.

Variation — A measure of the dispersion of individual values around their computed mean value. For any series of measurements, the dispersion of individual values around the mean is more or less uniform as shown by the normal bell curve.

APPENDIX 1 - GLOSSARY

Vegetation cover map — A map or overlay prepared to show the location and general vegetation composition of the various strata composing an inventory unit.

Vegetation density — The number of individual plants of a given species or type in a unit of area.

Vegetation height — The vertical distance from ground level to the top of an individual plant or canopy.

Volume equation — A statistically derived expression of the relation between volume and other tree or shrub variables.

Volume table — A table showing the estimated average tree volume corrcsponding to selected values of other variables.

Wejex printer — A control-strip printer with standard continuoustone density steps in 0.5 or 0.15 increments. Film is exposed by the Wejex before processing. The density step is read with a densitometer to evaluate chemical replenishment and processing variables made by changing the temperature and/or time of development.

Wrong-reading — A image which is reversed or a mirror image of the original.

APPENDIX 2 - FIELD FORMS

KASGAIL RURAL COUNCIL VEGETATION INVENTORY

PLOT NUMBER
PHOTO STRATUM
LAND COVER
LAND USE

LAND CONDITION
FOREST TYPE
TREE DENSITY
SOIL TYPE

PLOT WEIGHT
CREW
DATE

TREE NO.	SPECIES NAME	SPECIES CODE	DRC (CM)	DBH (CM)	BOLE HT. (m)	TOTAL HT. (m)	CD (m)	% CULL

REGENERATION PLOT (1m x 10m) < 5 cm

DIST	A/P	SPECIES	DIST	A/P	SPECIES	DIST	A/P	SPECIES	DIST	A/P	SPECIES	DIST	A/P	SPECIES

REMARKS:

WOODLAND TREE SEGMENTATION RECORD

Location No ______ Date ______ Crew ______

Pt No ______ Tree No ______ Species ______ DRC ______

Total Ht ______ Estimator ______

Record Multiple Stems DRC Below CD ___

0.5 - Meter Length Class		2	4	6	8	10	12	14	16					T
		CM 2 - Segment Midpoint Diameter Class												
SUMMARY	1													
	2													
	3													
	4													
	5													
	6													
TOTAL														

		2	4	6	8	10	12	14	16					T
DOT COUNT	1													
	2													
	3													
	4													
	5													
	6													

Pt No ______ Tree No ______ Species ______ DRC ______ No Stems ______

Total Ht ______ Estimator ______

Record Multiple Stems-DRC Below CD ___

0.5 - Meter Length Class		2	4	6	8	10	12	14	16					T
		CM 2 - Segment Midpoint Diameter Class												
SUMMARY	1													
	2													
	3													
	4													
	5													
	6													
TOTAL														

		2	4	6	8	10	12	14	16					T
DOT COUNT	1													
	2													
	3													
	4													
	5													
	6													

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