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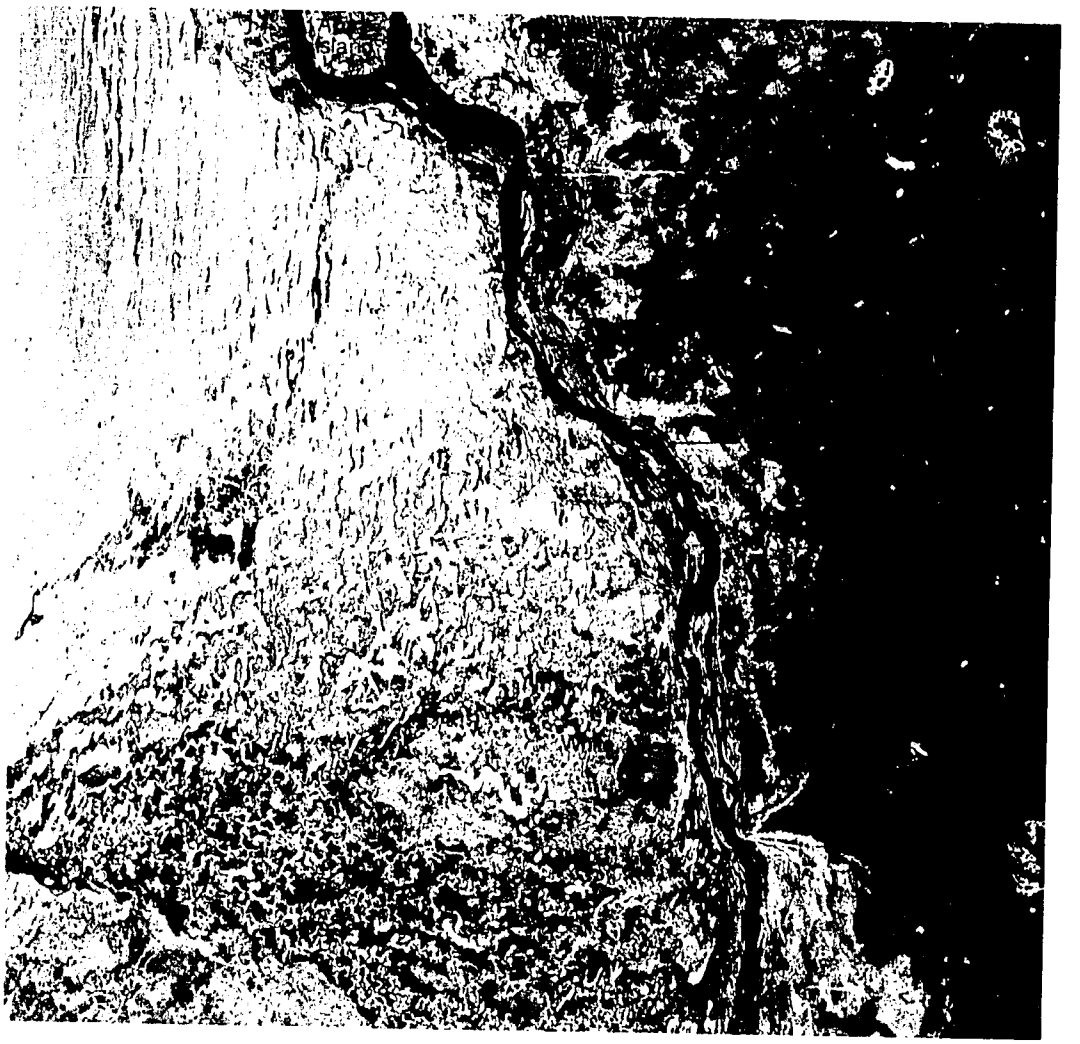
Remote Sensing Project

Final Report



Prepared for the Ministry of Agriculture and Natural Resources, Khartoum, Sudan by the Regional Centre for Services in Surveying Mapping and Remote Sensing under a contract with the United States Agency for International Development

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UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT

Sudan Emergency and Recovery Information and Surveillance System (SERISS)

Remote Sensing Project

Final Report

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Prepared for the

Ministry of Agriculture
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by the

Regional Center for Services
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Nairobi, Kenya

DEVELOPMENT

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This scene from a Landsat satellite shows the junction of the Blue Nile (East) and White Nile (West) at Khartoum. The area between the two rivers, south of Khartoum, is the Gezira irrigation scheme.

EXECUTIVE SUMMARY

The USAID contract with the Regional Centre for Services in Surveying Mapping and Remote Sensing (RCSSMRS) for technical services in the implementation of the SERISS Remote Sensing Project was signed June 26, 1986. The project goals and objectives were to implement and institutionalize improved crop estimating methods in Sudan by the appropriate use of data from the Landsat satellites. In the subsequent nine month period, project activity was intense. An area sampling frame (ASF) was constructed. Sample selection and ground survey were carried out by the Ministry of Agriculture (MOA) and National Remote Sensing Center (NRSC) staff, and the results analysed by the statisticians of the Ministry of Agriculture.

The results obtained from the Area Sampling Frame (ASF) activities contributed to the crop assessment and crop yield forecasting activity of the MOA for the season. Although the first use of these techniques in crop survey was subject to some delays, the system now in place has strengthened the survey capability of the Ministry of Agriculture and increased the objectivity of the estimates.

This report describes the project, "SERISS Remote Sensing," gives the methodology of the survey and documents the transfer of area sampling frame technology.

Survey results are found in Chapter VI., resource requirements are in Chapter VII. and specific conclusions and recommendations for future work in Chapter X.

Overall, the nine month activity period July 1986 – March 1987 was very successful. The area sampling frame was established in an exceptionally short time under the direction of the statistical consultant. The majority of the ASF construction, sample selection, and survey data collection were undertaken by the staff of the Ministry of Agriculture. Staff of the Statistics Department (MOA/SD) with assistance from the Sudan Soil Survey scientists and the staff of the National Remote Sensing Centre prepared the image interpretations required for the stratification of the agricultural region. Aerial surveys were carried out by the Sudan Survey Department, and through the steering committee the project maintained links with other Sudanese institutions.

The stratified area sampling frame in Eastern Sudan is of good quality, in Western Sudan some refinement is necessary. The overall survey results have an objective and technically sound probability sample design which provides a reliable basis for provincial and national level estimates of major agricultural crops. The survey procedures need to be modified next year to improve the timeliness of crop estimates. Recommendations to make the survey more timely include expanding the field staff and resources and improving the survey organization.

In addition to the crop survey activity the project was responsible for technical assistance to the National Remote Sensing Center in Khartoum. In collaboration with USAID Khartoum the RCSSMRS defined commodities required to establish and equip a color photographic laboratory to process copies of satellite images up to 1 meter by 1 meter in size. Construction of the laboratory was completed with the advice of RCSSMRS. Presently much of the equipment is installed and working. The laboratory itself awaits the delivery of the necessary photo chemicals which have to be brought in by surface.

Eight 4-wheel drive double cab Toyota pick-up trucks were procured for use by the enumerators in the field. Three computer systems which provide satellite image processing and GIS development were procured by USAID/Khartoum. The vehicles have been in active use throughout the survey activity. The computer systems have been delivered and are installed and operating in the NRSC, the MOA and RCSSMRS in Nairobi.

The MOA system is functioning well and producing maps of survey results using Atlas and Statgraph software. The capacity to operate a geographic information system (GIS) using TERRAPAK software will be brought into full operation as staff time becomes available after the completion of all survey activities and data reporting. The system in Nairobi is operating and requires input from the various levels of activity. Once the survey work is completed for the 1986/87 growing season, it will be possible to begin digitizing the base maps for the region. This is a considerable task which will require support from both Nairobi and Khartoum. Some work on this has been done by Price, Williams and Associates working on the FEWS program in Washington DC. The first season survey results which incorporate the use of the ASF technique are presented in ANNEX A, CROP PRODUCTION ESTIMATES 1986/1987.

Recommendations are that the area sampling frame be refined, especially for areas of traditional agriculture. That support be given to the Ministry by providing a training program for statisticians, computer operators and survey management, both in-country and overseas. And that multiple use of the sample frame should be considered especially in relation to other natural resources such as forestry, rangeland and hydrology.

The headquarters of the Regional Centre for Services in Surveying, Mapping and Remote Sensing, Nairobi, Kenya.

I. INTRODUCTION

In 1980 an Agricultural Planning and Statistics (APS) Project was established by the Government of Sudan in the Ministry of Agriculture. The project, supported by USAID funds, was designed to strengthen the Ministry's planning and policy analysis unit. As part of that project, statistics were to be improved to support better decision-making. In 1981, APS upgraded the Ministry's computer facilities and in 1985, APS began implementing surveys utilizing a village list frame. At that time Sudan had gone through one of the most severe droughts in its recent history and USAID alone was importing 500 million dollars worth of food aid.

The agricultural information system could not provide the data flow required to support such an intensive food aid effort. In order to meet these information needs USAID/Washington funded a satellite based crop estimation survey for Sudan. This project was the first to utilize satellite data for the purpose of estimating the Sudanese food crop. The results were produced in a remarkably short time. The following year, the Government of Sudan agreed with USAID/Khartoum to continue the effort with Sudanese institutions operating the whole activity.

To assist with this work the Regional Centre for Services in Surveying, Mapping and Remote Sensing (RCSSMRS), in Nairobi, Kenya was given a contract by USAID to acquire statellite images, provide technical assistance with the use of these images in crop estimation work, obtain aerial photography, conduct a crop estimation survey, and analyse the data. The RCSSMRS was selected because Sudan is a member of this African regional organisation which exists to cater to the needs of member states in these technical matters. Contract implementation required the procurement of vehicles for field survey work and computers capable of operating a geographic information system (GIS). All technical activities were to be institutionalized in Khartoum with backup from Nairobi and consultancies as necessary.

The contract provided for equipping the National Remote Sensing Centre (NRSC) in Khartoum with those items required for the production of large formal colour photographic prints of satellite data. It also required the installation of computer systems in both NRSC and the Ministry of Agriculture, Statistics Division (MOA/SD). These systems are capable of accepting and delivering data in map form, and of processing satellite images in their original digital form. Because the project design was based on joint collaboration between USAID, MOA, NRSC, and RCSSMRS, the responsibilities of each were defined as follows:

MINISTRY OF AGRICULTURE, PLANNING AND ECONOMICS ADMINISTRATION (PAEA)

- Heading the steering committee.
- Heading the technical committee.
- Controlling the finances.
- Appointing a co-ordinator.
- Providing for the field and office work of their technical staff involved in data collection and analysis. The technical staff included:-
  - Enumerators
  - Supervisors
  - Remote sensing specialists and photo interpreters.
  - Statisticians.
  - Other technical and administrative staff.
  - Logistics and support staff.
- Providing for:
  - Approval of work plan.
  - Supervision of Consultant work.
  - Release of regular reports.

NATIONAL COUNCIL FOR RESEARCH (NATIONAL REMOTE SENSING CENTER)

- Providing space for project staff and new equipment.
- Providing access to existing equipment and materials for the purpose of the project.
- Supplying available staff to the project.
- Recruiting the photo-scientist.
- Recruiting the computer specialist and computer technician.
- Recruiting young graduates to be trained for the continuation of the project.

USAID/SUDAN

- Supervising and monitoring the project.
- Participating in the Steering Committee.
- Funding the project.
- Ordering of foreign equipment.
- Liaising with Consultants.
- Administering the contract.

RCSSMRS/NAIROBI

- Providing a permanent project adviser.
- Providing consultants as required.
- Supporting training needs in Khartoum.
- Providing the Nairobi Centre facilities for use of the project.
- Conducting training courses in Nairobi.
- Preparing all technical specifications for equipment to be procured abroad and assisting in its installation and the training of staff in its use. Preparing technical specifications for contracts and signing them.
- Procuring satellite data and processing services.
- Establishing a data bank for the GIS.
- Specifying training needs, local and foreign, of all staff and designing a training programme.
- Constructing a sampling design and reviewing and revising the survey questionnaire.
- Undertaking data processing and analysis including modelling.
- Procuring NOAA Satellite data and analysis services.
- Obtaining the necessary aerial photographs including new survey flights as required.
- Exchanging data with Khartoum.
- Making recommendations to strengthen the capabilities of NRSC.
- Preparing and signing local and foreign subcontracts.
- Procuring local equipment and materials.

The necessary aerial survey work was undertaken by the Sudan Survey Department in close collaboration with the RCSSMRS. All field staff were provided by the MOA which dealt with the data collection phase. The computer expertise was provided by the staff of the Statistics Department of the MOA assisted by a short-term consultant from the U.S. Department of Agriculture. Support and training for photo-interpreters in the use of statellite data was provided by RCSSMRS in Nairobi and Khartoum. Instructors included Sudanese government staff who had previously attended similar courses in Nairobi.

RCSSMRS assisted the National Remote Sensing Center (NRSC) with the completion of their remote sensing laboratories and the installation of a fully equipped photographic darkroom. Computer systems were purchased by USAID through their procurement system and installed in the laboratories of the National Remote Sensing Centre and the computer centre of the MOA/SD. Familiarization with the computer systems and some basic training in the use of the software packages and provided by the supplier in consultation with RCSSMRS. All the above was coordinated through a steering committee chaired by Dr. Abdel Monheim el Sheikh. The committee was composed of representatives from:

- The Ministry of Agriculture and its different divisions, including forestry, rangeland, and animal resources,
- The donor agency, USAID,
- The implementing agencies, RCSSMRS, NRSC and the Sudan Survey Department,
- Other concerned agencies including the Institute for Environmental Studies (IES) and the National Council for Research.

The day to day activity was handled by a small technical committee from the Statistics Department of the MOA.

These activities were required for the development of an integrated system for food grain and crop yield estimates for the major food producing area of central Sudan. The project area includes Darfur, Kordofan, Central and Eastern regions of the country. The project area includes irrigated projects, large mechanized farming schemes and traditional agriculture. Given the equipment and manpower described above the steps necessary to estimate food grain production can be summarized as follows:

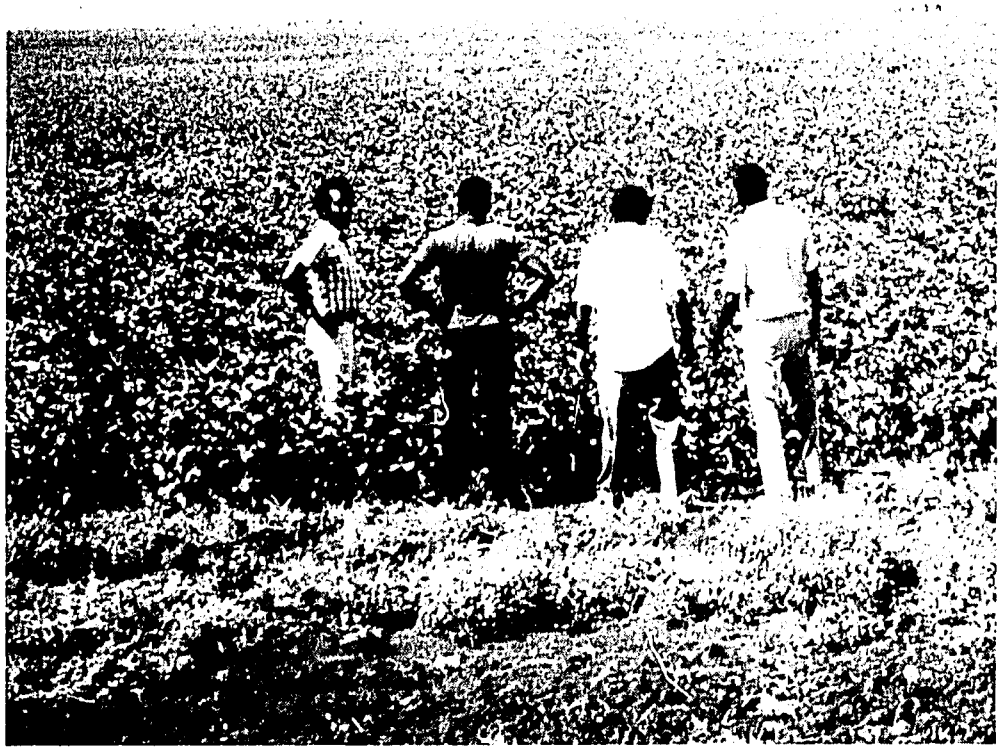
- The preparation of an area sampling frame using satellite data and aerial photographs as necessary.
- The selection of an appropriate sample.
- Data collection by enumerators visiting each sample area selected to gather data by questionnaire and inspection.
- Data editing and the use of computer systems for data summary and analysis.
- The Calculation of crop yield forecasts and harvest estimates for food grains.

In order to implement the above program of activities, adequate field transport is required for the enumerators. Suitable computer systems with the appropriate software have to be available in Khartoum and Nairobi. Staff training on these systems has to be done as necessary. The NRSC in Khartoum has to be able to process satellite data both by computer and in photographic form. In the first nine months of the project, many of these requirements were fulfilled. However, not all tasks were completed on schedule or exactly as planned.

The greatest achievements was the overall success in the institutionalization of the area sampling frame (ASF). The project experienced delays because a late rainy season made the original schedule unworkable. Other delays in photo acquisition, for example, were overcome by using the photolab facilities at the RCSSMRS in Nairobi. The late start of the project and late delivery of aerial

photographs caused difficulties. Problems in the field were unavailability of vehicles and gasoline, and late paymont of field allowances.

The main objective, the implementation of a sound methodology for food crop estimation has been achieved. A future requirement is to improve the data collection and management framework to ensure that full use is made of the hardware and software installed. The staff of the MOA/SD require support and time to gain experience in the operation of all components of the system. The results presented here represent the output of a project which began late in the season and which had to put new equipment into place and use it while data gathering activities were in progress. The properly phased introduction of the area sampling frame technique into the crop estimating procedure of the Sudan Government will do much to improve the confidence of users of the data.



A team of scientists viewing a field of cotton in the Gezira scheme.

II. OBJECTIVES

The stated objectives of this project were to assist the Ministry of Agriculture in implementing an area sampling frame approach for their crop survey work by using remote sensing techniques and to strengthen the National Remote Sensing Centre so that it could support this work. In order to achieve these objectives the following specific objectives were defined:

A. ESTABLISH CROP AREA AND PRODUCTION FOR 1986/87 FOR MAJOR FOOD CROPS USING REMOTE SENSING TECHNIQUES.

This specific objective required the establishment of an ASF in the central agricultural area in Sudan between 12 and 16 degrees north latitude from the eastern border to the western border of the country. This was to be accomplished by obtaining statellite images, aerial photography and ground survey information. Interpretation of the statellite data was to be done by scientists of the Ministry of Agriculture and the National Remote Sensing Centre and selection of the survey sample was to be by the Statistics Division of the Ministry of Agriculture. Ground survey teams were to include an airphotospecialist responsible for relating areas on the ground to areas of the photos and satellite images.

B. INSTITUTION BUILDING

The main component in this item was to support the National Remote Sensing Center (NRSC) and the MOA/SD in building their remote sensing and agricultural statistics capabilities.

C. TRAINING

Personnel were to be trained from the MOA and the NRSC in both remote sensing and agricultural statistics as applied to crop forecasting, crop yield modelling and geographic information systems (GIS). Training was to be conducted in Sudan, Nairobi and the US as required.

D. GEOGRAPHIC INFORMATION SYSTEMS (GIS)

A GIS was to be established for Sudan. Information from different data bases was to be entered into the GIS computer system provided by the project. The layers of information were to be developed from the project or obtained from other sources. Some of the information layers were to include soils, rainfall, agricultural production, and health data. The computer hardware and software were to be capable of sophisticated information manipulation.

A crop of sorghum grown with irrigation.

III. BACKGROUND

This report presents the results of the first area sampling frame (ASF) agricultural survey of the project entitled "The Sudan Emergency and Recovery Information and Surveillance System" (SERISS). SERISS has two project objectives, (1) collecting and publishing nutritional information about infants and mothers and (2) developing methods to improve agricultural statistics in Sudan using remote sensing techniques. Since there may be confusion about the two different objectives of the SERISS project, the second part is referred to as the SERISS, remote sensing project. It is the latter which is described here.

One of the more important requirements of a nation is to have adequate food to feed the people. Food supplies depend on weather, agricultural inputs and prices. Grain stocks that are produced can be stored, exported (legally or illegally) or consumed. Agriculture and food policy help the country's planners to manipulate the options so that adequate food supplies are available to people at reasonable costs. At the same time the planners must help the farmers obtain reasonable returns for their labor and other inputs. The main objective of this project is to institutionalize improved methods of crop estimation so that planners and policy makers are better able to perform their tasks.

Crop estimation is done in a variety of ways around the world. Each approach represents a balance between cost, speed, accuracy and objectivity. The optimum balance in a given situation must also take account of available resources, including manpower, and must fit established policies. In Sudan the fluctuations in crop production have a major impact on the national economy because it is primarily an agricultural economy. Food production in most years is adequate to meet the country's needs. However, the climatic regime includes periods of drought, and food production in these periods is inadequate. To avoid famine timely warnings of inadequate food production are essential.

An effective method of monitoring crops over large areas is to use the data from earth resources satellites. When in photographic form the data from Landsat are virtually picture maps, each of 185 × 185km extent. Using these images to guide the selection of a sample of the agricultural areas for statistical survey purposes is most efficient. The actual sample selection must be done without bias. For sampling in agricultural regions the use of an area sampling frame has many advantages and this is the procedure adopted.

The area sampling frame method was first developed at Iowa State University in 1938. In 1956, the U.S. completed the ASF for the entire continental land area and in 1977 the National Research Council (part of the U.S. National Academy of Sciences) was requested by President Carter to study all aspects of food and nutrition. One of the main recommendations of that study was that better information should be gathered at National and Provincial Levels and that an ASF was the best agricultural statistics methodology to use. This has ben introduced into Sudan in the Ministry of Agriculture during this project and has been operated by the Ministry's own staff with only a small advisory role played by consultants. There are documents that describe the construction of the ASF in Sudan and a paper on this topic was presented by MOA staff at the Twentieth International Symposium on Remote Sensing of the Environment in Nairobi, Kenya, December 4 – 10 1986.

Sesame being harvested in the Gezira scheme.

IV. INFORMATION CRITERIA

To support decision-making by planners, an information system must have certain characteristics. The criteria used to evaluate an information system are listed below and the description of how the SERISS remote sensing relates to these criteria follows.

Institutionalization

The ASF methods implemented by MOA between July 1986 and Feb 1987 are almost completely institutionalized. The MOA staff built the ASF, selected the sample, collected the data in the field, edited, and entered data into the computer and summarized the data by provinces. These activities were accomplished with some technical support from consultants made available under the SERISS contract with RCSSMRS or under the USDA PASA. MOA staff have indicated that a continuation of this technical support would be desirable for the coming season. It should be noted that the technical assistance supplied included short term consultancies by the area sampling frame expert, a computer expert (supplied by the USDA/PASA) and remote sesnsing staff from RCSSMRS, Nairobi, Kenya. The staff of the MOA have operated all the individual phases of the work including the stratification, sample selection, data collection, compilation and publication. A total of 60 enumerators with photo interpreters, drivers and management staff have participated in this work.

Accuracy

The 1986/87 survey results meet the 10% goals at the national levels for the estimates of major crops but not all the individual provincial level estimates meet this goal. To bring the provincial level estimates to this level requires improved stratification and increased sample size which will increase the cost of the survey and require the allocation of additional manpower and vehicles.

Timeliness

The timeliness factor needs to be clearly discussed by data users and MOA. Most of the time requirements this year were the lead time required to set up the area frame from satellite data, and part was a function of late rains. Time schedules need to be more realistic for the 1987 survey. Data can neither be collected before the fields are planted nor before the rains stop. Once the rains stop, then all available teams should be deployed as fast as possible.

Objectivity

Subjective estimates, no matter how good, do not have the same credibility with users as estimates that are produced by an objective statistical method. Subjective estimates do not follow extreme conditions as well and subjective estimates are easily modified by pressure from special interest groups. In addition, subjective estimates depend on the personnel and when personnel change, so do the estimates. An objective system such as the ASF implemented in 1986 does not have these limitations. The result is, therefore, an objective system for all who require reliable estimates of food crop production.

Comprehensiveness

Comprehensiveness has to do with the number of items estimated: With ASF methods many types of data can be collected. The Statistics Divison needs to communicate with the users and request the users to submit suggestions for increased data. It could not be done this year because survey management were concerned with basic survey operations. In future the questionnaire can be expanded a little.

Cost-effectiveness

The cost of implementing any system of crop statistics is a function of the number of people and the length of time employed in the gathering, analysis and reporting of data. The ASF is recognized as the most efficient method of drawing a sample and gives the most accurate data for a given sample size. Therefore the ASF represents the most cost-effective way of conducting an agricultural statistics survey. (Note, specific costs associated with the use of satellite imagery, GIS and crop yield modeling are themselves additional activities with their own individual cost-effectiveness.)

A survey team including air-photo interpreters, enumerators and statisticians reviewing satellite imagery in the field.

V. TECHNICAL REPORT

A. METHODOLOGY

An ASF is a method used in many countries to estimate crops and livestock. It is based on multistage sampling starting with satellite images and requiring ground based survey methods. The concepts of the area sampling frame are simple although difficult to implement in practice (Houseman 1975). The idea is to use satellite images to divide the area into homogeneous land use categories which can be sampled effectively to get an estimate of total production. Satellite images cover huge areas on the ground making them ideal for global or first level stratification. The resolution is quite coarse, 30 meters, so multilevel and multistage sampling using aerial photography and ground data collection provides the additional detail required for this survey. These steps are summarized below.

1. The first step is to divide the project area into various homogeneous strata within each province such as areas of irrigated, mechanized or traditional agriculture, forest etc. This is done using statellite images.
2. The second step is to subdivide each stratum into a number of parcels of land, first PSUs and then sampling units. Denote the number of sampling units as N where h identifies the stratum.
3. The third step is to select a representative sample of parcels of land for data collection and enote the sample number as n.
4. The fourth step involves collecting the desired data without error from the selected sample.
5. The last step is to multiply the sample data by the correct expansion factors (N/n) to estimate the totals for each of the stratum.

This sampling technique is rigorous. Accuracy depends upon the stratification, sample selection, data collection and computer data entry edit and summary.

Estimation and Variances

The crops in Sudan are estimated by provinces and strata. There were two different sample designs used – in the Irrigated and Mechanized strata, one stage probability proportional to size (PPS) samples were selected.

An estimate for the total when a sample of n is drawn is

$$\hat{Y}_j = \frac{1}{n} \sum_{i=1}^{n} \frac{y_{ij}}{z_i}$$

where $\hat{y}$ is the estimated total

n is the number of PSUs drawn

y_{ij} is the sum of the jth crop in PSU i

z_i is the probability of selecting the jth PSU.

In the traditional sector, a two stage sampling design was employed. Also, it is necessary to estimate variance components for both stages to reallocate the sample. An estimator for the strata total is:

$$\hat{Y}_j = N\,Y_j \qquad \text{where}$$

$$Y_j = \frac{\sum_{i=1}^{m} \sum_{k=1}^{n} y_{jik}}{m\,n}$$

m is the total number of PSUs selected

n is the number of segments slected in each PSU.

The variance for $\hat{y}$ is difficult to write since two stage systematic PPS sampling was employed. A simplified variance formula for both sample designs is:

$$V(\hat{y}z) = \frac{\sum_{i=1}^{n} \frac{y_i}{z_i} - \hat{Y}_z'}{n_i(n-1)}$$

The variance formula above is nearly correct for both estimates. All formula apply within strata and provinces.

Questionnaire data gathered by enumerators.

For this project the questionnaire has been designed by the MOA statisticians and used in the field by the ministry's staff of enumerators. As the project continues the experience accumulated by the ministry will lead to modification of the questionnaire and methods of data collection. These modifications will take advantage of the benefits of area frame sampling in survey design and permit increase in the types of data collected.

The methods used in this survey are a combination of remote sensing data analysis, statistical sampling based on area, known as area sampling frame (ASF), and field survey using enumerators and questionnaires. When completed the questionnaires are edited and checked and the responses entered into computer files for summary and analysis. When summarized the data are expanded using the statistical properties of the area sampling frame. These expansions are the estimates of the crop being analyzed.

However it must be noted that the individual crop production estimates depend upon two variables, the area of each crop planted and the yield of each crop. The product of these two values is the production estimate, and this deceptively simple approach depends upon the availability of acceptable estimates of both area and yield.

The project seeks to estimate the total planted area for each crop as early as practicable in each season. This is done by the enumerator completing a questionnaire about the crop planted in a given area. If the crop has not been planted the intentions of the farmer can be surveyed. These results are subject to changes resulting from failure of rains and the replanting of other crops, or the destruction of the seed in the ground by pests or disease. In such cases a follow up survey is required.

The yield of a given crop is equally difficult to ascertain. Again this project uses a questionnaire approach, and supplements this with crop-cutting. This is done by harvesting an area of the standing crop to determine yield per unit area. It must be noted that in both cases neither the area nor the yield can be verified against any census or verifiable crop production figure. It is therefore of the greatest importance to use techniques which are reliable, can be replicated and are amendable to error determination.

The precision with which an estimate can be calculated and the accuracy of the result are important elemenis in such work and it is of great importance to minimize sampling errors. Non-sampling errors must also be minimized but this requires supervision of the data collection process and editing and checking of the data.

Sampling errors can be controlled by adopting an appropriate sample design. The precision of the estimate can be assessed by measuring the variance of the sample or the Coefficient of Variation (C.V.). Low values indicate more precise estimates. Low values result from samples drawn from populations which are relatively homogeneous, or from a census. A sample large enough to encompass the variability of the population will also give a stable value for the variance or the C.V., however the cost of gathering data from a large sample is often prohibitive.

V. REMOTE SENSING

The satellite data used in this project are being interpreted by direct visual assessment of photographic hard copy products created from the digital data. As the personnel in Khartoum become familiar with the computer systems installed it is anticipated that the computers' image analysis capability will become fully used.

Image analysis by computer is a precise and time consuming activity which is best done by staff with experience of local conditions in the region being studied. Such analysis is also constrained by the scale of the images being used. Satellite data are excellent for the study of large areas, but not for the study of small scale features associated with small-holder farming. For air photos the reverse is true. The systems are therefore complementary and should be used together as appropriate.

In this project the study of a large area was required and within that area the study of small-holder farming was also required. Available maps and records do not provide the necessary information for an adequate definition of the agricultural area in terms of agricultural practices. Satellite images of 1985 obtained by USAID provided a recent overview of the area in sufficient detail (35m resolution) for the definition of the major agricultural strata. By interpreting these recent images in this way a viable stratification was achieved.

VI. SURVEY FINDINGS AND ANALYSIS

The following tables (I.A. to III. E) summarize results obtained from the data collection effort that took place from October 1986 through February 1987. In the initial stages of the survey the interest is in the area being planted in each of the major food crops. Areas of each crop are an important input into the crop production calculation. In order to test the methodology the ASF was applied to the areas where management records provide some basis for checking the estimates from the survey. The tables of values for crops in the irrigated sector illustrate the efficiency of the technique.

A. IRRIGATED AGRICULTURE

Table I.A. Irrigated Sorghum (Dura) Estimates
Stratum I. Irrigated — Scheme Management data vs ASF estimates

Scheme	Prelim. estimates from scheme	ASF estimates 1000 fed	C.V. of estimate	Sample Size
Blue Nile	61	94	24%	6
Gezira	443	410	7%	41
Rahad	72	84	12%	5
White Nile	22	26	32%	15
Gash	34	10	50%	5
New Halfa	73	80	21%	9
Total	705	704*	6%	81

*The estimate of the total differs from the actual target value by 0.15 percent (less than 1 percent).

Table I.B. Irrigated Cotton Estimates
Stratum I. Irrigated Land — Scheme Management vs ASF estimates

Scheme	Prelim. estimates from scheme	ASF estimates 1000 fed	C.V. of estimate	Sample size
Blue Nile	54	84	19%	6
Gezira	415	422	8%	41
Rahad	124	135	4%	5
White Nile	55	50	14%	15
New Halfa	72	57	28%	9
Total	720	748*	5%	76

*The estimate of the total differs from the actual target value by 3.7 percent.

Table I.C. Irrigated Ground Nut Estimates
Stratum I. Irrigated — Scheme Management data vs ASF estimates

Scheme	Prelim. estimates from Scheme	ASF estimates 1000 fed	C.V. of estimate	Sample Size
Gezira	149	151	13%	41
Rahad	58	55	17%	5
New Halfa	25	22	43%	9
Total	232	228*	10%	55

The estimate of the total differs from the actual target value by 2.0 percent.

The agreement between the ASF estimates and the management data is remarkably good. The measure of error expressed by the Coefficient of Variation (CV) shows low values and indicates that the estimates are reliable. Since this is the first time coefficient of variation (CV) has been used, it is explained here in some detail. CV refers to sampling errors only. It is a measure of precision (these terms are defined in the glossary). Each statistic produced has some margin of error associated with it because of the nature of the way it was produced.

CVs indicate the range of possible values a target value can have given the estimator and its associated CV. For example, in Table I.A. estimates of Dura were made for the various irrigation schemes. In the Gezira, the estimate that was generated from the ASF data was 410,000 feddan with an associated CV of 7%. What this suggests is that there is a good chance that the real (target) value being estimated will be somewhere between 7% above 410,000 feddans and 7% below 410,000 (438,700 and 381,300).

Table I.A. shows what can be expected from following proper sampling procedures. It also shows the limitations of probability sampling. In the irrigation schemes, management planners can provide accurate estimates of area planted to each crop. The irrigated fields have been surveyed so that exact areas are known. In addition, all fields can be observed by driving down the roads along the canals.

The first column of numbers were obtained from scheme management personnel in the different schemes. These numbers are considered accurate and true. The second column of numbers were generated from the survey data collected from the samples. In the Blue Nile, the area planted in Dura was 61,000 feddan. The coefficient of variation (CV) is 24%. The estimate is off by 33,000 feddan or 55%. With a sample of 6, the CVs, and practical experience indicate that the errors are large.

In the Gezira, the estimate is off by 33,000 or 7.5% of 443,000 feddan. The CV computed from the sample indicates that a 7% error would be normal when generated with a sample size of 41. Accuracy is a function of sample size and nonsampling errors. The important point in this table is that the errors compensate between strata. For example, in the scheme totals row, the target planted area and the total of the estimates are within 1000 feddan of each other—0.15% or less than one percent. The sampling errors shows a 6% CV with a sample size of 81. This illustrates beatifully what can be obtained with good quality probability sampling. In surveys where nonsampling errors are not controlled increasing the sample size may decrease survey accuracy.

Irrigated cotton illustrates the same phenomenon. Namely, as the schemes are combined and the sample increases, the CV decreases. Again the estimate of total area planted with cotton is 3.7 percent from the target value and the associated CV is 5% with a sample size of 76 PSUs.

Table I.C. shows the same relationships with groundnuts. In total, the estimate is quite close to the target value, but the individual estimates of the schemes show variability. The estimate of the total groundnuts is within 2% of the figure considered the target value. It is based on a sample size of 55 PSUs.

B. MECHANIZED FARMING

Originally, there were two strata identified with mechanized farming, namely mechanized demarcated schemes with clear boundaries and regular shape, and undemarcated schemes which may or may not have clear boundaries and regular shape. The photointerpreters thought that they could differentiate between these two types of land quite easily on the satellite FCC images. It is true that in most cases the separation was correct but in a few cases the land was not not categorized correctly. Therefore the technical staff decided to combine these two strata into a Mechanized stratum. The following table is a result of that decision.

Table II. **Comparison of estimates of sorghum area. Mechanized Farming Schemes.**

Scheme crop	Estimates of Area (000) Feddan				Estimate of Prod (000) M. Ton
	MFC Final	ASF Plant	ASF Harvest	CV ASF Harv.	ASF
Gedarif	1659	924	917	7%	524
Damazin	1132	1312	1312	13%	414
Dilling	234	208	208	27%	40
Total	3025	2444	2437		978

Table III A-E present the estimates in the West. Government estimates in the west are subjective. There are no check data as in the Irrigated sector. Government subjective estimates could be quite different from the survey results especially for the minor items. In South Darfur, the ASF survey results were unfortunately based on only 12 PSUs. This is a very small sample and needs to be enlarged, next year.

The survey results are reasonably close for area planted but the yield estimates from the survey are low. Subjective results from the field indicate there was extensive pest damage caused by rats, birds and grasshoppers.

The most interesting table will be the table III E. Total summarized data for the four provinces. One could expect the survey results to be within 10% for the entire west for the major crops but with the sample sizes that were used, large CVs would be expected. Overall the results for the areas of traditional agriculture show large CVs and the small sample plus the variability strongly suggests that the stratum needs to be represented by a much larger sample. It is possible that the stratum also needs to be refined by re-interpreting the satellite images and the aerial photography. In many cases there is a need for additional aerial surveys.

Table III.A **Comparison of South Darfur Estimates Stratum III. Traditional Agriculture Estimates.**

	Gov. est area	ASF est. plan	ASF est. harv.	C.V. est. harv.	Gov. est. prod.	ASF est. prod.	C.V. prod. est.
	(000's Feddan)				(000's tonnes)		
Millet	860	1073	985	27%	77	70	26%
Sorghum	470	238	191	52%	42	12	49%
Sesame	80	95	87	35%	5	4	44%
Ground Nuts	500	349	342	50%	90	32	49%

Table III.B. **Comparison of North Darfur Estimates Stratum III. Traditional Agricultural Estimates.**

	Gov. est. area	ASF est. plant	ASF est. harv.	C.V. est. harv.	Gov. est. prod.	ASF est. prod.	C.V. est. prod.
	(000's Feddan)				(000's m. tonnes)		
Millet	900	1505	1302	36%	68	68	38%
Sorghum	100	97	64	77%	7	3	76%
Sessame	40	5	0	—	4	0	—
Ground nuts	85	2	0	—	8	0	—

In the areas of traditional agriculture the variability of the results is greatest. This arises because crops are sometimes replanted if rains are late and this may be reflected in Table III.C. where the difference between figures for millet and sorghum could result from replanting or from misunderstanding the planting intentions of the farmers. The estimate of total planted area is similar if the two crops are taken together.

Table III.C. Comparison of South Kordofan Estimates Stratum III. Traditional Agriculture Estimates.

	Gov. est. area	ASF est. plant	ASF est. harv.	C.V. est. harv.	Gov. est. prod.	ASF. est. prod.	C.V. est. prod.
	(000's Feddan)				(000's m. tonnes)		
Millet	90	383	375	54%	11	13	56%
Sorghum	498	167	167	53%	75	15	56%
Sessame	246	45	45	49%	30	2	54%
Ground nuts	83	124	124	80%	21	16	74%

Table III.D. Comparison of North Kordofan Estimates Stratum III. Traditional Agriculture Estimates.

	Gov. est. area	ASF est. plant	ASF est. harv.	C.V. est. harv.	Gov. est. prod.	ASF. est. prod.	C.V. est. prod.
	(000's feddan)				(000's m. tonnes)		
Millet	1635	2701	2344	18%	98	70	19%
Sorghum	175	136	105	53%	13	3	63%
Sesame	690	1844	1656	23%	35	36	27%
Ground nuts	206	651	620	38%	41	67	41%

Table III.E. Comparison of Estimates for the Total Area West of White Nile. Stratum III. Traditional Agriculture Estimates

	Gov. area est.	ASF plant est.	ASF harv. est.	C.V. harv. est.	Gov. est. prod.	ASF est. prod.	C.V. est. prod.
	(000's feddan)				(000's m. tonnes)		
Millet	3485	5662	5006	14%	254	221	16%
Sorghum	1243	638	527	29%	137	33	32%
Sesame	1056	1989	1788	21%	74	42	24%
Ground nuts	874	1126	1086	28%	160	135	29%

In tables III A-D the CVs are large, South Kordofan in particular has CV values of 49% or higher in all cases. While this is a reflection of small sample sizes it also indicates the variability of the data. Throughout Kordofan and Darfur this pattern of high CV values is found and the government estimates differ from the ASF estimates especially for the area of each crop. However the production estimates do not differ so widely in many cases which suggests that the sample survey may be generating new data more indicative of the actual yields and areas planted.

Table III E consolidates all the data for the traditional agriculture west of the White Nile. This gives a better statistical statement of the results, with smaller CVs resulting from the larger sam-

ple size over the area as a whole. The total food production estimated by the government is 626,000 tonnes and the ASF estimate is about 30% less, (431,000 tonnes). Of particular importance is the summary for each crop. Millet production estimates do not differ greatly between the government (254,000 tonnes) and the ASF (221,000 tonnes) but the ASF estimate of the area of millet harvested is some 1.6 million feddans greater than the government estimate. With a CV of 14% it seems that the ASF might give a more accurate figure.

The figures for groundnut production do not differ greatly and the government estimate (160,000 tonnes) is within the margin of error (24%) of the ASF figure (135,000 tonnes). Here the interesting feature is that the ASF estimates a lower total production from a larger area. This is even more striking for sesame where the ASF estimate (42,000 tonnes) is only 56% of the government figure for total production (74,000 tonnes) from an area estimate (1,788,000 feddans) almost double that of the government (1,056,000 feddans). Sorghum estimates show a large difference, the government estimating a total production (137,000 tonnes) four times greater than the ASF (33,000 tonnes) from approximately twice the area.

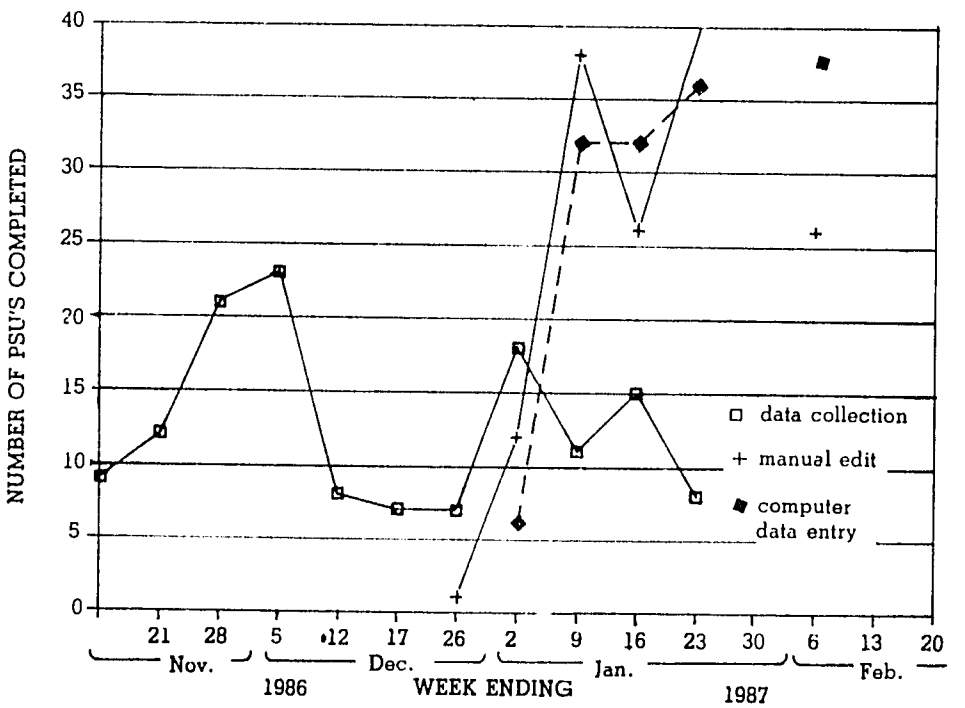
The conclusion from this is that the difficulties of estimating production in the areas of traditional agriculture are more complex than previously known. Clearly the yield estimates for the traditional areas require further study and there is need for a more detailed analysis of the area under agriculture in the west.

In terms of the national food production totals the discrepancies between the government and the ASF estimates in the west are not critical amounting to less than half of one percent of the total food crop. However this area of traditional agriculture is the one most in need of further attention in future crop surveys. The size of sample taken in these provinces must be increased and the stratification needs to be further refined. In this context the Sudan Survey Department needs to be given the priority task of gathering good aerial photographs of Kordofan and Darfur both to assist crop estimation and for national planning, especially for development purposes.

Survey Work Flow

The next chart shows what was accomplished for each week of the survey for three separate activities, data collection data edit and summary. The work is recorded by the number of PSUs completed each week. The first week, 8 PSUs were completed in the field.

Figure 1 PSU counts per week for three activities.

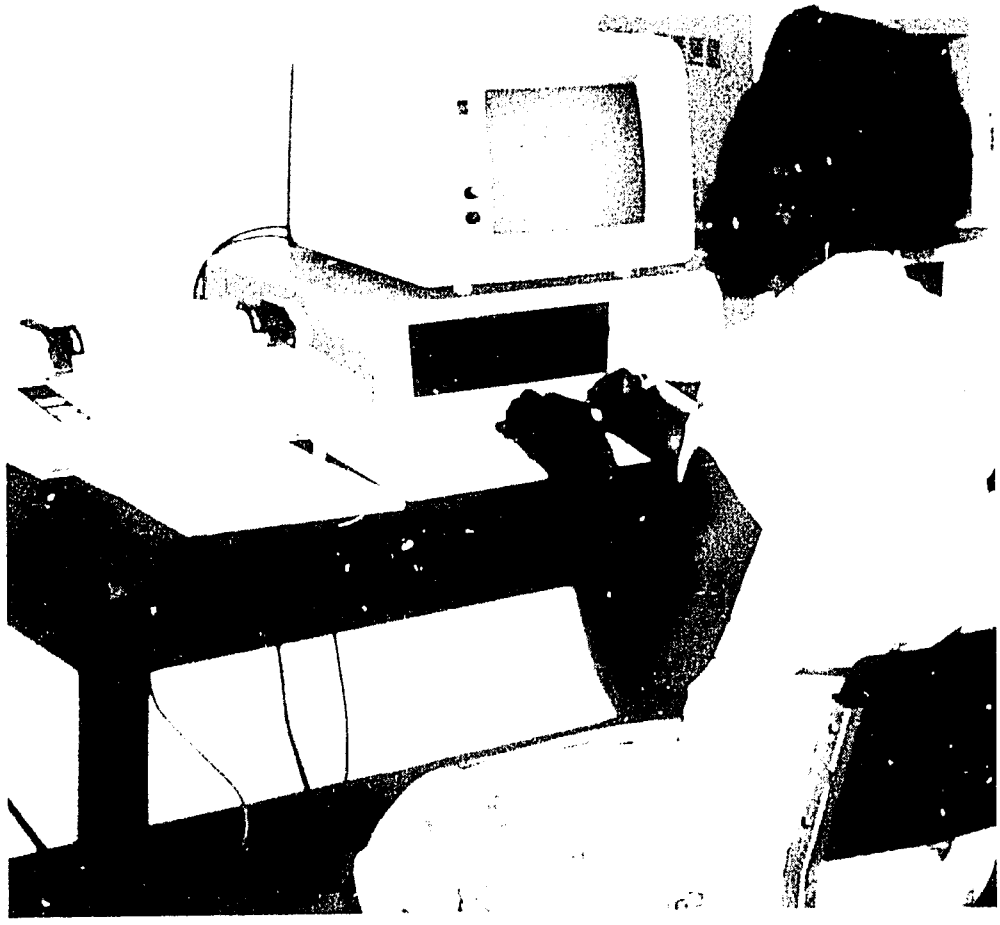


The maximum number of PSUs completed in any week was 23 PSUs in the 4th week of the survey. Obviously there were several teams in the field working – the more teams, the more PSUs that could be completed. In addition, the work was in the east where PSUs are easier to locate and enumerate than in the west. There is a higher concentration of PSUs and therefore less distance to travel between the PSUs in the east.

Survey and data collection were started in the west in late December. Work went slow in this area because the segments were more difficult to locate than in the east. The teams were having trouble obtaining benzine and per diem in time. For instance, one team assigned to South Darfur had twelve PSUs with 24 segments. It took the team 40 days in Darfur to work 19 days in the field. There were two vehicles but the team leader used one vehicle only because of a fuel shortage.

The other two curves on the same figure indicate the number of PSUs completed for hand data edit and computer entry and summary. The maximum for these activities is close to forty per week. Only one computer was used so computer entry and summary could easily be doubled or tripled by adding more computers to the task. Data edit could be a bottle neck but the edit team can handle more than forty PSUs each week.

As it now stands, data collection is a constraint. Next year, data collection and survey resources can be better allocated. But obviously, many more PSUs can be edited and summarized than can be collected with available resources.

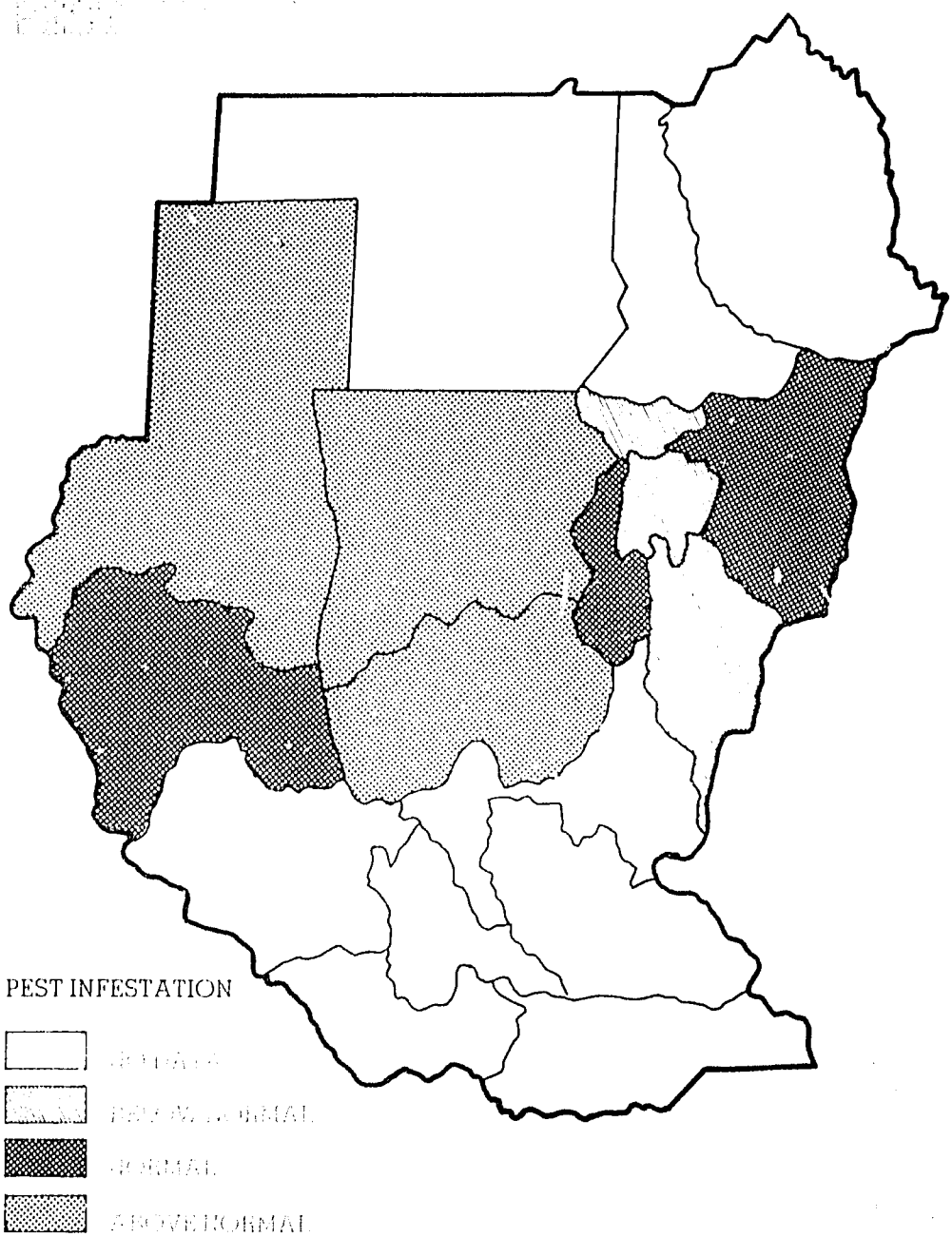


Survey data being entered into a computer system for analysis.

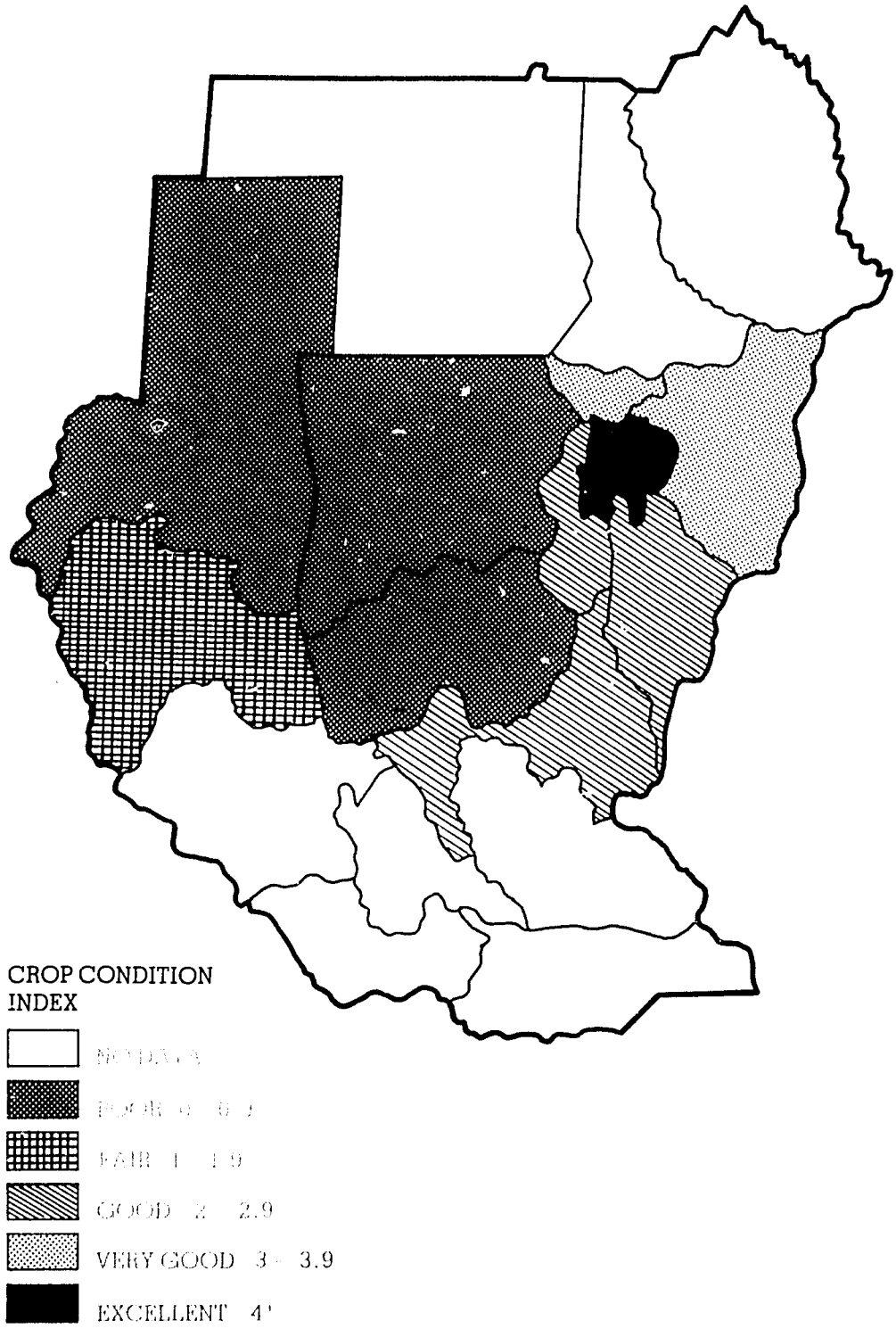
E. ATLAS MAPS

This section shows examples of maps and graphs that are being produced for the Agricultural Situation Outlook report which is published on a regular basis by PAEA/MOA. The first set of maps are from the ATLAS software and the TERRAMAR hardware. These maps were digitized into the ATLAS software package by FEWS personnel in Washington. The software package allows one to label the maps and output graphs showing different types of data on maps of Sudan. Two of these are shown below.

The agricultural information was put on the outline map of Sudan so as to make vital points, and by comparing these maps the association between pest infestation and crop condition can be inferred. Many other variables should be viewed in this way as the project progresses.



CROP CONDITION RATING



VII. RESOURCE REQUIREMENTS FOR DATA COLLECTION

1986/87 AREA SAMPLING FRAME SURVEY COST ANALYSIS

Next, Table IV shows a Lotus spreadsheet that presents costs and survey resources that were required in 1986. The spread sheet shows input costs from the 1986 survey including cars, fuel and per diem. The first three number columns show the 1986 survey costs. The second three columns show per segment costs for the east and west. These were separated because it is more expensive to collect data in the west but at the same time the west may be more important to the users.

Table V shows projected costs for 1987 under different sample size options. Total costs are computed by multiplying the average cost for data collection for one PSU by the number of PSUs. The calculations are done automatically once the spread sheet is set up so that managers can work out total costs under different allocations of samples.

The basic cost data will be updated and refined over the next few months to improve accuracy and to document the entire process better. Recurrent local currency costs and associated cost projections with proposed sample sizes of 300 and 400 PSUs are shown. It is assumed that costs per PSU will be equally prorated per PSU to the proposed increased samples without any allowance for increased costs(e.g.as of February1 per diem rates were increased by as much as 30 per cent).

No allowance is made for increased efficiencies that can be realized for using the same sample units as the previous survey. It will not be necessary to have photo interpreters "spot" old PSUs because locations have been documented on the questionnaire and can be located by the driver with minimal assistance. Use of the same sample will allow non-agricultural PSU's to be excluded from the survey to save on enumeration costs. (i.e. one person can travel to the non-agricultural PSU's to determine if there will be any agricultural activity for the current year. This will cut down on the total

Table IV. Recurrent local cost summary and projections
Lotus 123 Spreadsheet showing 1986 survey costs.

	West = 44, Item 1986/37		East = 118 Actual Cost	Cost per PSU		
Fuel	West	East	Total	West	East	Total
Fuel						
Gas Oil	25000	50000	75000	568	424	463
Benzine	25000	50000	75000	568	424	463
Total	50000	100000	150000	1136	847	926
Per Diem						
Drivers (13ls.)	7200	5250	12450	164	44	77
Interviewers (17.5ls.)	26600	30000	56600	605	254	349
Supervisors (22ls.)	19760	5760	25520	449	49	158
Photo Interpreters (83ls.)	7500	7500	15000	170	64	93
Total	61060	48510	109570	1388	411	676
Supplies						
Maps	5432	14568	20000	123	123	123
Aerial Photos	67901	182099	250000	1543	1543	1543
Pencils	109	291	400	2	2	2
Questionnaires	407	1093	1500	9	9	9
Envelopes	81	219	300	2	2	2
Miscell.	543	1457	2000	12	12	12
Total	74474	199726	274200	1693	1693	1693
Total Local Currency	185534	348236	533770	4217	2951	3295

These expenses are the most precise data available in April 1987. As better data becomes available, then better cost projections can be made. The next table shows what costs are projected for different PSU numbers.

man-hours of travel required.) The experience gained from conducting the first ASF survey in Sudan will be reflected in greater management efficiency in the second year of operation.

The goal will be to allocate the sample according to the total budget in the best way. The best possible sample will be the one that will provide the smallest sampling error for a given expenditure. We now have the advantage of knowing the relative sampling errors in different agricultural sectors by Province. This information along with the associated known costs from the 1986 survey can be used to derive an optimum sample allocation to obtain lowest sampling error for a fixed cost.

Experience from the 1986 survey indicates that the size of the enumeration team can be reduced from five to two with the added advantage of being able to put more teams in the field.

This modification would result in the survey data being collected in a shorter amount of time. The aforementioned modification will require more vehicles to transport enumerators, but overall costs may not be much increased because total time will be shortened. The intensity of the effort can be doubled and with the peak data collection completion rate of 3.3 PSUs per week per team, maintained for 12 teams, the survey can be completed in 10 weeks. If prescreening is done to eliminate from the survey the PSUs which do not have agricultural activity, the data collection period can be further reduced.

Data collection should be initiated in mid-September, so that results for a survey of planted area will be available by the first week of December.

Table V. **Resource requirements for 300 and 400 PSUs**

	West = 100, East = 200 Cost for 1987 Projected			West = 200, East = 200 Cost for 1987 Projected		
	West	East	Total	West	East	Total
Fuel						
Gas Oil	56818	84746	141564	113636	84746	198382
Benzine	56818	84746	141564	113636	84746	198382
Total	113636	169492	283128	227273	169492	396764
Per Diem						
Drivers (13 Ls.)	16364	8898	25262	32727	8898	41626
Interv S. (17.5 Ls.)	60455	50847	111302	120909	50847	171757
Supervs. (22 Ls.)	44909	9763	54672	89818	9763	99581
Photo Inter (83 Ls.)	17045	12712	29757	34091	12712	46803
Total	138773	82220	220993	277545	82220	359766
Supplies						
Maps	12346	24691	37037	24691	24691	49383
Aerial Photos	154321	308642	462963	308642	308642	617284
Pencils	247	494	741	494	494	988
Questionnaires	926	1852	2778	1852	1852	3704
Envelopes	185	370	556	370	370	741
Miscell.	1235	2469	3704	2469	2469	4938
Total	169259	338519	507778	338519	338519	677037
Total Local Currency	421668	590230	1011899	843337	590230	1433567

The work statement given in the contract covers a detailed set of activities and the background and administrative information pertinent to the operation of the contract. Of these activities, those which pertain to the contractor's activity are quoted below and a short narrative outlining the actions taken and the results achieved are given in each case.

1. In the work statement given as Section C of the contract schedule, the third paragraph of item 1. "Background" states;: "The Regional Centre for Services in Surveying, Mapping and Remote Sensing (RCSSMRS) of Nairobi nya through its Remote Sensing Departmei RSD) has been selected as the contractor to support the project by providing remote sensing data and analyses and other project support services under this contract. The RSD will work closely with the MOA and the Sudanese National Remote Sensing Centre (NRSC) to process, analyze and interpret data generated from satellite imagery and appropriate "ground truthing" surveys. These procedures are intended to improve the MOA's production estimates and improve the usefulness of the forecast to the GOS and international donors."

In this report, the RSD demonstrates that these broad objectives have been met. Appropriate ground surveys have been done, the data have been edited, entered into the computer systems and analyzed. The results were reliable estimates of the food grain crop of the main agricultural area of Sudan. The first of these estimates was available in October 1986 and the final one in December with an estimate of the total harvest given in February 1987.

All this work has been based on a powerful and efficient sampling technique known as the area sampling frame (ASF). By using satellite data of the central agricultural area of Sudan to stratify the food production area and construct a suitable ASF the selection of an objective sample is possible. The results of this sampling strategy have been good. The methodology is widely approved and the results carry with them a measure of precision. To improve the precision of these survey estimates, there are two actions possible, one is to increase the size of the sample and the other is to refine the stratification. Both of these actions require the input of resources. Other survey activities include the design and administration of the questionnaire, both may be changed to meet particular needs. However, the system provides for objective estimates and dispute is limited to the issues of sample size, stratification and the construction and administration of the questionnaire. The MOA finds this an important advantage and a significant improvement over the techniques previously used.

This work has been done in close collaboration with MOA and NRSC staff. Funds have been expended in those areas which enhance and complement the established activities of the GOS in the area of crop statistics. The computer systems installed have the necessary capacity to analyse and help interpret data from the Landsat satellites. The operation of the ASF during the life of this contract has been handled by existing staff of the MOA and NRSC. From time-to-time consultant support is desirable and was provided by the project when necessary. Other support given by the project includes the necessary resources to ensure the collection of data in the field, especially the provision of vehicles and their operating costs. Overall the operation of the first year of this project has been very successful, and this success requires consolidation to provide a firm base for future development. Much of this success was from the use of 1985 satellite data provided by USAID to construct the sampling frame. The satellite data form an important resource which can be used to monitor change in agriculture in relation to other natural resources. As the computerized geographic information system (GIS) installed under this contract, is developed together with the satellite image interpretation capacity, a powerful system for natural resources assessment and management will result.

2. Under the terms of the work statement item 2, RCSSMRS was required to provide full-time and part-time technical assistance using RSD staff and consultants to provide the following services:

a. Assist in the "ground truthing" surveys by:

1. designing sampling procedures to be used in the surveys;
2. assisting in the preparation and review of survey questionnaires to be used by MOA enumerators;
3. assisting the MOA in training the enumerators and in distributing and collecting the questionnaire;
4. installing and configuring a micro-computer system (to be procured by USAID/Sudan) capable of producing maps from the data collected in the surveys; and

5. training operators in the procedures to enter data from the surveys into the microcomputer system and generate the results in map form.

These objectives have all been met. Specifically;

1. The design of the sampling procedures to be used in the surveys was accomplished in two parts. In his initial visit (10 – 30th July 1986) the consultant, Mr. Wigton, explained the sampling procedures to be used. He met with the Technical Committee to discuss these procedures and programme the work required to establish an area frame. The analysis of maps and satellite images required for this was undertaken by the MOA staff and staff from the National Remote Sensing Centre (NRSC).

The consultant reviewed this work from time to time, with the Technical Committee. He assisted in the definition of the aerial photography required and the use of enlargements of Thematic Mapper data from the Landsat satellites where appropriate. The selection of the actual sample was done under his direction and the calculation of expansion factors used in the preparation of the estimates. This support and assistance was part of an interactive programme of work which produced a complete area frame in a remarkably short time.

2. The preparation and review of the survey questionnaire was a collaborative activity with the MOA staff and Dr. Goozner (USDA/PASA) who was attached to the MOA staff to assist with the computer work. The questionnaire was agreed by the Technical Committee, translated into Arabic and reproduced for use in the field.

3. Assistance in training the enumerators was provided by meetings between the consultant and the supervisors, and between the consultant and air-photo interpreters and the satellite image analysts. The interpreters and the image analysts also worked with the enumerators and supervisors in training sessions in Khartoum and during the fieldwork. Assistance with the distribution and the collection of the questionnaire included the provision of eight new double-cab Toyota 4 wheel-drive pick-ups which were in the field from November onwards. Assistance with this activity also included the provision of gasoline and supplementary allowances for fieldwork staff.

4. The micro-computer systems procured by USAID/Sudan were Terra Mar systems similar to those used in the FEWS project of the Technical Resources office of USAID's Africa Burea in Washington D.C. These systems, based on a Sperry Personal Computer, were installed in the MOA Statistics Department computer laboratory, and the NRSC laboratories in Khartoum and in RCSSMRS in Nairobi. These systems were all configured and operating in early January 1987, following installation by Terra Mar staff who provided on site familiarization training in all locations.

5. The training of operators is still in progress. The machines installed were capable of performing all the required tasks. Delays in approving training visits from the consultants have resulted in delays in training operators. Mr. Goozner learned some of these procedures and has produced the first map outputs from the system, which are included in the technical report. Approval for travel to Khartoum by U.S. based consultants is still required so that further training can be done. The nomination of a MOA staff member to assist in this work is still an important requirement.

Also under the contract RCSSMRS was required to:

b. Acquire, process, analyze and interpret data generated from two Landsat satellites by:

1. procuring the satellite imagery on magnetic tape from the sole source of the data, Eosat Corporation;

2. contracting for the translation of the data from magnetic tape to hard copy.

3. interpreting the data in Khartoum to provide an estimate of the density and type of planting zones and the biomass production; and

4. providing training to NRSC and MOA staff in the analysis and interpretation of Landsat data.

The requirement to estimate biomass production as stated in b.3. above was not met directly from satellite data because of difficulties in obtaining the requisite flow of data. Indirectly the objective was met through the crop estimates themselves. All other objectives were met in full.

1. Orders for satellite data were placed early in the season and data acquisition included good scenes for August and September. There was a problem with cloud cover so additional data were acquired for October and November. A total of 27 images was acquired over the 42 scene centers and Eosat Corporation waived acquisition fees until December 31st 1986 so that a saving of $1,600.00 per scene resulted.

2. An agreement was reached with USGS Sioux Falls, EROS Data Center, for the processing of the satellite data from magnetic tape to hard copy. The hard copy colour transparencies were supplied to Nairobi where enlargements of detail were made for field use.

3. Interpretation of the data in Khartoum was very successful. The types of planting zones were

estimated and the enumerators sample data expanded to give estimates of the planted area in each zone. The density of the plants cannot be reliably determined from satellite data alone. The density figure is indirectly available from the crop cutting data and crop yield estimates used in the overall production estimates. Biomass estimation can be derived from weather satellite data. Attempts to achieve this were frustrated by changes in the supply of such data by NOAA and NASA and by changes in the agreements between NOAA and USAID/OFDA in Washington. The new arrangements between USAID and NOAA should provide appropriate data during the next growing season. This is being investigated.

4. Training and assistance in the interpretation and analysis of Landsat data was provided to MOA and NRSC staff in Khartoum and Nairobi as requested. In particular, Terra Mar staff visited Nairobi and provided 50 hours of training to a group of staff from MOA and NRSC during the period 3 – 14 December 1986. Terra Mar staff were also in Khartoum 1 – 7 January 1987 for some 7 days of training. Other training included the visits of staff to Nairobi for work (rather than simple instruction) involving the preparation of Landsat image enlargements for use in the field. The expertise available in MOA and NRSC is such that "training" is more appropriately seen as gaining familiarity with new procedures and new equipment. The existing levels of expertise are high.

Further requirements under the contract were:

c. Develop an air-photo survey program based on the Landsat planting zone estimates by:

1. determining sample areas to be surveyed;

2. arranging for aerial photographs taken either by the Sudan Survey Department or a firm in Khartoum under a local currency sub-contract and;

3. assisting the NRSC in interpreting the aerial photographs.

All these requirements were met. The sample design was fully implemented.

1. The sample requirements for aerial survey were defined.

2. The Sudan Survey Department agreed to do the necessary survey flying and did the work late. The first delivery of data was in November (19th) and only 70% of the work was completed and delivered as of March 31st. 1987. The Sudan Survey Department would not give clearance for any other contractor to undertake this work and therefore they assumed effective control of all survey activity The UN/FAO integrated camera-radiometer technique was discussed in full with FAO staff members, UNEP/GEMS in Nairobi who funded its development, ILCA research staff (currently using the instrument in the field) and the scientist from Queen Mary College, University of London who developed the instrument. The system presently available gives sample photographs only on 35mm colour film, does not provide comprehensive area coverage and cannot be adapted to do so. Conventional b&w survey photography was therefore used.

3. Little or no assistance was required by the MOA and NRSC personnel who are well trained and fully capable of interpreting the aerial photographs whenever they are available.

The final set of contractual requirements were:

d. Develop a Geographic Information System (GIS) modeling capability by:

1. defining a models using soils information agro-climatic data, and other partinent inputs;

2. procuring and analyzing NOAA satellite data to adjust model data for precipitation amounts and distribution;

3. installing and configuring a micro-computer system in Khartoum for the GIS;

4. installing and configuring equipment (to be procured by USAID/Sudan) in Khartoum and Nairobi to interpret images and for model and data mapping; and

5. providing training to analyze NOAA satellite data, to use the micro-computer system and the interpreting and mapping equipment of the GIS.

e. Incorporate the data developed through the above project into food grain production estimates as described in C.3.a

f. Training Program the contractor will provide the USAID/Sudan Project Officer with a detailed plan for all training to be conducted. The training of foreign nationals outside their home country under this contract will be accomplished in accordance with the policies, allowances, guidance and reporting requirements of AID Handbook 10 Participant Training.

Requirements under d above were only partially met because of difficulties with the flow of data from NOAA, and from FAO and the field. Many of the objectives were achieved as follows.

1. The models were defined. Both the models used by the Centre for World Food Studies (Wageningen, The Netherlands) and by Climatic Assessment Technology (Houston, Texas) are suitable for the modeling of food grain production in Sudan. Both models require soils information and agro-climatic data and both are known to be operational.

2. Procuring and analyzing NOAA satellite data was not done because the promised flow of NOAA satellite data through the agreement between USAID/Washington D.C. (CFDA) and NOAA ceased. The alternate flow of data through NASA's research group GIMMS to be funded by USAID/Washington D.C. was not established in time for the crop season. Some data under the OFDA/NOAA agreement was delivered in February, 1987. These include data for October 1986. At the time of receipt the information could not be used effectively for the 1986 crop season.

3. Installation, configuration, testing and operations training were all completed for a Terra Mar system equipped with Terrapak software (GIS) as used in the FEWS programme for AFR/TR in Washington D.C. This system is installed in Khartoum in the National Remote Sensing Centre Laboratories.

4. Installation, and configuration of equipment (procured by USAID/Sudan) in both Khartoum and Nairobi to interpret images, and map data was completed in January 1987. This included the time devoted to initial operator training. Colour equipment for the NRSC photo-laboratory was also installed by January 1987 and awaits final delivery of photo chemistry (shipped by sea) before being fully operational.

5. Because of the problems with the supply of NOAA data no training in the analysis of this type of information was given. Training in the use of the micro-computer system and the image interpreting and mapping equipment of the GIS was provided by Terra Mar staff when the equipment was installed. Further training in the use of mapping programs was provided.

e. All the data gathered in the system both from satellites and ground survey has been incorporated into the food grain production estimates given in the Technical Report.

f. Training was limited to small groups of technical staff in Khartoum and Nairobi, and implemented as discussed and approved by the project officer.

3. MOA Project Paper. The additional insights provided by this paper have been incorporated into the contract activities by approval of the Steering Committee, as the revised schedule permitted. The terms of the contract have limited some of the paper's aims and particularly the activity schedule. Whilst it is misleading to attempt to specify non-compliance with responsibilities listed in the paper the contractor wishes to note that late signing of the contract document, late delivery of aerial photography, late rains and a late growing season all contributed to the failure to meet the schedules initially proposed in the project paper. However, the revised work plan approved by the Steering Committee has been substantially completed.

4. Reports.

a. Together with MOA and NRSC personnel the contractor provided food grain production estimates on October 15th 1986, on December 31st 1986 and a harvest report based on survey data in early April 1987. The absence of a November report was a result of the lack of aerial survey photography. The delay of the final report from mid-January to early April resulted from the late growing season and delays with field teams in Kordofan and Darfur (vehicle breakdowns, difficulties with gasoline supplies). Frame construction and late acquisition of aerial photography for Darfur and Kordofan was also a factor in this delay resulting in late data collection in these areas.

b. Monthly reports on progress and trip reports were provided as required.

c. Training reports as per requirements are attached.

5. Work Plan. The contractor began work promptly on signature of the contract. The required work plan was submitted to the project officer, Dr. G. Ghobrial, in USAID/Sudan within two weeks and was approved by the Steering Comittee at its meeting on 14th July, 1986. (See July monthly report and attached trip report.) The project officer being a member of the Steering Committee, the full requirements of the contract were thus complied with.

B. SPECIAL CONTRACT REQUIREMENTS

Technical Directions

Under Section H of the contract there are several special requirements. The first of these is "Technical Directions". The USAID Project Officer assigned to this project was Dr. George Ghobrial, who is very knowledgeable about agriculture in Sudan. No technical directions constituted changes in the contract and the contractor wishes to record its appreciation of the constructive working relationship with the project officer.

RSD Staff Salaries.

In compliance with the contract requirement, no staff salary for any RCSSMRS member supported by USAID funding has been charged to this contract.

Key Personnel.

The key personnel defined in the contract have been available for work under the contract as

necessary. There has ben no diversion of their activity away from work performed under this contract.

Consultants

The consultant used, Mr W. Wigton, has been approved for this project by the Project Officer. The consultant has been paid at approved rates.

Security Requirements

The contractor has not had any access to classified information of the U.S. Government.

Duty Post

The work performed has been principally in Khartoum. Some support work and training was done in Nairobi as agreed.

Relationships and Responsibilities

All contract activity has been under the general co-ordination and direction of the Steering Committee chaired by Dr. Abdel Moneim El Sheikh. Much of this work has been carried out in direct collaboration with the project Technical Committee. All activity has been with the approval of the Project Officer.

Travel Expenses

No contractor personnel have been discharged for misconduct, or for non-performance. There are therefore no travel expenses incurred in this context.

Rights in Data

The data resulting from the contract have been supplied only to the Ministry of Agriculture GOS which has published this information in its crop reports. The technical report forming part of this contract report has been approved by the GOS Steering Committee. All the raw data from the survey are stored in the MOA computers, access to these is at the discretion of MOA. The rights in Landsat data are governed by the trade secrets legislation of the U S.A. Use of these data within the project and for project purposes is permissible but use of these data is otherwise not permitted without the express written agreement of EOSAT Corporation, Lanham, Maryland, U.S.A.

G. SUPPLIES OR SERVICES AND PRICES/COSTS

For the supplies and services detailed a total of U.S.$809,163.00 and LS287,000.00 has been allotted. In the itemized budget specific allocation of funds was made and the allocation plus comment on the actual expenditure is given below.

U.S. Dollar Budget.

1. SATELLITE DATA PROCUREMENT
$222,525.00

Comment: This allocation was based on an expected need to purchase 43 images in tape format ($3,300.00 each) plus the charges for ordering new images ($1,600.00 each) plus the cost of ensuring cloud cover did not exceed 30% in each case ($275.00) giving a cost of $5,175.00 per image for 43 images or a total anticipated cost of $222,525.00. However, only 27 of the requested images were obtained within the time period with less than 30% cloud. EOSAT Corporation suspended the $1,600.00 charge from July until December 1986 and so costs have been substantially less than expected. As of 31st March 1987 only $93,155.84 had been disbursed against this line item. Agreement had been reached with the Project Officer and the Contracting Officer to reprogram some of the unspent balance for the purchase of additional computer equipment for Khartoum.

2. SATELLITE DATA PROCESSING
$90,624.00

Comment: This estimate was based on an expected cost of commercial processing of the satellite data tapes and the supply of color composite transparencies in a 9x9 inch format at a cost of approx. $1,500.00 per tape. An additional amount ($500.00 per scene) was added to allow for more detailed computer analysis and a budget of $300.00 for photographic reproductions of each product for use in the field. As of 31st March 1987 great savings had been achieved because the US Geological Survey had undertaken the processing work for a total cost of $450.00 per scene and the photographic work for field products was done in Nairobi. Including specialized enlargements and multiple copies, total expenditure under this item had only reached $35,191.00 by 31st March 1987.

3. AERIAL PHOTO SURVEYS
$75,000.00

Comment: The cost of aerial surveys was estimated on the basis of services being freely available in Khartoum. In fact the available sources of service were limited to the Sudan Survey Department to whom an initial payment of LS150,000.00 had been made in November 1986. As of 31st March 1987. 70% of the required work had been completed and delivered. It is expected that, when the balance of the required work is delivered the allocation in this line item will be fully expended.

4. TRAINING
$51,720.00

Comment: This item included funds for some training to be conducted in the U.S.A. Because of the late start to the project only essential training was done including work in Nairobi with the photo-scientists and a familiarization activity for the civil engineering consultant. As of 31st March 1987, only $24,292.82 had been expended. It was intended that further training on the computer systems was given in May and June 1987. In June three scientists went to the U.S.A. for several weeks of training. By the end of the project these funds will be fully expended. See training report, below, for further details.

5. CONSULTANT
$100,368.00

Comment: This budget included provision for consultants in crop production modeling, sampling statistics, and computer systems to assist during the term of the contract. The sampling statistics consultant, Mr. W. Wigton, is the only consultant engaged so far. Modeling the crop production was delayed until the next crop year. Some computer training has been done from this budget and the balance under the computer installation and training contract. As of 31st March 1987 total expenditure from this line item is $53,658.21 with some $12,000.00 committed to a further visit by Mr. Wigton.

6. PHOTO LAB INSTALLATION AND SUPPLIES
$30,000.00

Comment: This item has been spent entirely in local currency. Most of the material and workmanship has been obtained locally. AID/Sudan has been requested to transfer these funds into local currency; an equivalent of LS130,000.00 is needed.

7. GEZIRA ORTHOPHOTO MAP
$20,000.00

Comment: This allocation was to provide for the printing of a map showing the whole Gezira scheme on one sheet using a satellite image base. Data from the German Metric Camera, Spacelab experiment, are available and the German research team agreed to collaborate with us in this venture. It now seems that they will finance the whole activity. Consequently there is no expenditure under this item.

8. CONTRACTOR PERSONNEL
$79,600.00

Comment: This item provides for RCSSMRS staff costs incurred under this project. No charges have been raised for the time of staff members receiving salary support from the USAID grant to RCSSMRS. Costs of travel and per diem incurred on visits to Khartoum are included. A total of 165 staff days have been spent in Khartoum at a daily rate of $180.00. In addition to this are travel and incidental costs. As of 31st March 1987 $59,707.00 had been expended from this line item.

9. OVERHEAD
$139,326.00

Comment: This is billed at 20% of direct cost. As of 31st March 1987 a total of $81,762.00 had been billed against this line item.

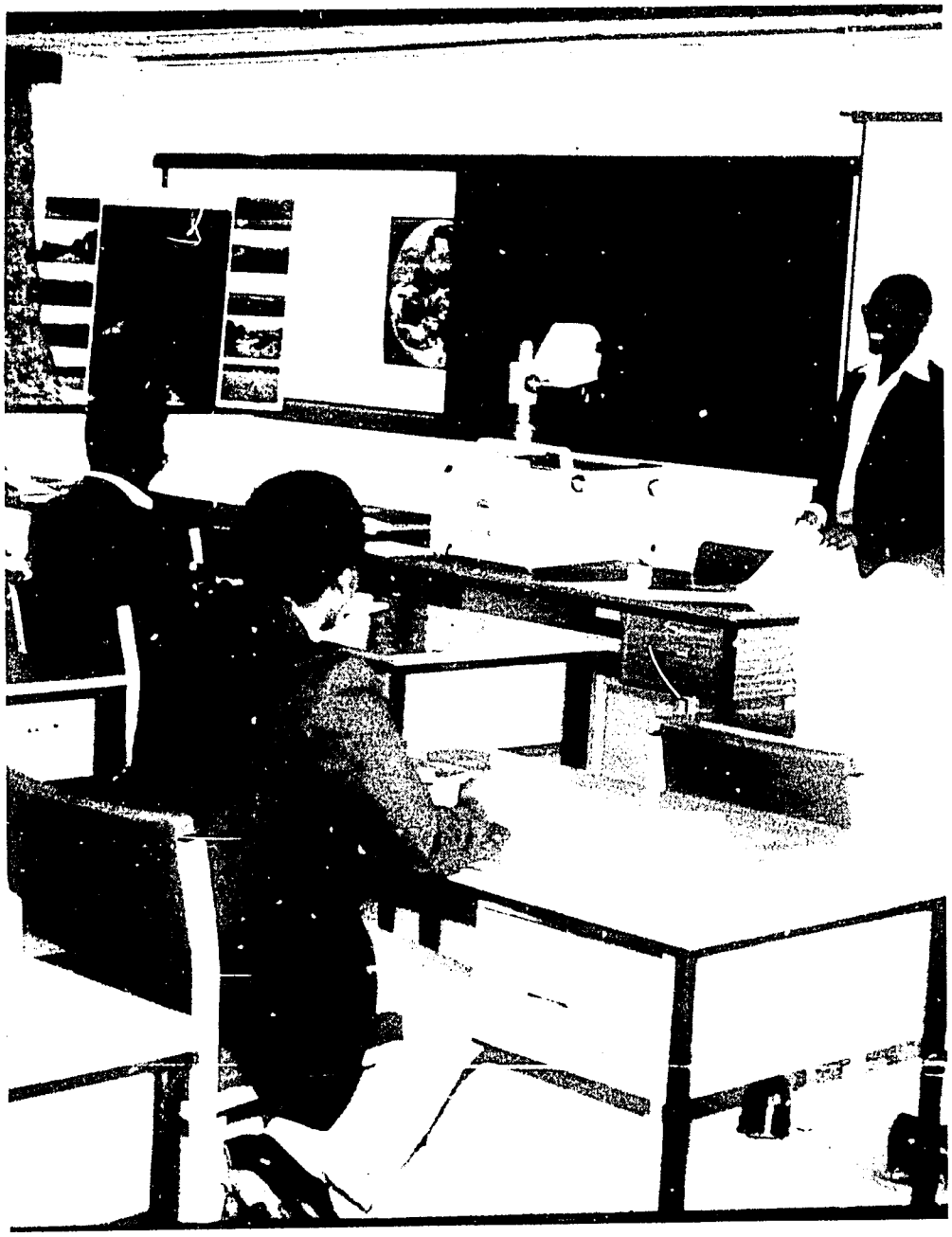
10. TOTAL
$809,163.00

Comment: As of 31st March 1987 $405,267.61 had been expended and a further $80,000.00 committed to approved capital purchases of computer equipment, as authorized by the USAID/Sudan contracting officer after approval by the Steering Committee. Expenditure for April, including consultants' visits and final report preparation will approach $20,000.00. When the Sudan Survey Department completes the flying of the sample sites a further $37,500.00 will be payable to them. Other expenses to be met from this contract include further training of MOA and NRSC staff on the computer systems, and the costs of commissioning the photo-laboratories of the NRSC once the remaining commodities are delivered. Funds are also required for the production of data tapes for use on the computer system, and for the consultant to work with the MOA staff to refine the area frame and select an increased sample in the west. Most of these expenses should be incurred before June 30th.

The project has operated within budget, partly because the number of new satellite images acquired was less than expected and partly because the supplier temporarily reduced charges for image acquisition at the time the project required this data. Other major savings resulted from the services of the U.S. Geological Survey, EROS Data Center being substantially cheaper than the estimated processing costs. Other apparent savings resulted from the late start of the work, the late season, and the slow delivery of some items. These expenditures will still be incurred as the aerial photography is delivered, crop modeling begins and sampling in the western agricultural area is strengthened.

Most of the equipment obtained for the NRSC and MOA was purchased by the USAID purchas-

ing officer. The contractor was responsible for preparing the lists of equipment and specification needed. After the equipment arrived, the contractor was to install equipment, commission them and train the local persons in their use. To obtain an up to date list of all equipment received NRSC and USAID procurement officer should be consulted.



Students attending a training course in remote sensing.

IX. TRAINING REPORT

The training activity undertaken in this project has been by agreement with the Project Officer, Dr. G. Ghobrial, and with the general approval and permission of the Steering Committee. The training has involved staff from the Ministry of Agriculture and Natural Resources and the National Remote Sensing Centre of the National Council for Research. Staff from both organizations have attended sessions of instruction in Nairobi and Khartoum. The overall programme of training approved by the Steering Committee was more modest than originally envisaged because of the late season and the late start to the work.

The approved programme was:

Trainee	Unit	Venue	Duration	Cost ($)
1) Photo-scientist (1)	NCR	Nairobi	4 weeks	3,000.00
2) Photo-technician (1)	NCR	Nairobi	4 weeks	3,000.00
3) Digital Image (3) Processing and (4) GIS/Modelling. (2)	MOA/SD NCR MOA/Soil Survey	Nairobi	10 days	19,000.00
4) Photo-interpreters (15?)	MOA/NCR	Khartoum	2 weeks + 0-i-j	5,000.00
5) GIS Training (6) (3) (3)	MOA/SD NCR MOA/Soil Survey	Khartoum	2 weeks	10,000.00
6) Remote Sensing for agriculture (2)	MOA/SD	U.S.A.	2 months	6,000.00
7) Seminar	All	Khartoum	1 day	5,000.00
			Total Cost	51,000.00

This training programme has been modified to take advantage of the Twentieth International Symposium on Remote Sensing of Environment held in Nairobi 4th-10th December 1986. Attendance by over 400 scientists from the international remote sensing community provided a unique opportunity for interaction and consultation with a wide range of experts. The displays of equipment and project materials provided a unique opportunity to see the range of available products and their applications. Accordingly, visits to Nairobi were concentrated around this time to permit trainees to take advantage of the Symposium. The introduction to image processing and GIS was also offered in Nairobi at this time and nine people from Khartoum attended. As at the end of April 1987 the first five activities listed in the approved training programme have been completed. Item 7 is scheduled for 16th May and training in the U.S.A. is being organized for 3 people, this represents an increase in commitment from the allocation made in item 6.

By specific activity, training has taken place as follows:

1) Photo-Scientist

Mr. Azahri E. Ahmed appointed by the National Council for Research to work in the NRSC, Khartoum, was in Nairobi for the three week period

3-24th December 1986. During this time Mr. Ahmed attended the International Symposium on Remote Sensing of Environment for two days and the remainder of the time he worked in the photographic laboratories of the RSD. The activities covered are described below.

2) Photo-technician

Mr. El Hassan Ismail appointed by the NCR to work in the NRSC Khartoum, also came to Nairobi for the period 3-24th December 1986. His work programme was closely tied to that of Mr. Ahmed. Their programme of work is outlined below.

Work Programme of Azahri El Ahmed Photo-scientist

El Hassan Ismail Photo-technician Nairobi, 3-24th December 1986.

4/5th December – Attendance at Symposium.
8/11th December – Familiarization with RCSSMRS photolab.

- Discussion of previous experience.
- Tour of laboratories.
- Demonstration of basic techniques of exposure and development of photographic products of satellite data. Basic introduction to the operation of a processing system.

12/24th December – Participation in the on-going work of the photo-laboratory including:

- Mixing chemistry for different colour processes.
- Mixing b&w chemistry.
- Exposing and developing prints.
- Focusing, framing and printing colour images in formats up to 1mx1m.
- Operating large format processor.

The work of the photo-laboratory in December included the production of:

20 Large format colour prints.
96 Medium and small format colour prints.
18 Colour film products.
4 Slides.
4 Large format b&w prints.
29 Medium and small scale b&w prints.
11 b & w film products

The two trainees had the opportunity to participate in all steps of the production of the specialized items all of which are prepared on a custom basis for users of remote sensing data.

3) Digital Image Processing and Modelling

This training activity was designed in two phases, an initial familiarization with the system in Nairobi and a more detailed training in Khartoum. The digital image processing systems procured for installation in MOA and NRSC in Khartoum and RCSSMRS in Nairobi, were Terra Mar systems. The company exhibited its system at the Twentieth International Symposium on Remote Sensing of Environment and for the following four days provided a tutorial seminar on the operation of their system. This seminar was geared solely to this project. Attending this seminar and the symposium from Khartoum during the period 3-12th December 1986 were:

Mohamed M. Ali – Computer Specialist NRSC.
Mohamed Abdulla Mohamed – Act. Director NRSC.
Osman Abdulla Abu Zein – NRSC.
Osman Abdulrahim Osman – Director NRSC.
Hassan Fadul – Soil Survey/MOA.
Zein El Abdin Omar Sharif – Soil Survey/MOA.
Hassan El Sheikh Elbashin – MOA/SD.
Mukhtar Ibrahim Mohamed – MOA/SD.
Mohamed Abdulrahman Jamil – MOA/SD.

Some 50 hours of instruction were included in this time, plus the opportunity to view the results of similar analyses presented by the exhibitors at the Symposium. The MOA team from Sudan also participated in the presentation of a paper describing the project activity and methodology, which was well received by scientists present.

4) Photo-interpreters' training

Staff of the MOA Soil Survey and the Statistics Department and staff of NRSC worked with the consultant to define the training needs for photo-interpreters. In defining these needs it became apparent that work with enlargements of satellite data would be beneficial to the project in the irrigated and mechanized farming areas. In order to assemble suitable materials Hassan Fadul and Mukhtar Ibrahim travelled to Nairobi with the consultant, Mr. Wigton, on 20th September. For the following 11 days they worked with the photo-scientist in defining and producing products required for suvey purposes. A total of 98 such customized products were completed in this period. Taking these products back to Khartoum, the consultant plus MOA staff provided photo-interpretation training for some 11 interpreters of MOA and NRSC survey staff, this included field instruction and on-the-job training. Mr. Baraza of RCSSMRS participated in this activity for the period 1-21st October and the consultant during the period 3rd September – 11th October (including 20th September – 1st October in Nairobi).

Organized by Hassan Fadul this training involved the following staff members:

Osman Abdulrahim.
Mohamed Abdulla.
Ibrahim Adam.
Babiker Suleiman.
Khalid Ahmed Khalil.
Ismail Adam.
Mukhtar Ibrahim.
Hassan El Sheikh.

Other staff from the MOA Soil Survey in Wad Medani participated in this activity also. Because this activity was on-going including on-the-job training with interpreters attached to survey groups, it is difficult to specify the training activity in man-days. There was a period of 12 days in Khartoum during which there was orientation and training in a general sense. This was followed by some weeks of detailed work in Wad Medani during which interpreters worked on the data for Kordofan and Darfur plus areas to the east and trained others in the interpretation of satellite images. Similar activity took place in Khartoum using the data for Darfur. There was another major interpretation activity following the delivery of aerial photographs in November, and on-the-job training was very important in the period to mid-January 1987.

5) GIS Training

A follow up to item 4 above was a further session for staff in Khartoum. This is the training identified as item 5 on the approved training programme. For this activity Terra Mar sent a systems engineer instructor to Khartoum for a seven day period (1-7th January 1987). This included the setting up of the systems. The training activity was attended by a total of 17 people from the MOA, NRSC and the University. Of the MOA and NRSC staff actively engaged on this project, the following were present.

Mohamed M. Ali – Computer Specialist NRSC.
Mohamed Abdulla Mohamed – Ag. Director NRSC.
Osman Abdulrahim Osman – Director NRSC.
Hassan Fadul – Soil Survey/MOA.
Zein El Abdin Omar Sharif – Soil Survey/MOA.
Babiker Suleiman – Soil Survey/MOA.
Ibrahim Adam – MOA.
Ismail Adam – NRSC.
Khalid Ahmed Khalil – Soil Survey/MOA.
Mukhtar Ibrahim – MOA/SD.
Hassan El Sheikh – MOA/SD.
Mohamed Abdulrahman Mohamed – MOA/SD.

The other five attending were from the Soil Survey (2) and the University (3).

This training activity was intense and included some 12 hours of introduction to the system, system structures, configuration and use. There were some 28 hours of individual demonstration and familiarization with the operation of the system and 10 hours of image analysis demonstrations. Some time was spent setting up the GIS component and digitizing an outline map of Sudan. However, in the absence of new data sets it was agreed that further GIS training would follow when data were available and staff were free of the demands of the field survey.

Further specific training using the GIS capability of the Terra Mar systems was planned for March and May. USAID/Sudan did not approve travel for the consultant from Price Williams as requested in March 1987. Consequently training in the use of ATLAS software was reduced to those products which produced from his reading of the available manuals, and by using the outlines digitized by Price Williams and supplied on diskette.

Training in the use of Terrapak GIS software was scheduled for Khartoum, May 11-19th. The instructor was Wally Jansen from Terra Mar. Robert Uleman also of Terra Mar conducted similar training in Nairobi 5-7th May and 20/21 May.

6) General Remote Sensing Training for Agriculture in the U.S.A.

The most recent discussions with the Steering Committee and the project officer, Dr. G. Ghobrial, have identified the following candidates for this training.

Mukhtar Ibrahim Ahmed.
Mohamed Abdel Rahmon Jamil.
Ismail Adam.

Details were worked out for Mukhtar Ibrahim Ahmed to have a 4 week study visit to the National Agriculture Statistics Service of the U.S. Department of Agriculture to participate in some of the work of the 1987 crop season in the U.S.A.

Mohamed Abdel Rahman Jamil and Ismail Adam went to USGS EROS Data Center in Sioux Falls for a 6-8 week period of instruction on GIS systems and their use alongside remote sensing data for agriculture and natural resources studies. This training was completed in September.

7) Seminar

The seminar presentations and submission of the final report on project activity were presented on the 23th May in Khartoum.

A scientist using the computer system to analyse a satellite image and enter the results into the geographic data base.

X. FUTURE WORK

A. SURVEY OPERATIONS

From the experience of the 1986 season, it is clear that overall management should be improved for next year's survey. This will require survey resources to be made available sooner. All parties have a clearer idea of what is required to obtain the data. It is generally agreed that more timely data collection is required. Stratification must be improved in the west where proper evaluation of the stratification is required especially in the non-agriculture categories.

The Sudan Survey Department has flown many of the sites correctly but additional coverage is necessary where PSUs were missed or not covered at all. Although in the East, the undermarcated mechanized areas were not covered in the growing season, the Survey Department photographed these areas in March and April of 1987.

Preparation for the 1987 survey began in May 1987 so that several activities were undertaken simultaneously. Although the MOA/SD staff understand the concepts of each phase, personnel are over extended with tasks and in 1986 operated more on a crisis basis than by planned activity. Data collection is a difficult task and will require outside support. It must be improved in 1987 so that deadlines required for survey publications are met.

The accuracy of the estimates can be improved by better allocation of the existing sample which will not increase the overall costs and by increasing the sample which has implications for the total costs. Increasing the sample will require more aerial photography in some areas. The sample can also be increased by selecting more segments in each PSU and completing PSUs not completed last year. Next year, mechanized agriculture will be one stratum, combining both demarcated and undemarcated areas. In some cases, expert interpreters can use satellite images to separate demarcated mechanized from undemarcated lands. However, areas in the east where the fields are irregular indicating undemarcated land are in fact included in the Mechanized Farm Corporation's (MFC) definition of demarcated land.

B. GEOGRAPHIC INFORMATION SYSTEM DEVELOPMENT

Geographic information systems (GIS) are a general technology that allows different types of data to be stored and displayed geographically. Data such as crop statistics, crop types and soil types can be displayed on maps as shown in figures 1 and 2. These examples were produced using a software package known as ATLAS, a simple GIS system, used to generate single theme maps. ATLAS double theme maps are being developed for *Agricultural Situation Outlook* reports to produce maps combining such variables as pest infestation and yield information.

Other more complicated GIS functions are available on the TERRAMAR hardware using TERRAPAK software to generate cartographic products at size up to approximately 26 by 32 inches. This should be routinely available to users when the National Center for Research hires and trains computer personnel to operate that system. The TERRAPAK system is a GIS developed for a micro Computer. Essentially what TERRAPAK provides are functions so that layers of information can be added, overlaid or subtracted showing relationships between two or more themes. These systems (hardware and software) are in place as a result of the 1986 project. Training (and management training) of users who can most profit from this technology is necessary to fully exploit the GIS system. One of the first applications is to display and interface crop statistics for the *Agricultural Situation and Outlook Report*, published by PAEA.

C. YIELD MODELS

The 1986 SERISS Remote Sensing Project implemented an ASF that can generate estimates of planted area for each crop and can serve as a sampling frame for crop cutting surveys. Crop cutting surveys are expensive and difficult to manage and not always accurate. Yield models offer an alternate way to provide yield data and at the same time minimize the amount of crop cutting necessary to obtain accurate estimates.

There are several types of yield models, and since the 1940's agronomists have been using rainfall and agricultural inputs to model yields. Some technical breakthroughs have been made in the last five years as a result of two NASA programs; Large Area Crop Inventory Experiment (LACIE) and Agricultural Resource Inventories Through Aerospace Remote Sensing (AgRISTARS) programs. Complicated nonlinear regression growth models are developed to model yields using data from research stations. Research stations have accurate rainfall, soils, crop variety, nitrogen amounts and other agricultural and meteorological inputs as well as yield data. With

these data for several growing seasons, accurate yield models can be built.

Once the models are built for research stations, regression analysis is used to adjust for differences between yields at research stations and yield values obtained from crop cuts from the farms in adjacent areas. In effect, crop cut data are used to calibrate the research station yield models. The method has been tested and found to work. It is recommended that this modelling activity is incorporated into future work under the SERISS project or its successor.

A survey team interviewing the owner of the fields selected in a sample survey.

XI. RECOMMENDATIONS

A) AREA SAMPLING FRAME

The area sampling frame now in place over the agricultural zone of Sudan has operated successfully for the agricultural strata. Sampling in these strata has shown some deficiencies in the stratification and the sampling procedure. To overcome these deficiencies it is recommended that:

i) The sample in the irrigated areas be reduced and the resources be redirected to the areas of traditional agriculture.

ii) The sample in the areas of traditional agriculture, especially in the west be increased. This may be achieved by selecting three segments within each PSU instead of two as well as increasing the number of PSU's selected.

iii) The stratum including traditional agriculture be refined by fieldwork and the definition of sample units be subject to more detailed study using aerial photographs and site visits.

iv) The sample survey be planned to produce data in a more timely manner, by directing appropriate resources to ensure completion of the survey on schedule.

v) Vehicle support to field teams be increased.

vi) Consideration be given to the use of diesel vehicles in view of the general availability of diesel fuel in the west and the increased operating efficiency compared to gasoline powered vehicles.

vii) The area frame should be entered into the digital data base as soon as possible and the stratification modified in the light of the results obtained. Other strata should be added such as forestry, rangeland, water bodies etc. as data permit.

B) CROP STATISTICS

Useful information may include many measurements not derived from a sample survey. For example crop yields can be modeled using rainfall and soil information. Crop prices in the market place can be recorded. Models of food demand and related nutrition status can be used to infer food crop availability. It is recommended that:

i) Continued support be given to the crop modeling activity in relation to the need for estimates of food crop of production. This is particularly important in view of the Regional Security Program being established in Nairobi by FAO to provide estimates of rainfall by grid location as a drought monitoring and famine early warning system for Eastern Africa.

ii) Consideration be given to the collection of ancillary data related to crop yields such as rainfall, agricultural inputs and the related data on market place prices of food grains.

C) GENERAL

During the project activity it has been apparent that there is a high level of expertise and competence in the Ministry of Agriculture in the area of sampling and crop statistics. It is therefore recommended that:

i) A program of support and development be implemented for the personnel. This program should include additional training, in country and overseas, for statisticians computer operators and sampling experts.

ii) The adoption of area frame sampling methodology be supported with technical assistance and commodities for a period of up to five years whilst training is completed and experience gained.

iii) The training and support should include the development of multiple use of the sampling frame to gather data for other purposes related to agriculture, famine and food security.

iv) The computer system installed in the NRSC laboratory should be used to operate a natural resources data base for Sudan at the national level. This should draw on the material and experience of the Ministry of Agriculture as necessary. This may require an expansion of the training program recommended in i) above, and should include all appropriate topics in natural resources.

v) Consideration be given to establishing an on going program of land cover monitoring using satellite remote sensing based on the principles outlined by UNEP for its Global Environment Monitoring Programme.

LIST OF ACRONYMS

APS	Agricultural Planning and Statistics Project. Ministry of Agriculture and Natural Resources, Sudan.
ASF	Area Sampling Frame.
AVHRR	Advanced Very High Resolution Radiometer – A multispectral scanner on the NOAA satellite
CCT	Computer Compatible Tape.
CV	Coefficient of Variation – a measure of relative sampling error.
FCC	False Color Composite, an image product that is made to look like a false color infrared photograph.
ISPC	International Statistical Programs Center.
MOA	Ministry of Agriculture Sudan.
MSS	Multispectral Scanner – an 80 meter resolution scanner on Landsat satellites.
NOAA	National Oceanic and Atmospheric Administration, U.S.A.
PAEA	Planning and Agriculture Economics Administration, Ministry of Agriculture and Natural Resources, Sudan.
PSU	Primary Sampling Unit.
RCSSMRS	Regional Centre for Services in Surveying, Mapping and Remote Sensing.
RSASP	Remote Sensing Agricultural Statistics Project, Ministry of Agriculture and Natural Resources, Sudan.
SERISS	Sudan Emergency and Recovery Information and Surveillance System.
SPOT	Systeme Polyvalent pour l'Observation de la Terre, a French satellite launched in February 1986 with a sensor system gathering data at 10m. and 20m. resolution.
SUDS	Survey Data Processing System.
TM	Thematic Mapper Scanner – A 30 meter resolution 7 band scanner on Landsat 4 and 5.
USAID	United States Agency for International Development.
USDA	United States Department of Agriculture.

GLOSSARY OF TERMS

Area Sampling Frame

A special case of cluster sampling. The sampling units are areas of land, commonly called segments, which have identifiable boundaries. The idea is to divide the entire land area of interest into sampling units and to select a sample of these called segments.

Coefficient of Variation

Relative sampling error expressed as a percent of the estimate.

Data

A collection of tables, estimates, figures or numbers either on tape or paper. These data may or may not be useful for decision making.

Digital Data

Data in digital form that are available for processing on a computer.

Estimation

Producing a statistic that indicates present conditions.

Forecasting

Predicting future events or conditions.

Information

Data that can be used for decision-making. Data known to be accurate, timely, objective, comprehensive or replicable - Information is data useful to decision-makers.

Landsat

A series of five satellites that were launched starting in July 1972, for the purpose of Earth resource observations.

Multiple Frame

The joint use of two or more frames collectively. The frames should include all members of the population. Usually this technique makes use of a general purpose frame for individuals that are less important and a list frame that has extreme operators.

Nonsampling Error

A general term that applies to all sources of error other than error attributable to the sampling. It includes error from any defects in the sampling frame, response errors, and errors in processing the data.

Objective Estimate

An estimate which does not depend on a persons or groups opinion. Usually the estimates are based on probability and sampling theory.

Pixel

A picture element or resolution element.

Precision

It is variation of estimates obtained in repeated samples under the same conditions around the expected value. Standard error is a measure of precision. Precision is an attribute of the sampling distribution of an estimator. It is the closeness of estimates under specified conditions to the related parameter of the distribution.

Resolution

The instantaneous field of view or the smallest area on the ground for which a sensor can measure reflected or emitted electromagnetic radiation.

Sampling Error

Random error attributable to sampling. "Sampling error" is a general term. It is commonly used as a short term for longer expressions such as sampling standard error or standard error of an estimate.

Sampling Frame

A list with addresses "or the equivalent of a list" of all sampling units of the population. It enables probability sampling. The phrase "or equivalent of a list" is inserted because frames often account for all sampling units in a population without having every sampling unit explicitly listed or defined in advance. A frame is needed whether sampling or a census is being undertaken.

Segement

The selected sampling unit. The block of land that is selected for data collection.

Spectral Signature

The reflected and emitted energy from an object. The values of energy stored on the CCT's for each resolution element.

Strata

The classification of sampling units in a population into groups called strata. The strata might be defined as domains for which estimates are derived, or as homogeneous groups of sampling units to reduce sampling errors, or for both purposes.

Subjective Estimates

This phrase refers to estimates that are produced based on personal knowledge about an item. The estimates are notobjective but are influencedby opinions of individuals.

ANNEX A
CROP PRODUCTION ESTIMATES

AGRICULTURAL STATISTICS DIVISION

Department of Agricultural Economics & Statistics
General Administration of Planning & Agricultural Economics
Ministry of Agriculture and Natural Resources
Khartoum — Sudan

Crop Production Estimates
1986 — 1987

Issue No. 4
Reporting Date: February 28, 1987
Date of Issue: April 30, 1987

General Remarks

The estimates are based on:

a) Available data at area headquarters and any other subunits.
b) Interviewing a number of experienced farmers, heads of villages, and local agriculturalists, to improve the collected data.
c) Our teams with the help of local staff tour the main agricultural areas to supplement or improve the existing information.
d) Results obtained from SERISS Project.
e) Crop cutting surveys have been conducted in the main producing areas in the mechanized sector (Gedaref, Damazin, Dilling), New Halfa and Rahad.

General Observations (Season 1986/87)

Climatic conditions: Are considered satisfactory in nearly all regions. The quantity and distribution of rainfall is reasonable in nearly all regions. There was a delay in rains in certain areas in Western, Eastern and parts of Central region which led to late harvest in those areas.

Crop Situation: Compared to the last five agricultural seasons, this season is considered as one of the successful seasons. The estimated production of food crops (sorghum and millet) has dropped from what has been stated in issue 3 and that is mainly due to:

1. Yield figures in the mechanized sector (Gedaref and Damazin) have been rectified according to the crop cutting survey results.

2. Drop in yield in the traditional sector (Darfur & Kordofan).

In comparison with the last season the area of both crops has declined by about 9%, nevertheless the expected production has dropped by nearly 9%, but still 50% higher than the average production of the last 5 years.

The estimated production of oil crops (groundnuts and sesame) is expected to be 53% more than the production last season,.

Cotton: The estimated production of cotton in this season is expected to be 23% more than last years production. It is observed that the area under Acala cotton is reduced by 48% compared to Acala area in last season. Shambat variety has replaced Acala variety and that is because of low prices and unfavourable markets of Acala plus its susceptibility to aphis.

Wheat: Area of Gezira's wheat of this season is reduced due to difficulties in irrigation. The preliminary estimate of this season's production is expected to be about 72% of last season's production.

The main factors which have contributed to the success of this agricultural season area:

1. Good rainy season and even distribution of rains in most producing centres.
2. Availability of agricultural inputs in most producing centres.
3. Better control measures against pests and disease but still more efforts have to be put especially in Western Sudan.

Pest and diseases:

Desert Locust: There was an alarm of desert locusts attacks from neighbouring countries. Control measures have been taken and so far no damage has been reported.

Grasshoppers and Local Locusts: Attacks of grasshoppers and local locusts have been reported in limited areas of Central region, Eastern region North Darfur, and North Kordofan.

Rats: Rat attacks have been reported in Central, Kordofan, and Darfur regions, mainly during sowing and seedling stages. 80-90% of the affected areas have been resown. Although some control measures have been taken to protect crops, but still damage of crops have been continuous in Kordofan and Darfur. Besides the direct damage, rats have indirect adverse effect and that is by leading to late sowing of crops.

American Boll Worm: The latest reports indicate that there was damage of crops especially in Darfur and some parts of Kordofan.

From what has been mentioned, it is clear that pests and diseases play an important role in reducing the yields of the different crops. The latest reports show that there are still big numbers of rats in Western Sudan. Taking in consideration, the multiplication rate and the intelligence of rats storing their food for consumption during the dry season, it is expected that they will be a menance for the coming season. On the other hand, the return of locust swarms from Red Sea coast and Arabian Peninsula is also expected. It seems that, if prompt and effective control measures against pests and diseases are not taken immediately, our production for next year will be badly affected even if climatic conditions are favourable.

SERISS Project:

This project is a joint effort between Governmentt of Sudan, USAID and the Regional Centre for Service in Surveying, Mapping and Remote Sensing (RCSSMRS) of Nairobi. The main objective of this project is to improve production estimates using remote sensing techniques.

Sorghum DURA): Estimates of Area, Production, and Yield, 1986/87 Crop Season with comparisons

Production Center () = Region	5-Year Average 1/			Crop Season – 1985/86			Crop Season 1986/87			Record
	Area 000 Fed	Prod 000 MT	Yield Kg/Fed	Area 000 Fed	Prod 000 MT	Yield Kg/Fed	Area 000 Fed	Prod 000 MT	Yield Kg/Fed	Yield Kg/Fed
Irrigated										
Nile Province (N)	15	8	500	40	20	500	35	18	500	615
Northern Province (N)	7	4	541	25	15	600	25	15	600	750
Blue Nile (C)	51	21	416	51	22	425	61	32	530	500
Gezira & Manaqil (C)	359	169	472	580	400	690	443	244	550	630
Rahad (C)	39	25	644	90	59	630	72	50	700	778
Suki (C)	4	2	429	35	21	610	35	21	600	N/A
White Nile (C)	39	14	369	60	27	450	19	9	450	485
Cash (E)	41	13	310	62	27	440	34	18	540	438
New Halfa (E)	49	20	416	140	53	380	73	40	550	500
Tokar (E)	24	9	364	40	16	400	30	12	400	674
Total Irrigated	628	285	454	1123	658	586	827	459	555	
Rainfed Mechanized										
Damazin (C)	1149	269	235	2665	839	315	2700	915	339	453
Kosti (C)	240	53	222	1160	174	150	967	232	240	639
Gedarif (E)	2512	680	271	3400	1020	300	3300	1020	309	400
Dilling (W)	363	87	240	625	172	275	718	137	191	445
Rank (S)	378	97	256	680	122	180	495	89	180	541
South Darfur (W)	1	1	400	7	1	180	10	2	200	400
Total Rainfed Mech.	4639	1187	256	8537	2328	273	8190	2395	292	
Rainfed Traditional										
Blue Nile (C)	556	133	239	600	108	180	600	120	200	350
Gezira	144	34	239	170	26	150	150	27	180	400
White Nile (C)	167	29	176	430	52	120	400	72	180	371
North Kordofan (W)	419	46	111	200	18	90	175	13	75	300
South Kordofan (W)	402	87	215	520	99	190	498	75	150	397
North Darfur (W)	49	5	107	115	21	180	100	7	70	380
South Darfur (W)	372	79	212	480	86	180	470	42	90	427
Southern Region (S)	760	126	166	700	126	180	400	72	180	520
Total Rainfed Trad.	2869	539	188	3215	536	167	2793	428	153	
Total All	8134	2011	247	12875	3522	274	11810	3282	278	

1/ 5 years average include 1980/81, 1984/85

Cotton: Estimate of Area, Production, and Yield, 1986/87 Crop Season with comparisons

Production Center () = Region	5 – Years Average 1/			Crop Season 1985/86			1986/87		
	Area 000 Fed	Prod 000 MT	Yield B.K.	Area 000 Fed	Prod 000 MT	Yield B.K.	Area 000 Fed	Prod. M. Ton	Yield B.K.
2/Egyptian									
Gezira & Managil (C)	370	203	3.9	401	201	3.5	417	289	4.9
Blue Nile (C)	35	13	2.6	—	—	—	16	7	3.0
White Nile (C)	54	18	2.4	53	19	2.5	55	15	1.96
Rahad (C)	—	*	—	—	—	—	40	31	5.5
Suki (C)	—	—	—	—	—	—	28	6	1.6
Tokar (E)	17	3	1.4	30	6	1.5	40	17	3.0
New Halfa	—	—	—	—	—	—	47	29	4.4
Total, Egyptian	496	242	3.4	484	226	3.3	643	394	4.3
Acala									
Zeidab (N)	5	2	3.4	2	1	3.0	1	*	2.0
Gezira & Managil (C)	102	80	5.5	—	—	—	—	—	—
Blue Nile (C)	21	12	4.1	53	25	3.4	38	17	3.1
Rahad (C)	117	80	4.8	118	93	5.5	84	74	6.2
Suki (C)	26	19	3.5	27	9	2.4	—	—	—
White Nile (C)	19	8	3.2	—	—	—	—	—	—
New Halfa (C)	74	41	3.9	69	53	5.5	26	22	6.0
Total, Acala	364	256	4.9	269	181	4.8	139	112	5.7
American									
Blue Nile (C)	29	6	1.4	2	1	2.8	2	1	3.0
Gedarif (E)	7	1	0.9	—	—	—	—	—	—
Nuba Mountains (W)	73	10	1.0	33	10	2.0	27	8	2.0
Equatoria (S)	30	2	0.5	25	2	0.6	10	1	1.0
Total American	139	19	1.0	60	13	1.5	39	10	1.8
Grand Total	977	517	3.7	807	419	3.7	821	516	4.4

1/ 5 – year average includes 1980/81 – 1984/85

*Production less than one thousand M. tons.

2/ includes Shambat Variety.

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Sesame: Estimates of Area, Production, and Yield, 1986/87 Crop Season with Comparisons.

Production Center	5-Year Average 1/						Crop Season — 1986/87		
( ) = Region	Area 000 Fed	Prod 000 MT	Yield Kg/Fed	Area 000 Fed	Prod 000 MT	Yield Kg/Fed	Area 000 Fed	Prod 000 MT	Yield Kg/Fed
Rainfed Mechanized									
Damazin (C)	225	25	110	655	16	25	700	88	125
Gedarif (E)	312	40	129	430	37	85	500	70	140
Dilling (W)	24	3	110	70	5	75	78	5	60
Rank	27	4	132	20	*	25	6	1	100
Kosti (C)	0	0	0	3	*	10	12	1	85
Total Rainfed Mech.	588	72	121	1178	58	49	1296	165	127
Rainfed Traditional									
Blue Nile (C)	201	24	119	175	11	60	175	18	100
White Nile (C)	30	4	127	25	1	50	25	2	90
North Kordofan (W)	705	41	58	650	20	30	690	35	50
South Kordofan (W)	138	15	107	250	23	90	246	30	120
North Darfur (W)	11	1	94	40	3	80	40	4	90
South Darfur (W)	178	16	92	100	8	80	80	5	60
Southern Region (W)	161	20	127	100	10	100	60	5	90
Total Rainfed Traditional	1424	121	85	1340	76	101	1316	99	75
Grand Total	2012	193	96	2518	134	53	2612	264	101

1/ 5-year average includes 1980/81 to 1984/85
* Production less than 1000 M. tons.

Wheat: Prel. Estimates of Area, Production, and Yield, 1986/87 Crop Season with Comparisons.

Production Center	5-Year Average 1/			Crop Season — 1985/86			Crop Season — 1986/87 2/		
( ) = Region	Area 000 Fed	Prod 000 MT	Yield Kg/Fed	Area 000 Fed	Prod 000 MT	Yield Kg/Fed	Area 000 Fed	Prod 000 MT	Yield Kg/Fed
Irrigated									
Nile Province (N)	6	4	666	10	6	600	8	5	600
Northern Province (N)	27	21	782	50	40	800	40	32	800
Gezira & Managil (C)	207	97	467	240	120	500	160	80	500
White Nile (C)	18	11	607	30	15	500	30	15	500
Total Irrigated	293	150	512	360	199	553	268	147	549
Total All	293	150	512	360	199	553	268	147	549

1/ 5 – Year average includes 1980/81 -- 1984/85
Wheat areas indicated the proposed areas.

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Millet: Estimates of Area, Production, and Yield, 1986/87 Crop Season with comparisons.

Production Center ( ) = Region	5-Year Average 1/			Crop Season — 1985/86			Crop Season — 1986/87		
	Area 000 Fed	Prod 000 MT	Yield Kg/Fed	Area 000 Fed	Prod 000 MT	Yield Kg/Fed	Area 000 Fed	Prod 000 MT	Yield Kg/Fed
Irrigated									
Tokar (E) flood	16	7	432	22	7	300	15	5	330
Total Irrigated	16	7	432	22	7	300	15	5	330
Rainfed Mechanized									
Damazin (C)				85	17	200	20	5	250
Gedarif (E)	6	1	161	20	3	120	10	2	200
Dilling (W)				1	*	200	1	*	150
Kosti (C)				20	2	90	40	4	100
Total Rainfed Mech.	6	1	161	126	22	174	71	11	164
Rainfed Traditional									
Blue Nile (C)	61	9	151	30	4	150	30	4	120
W. Nile (C)	76	13	171	40	6	150	20	2	90
Gezira	17	1	69	5	1	150	5	1	100
North Kordofan (W)	1186	88	74	2000	140	70	1635	98	60
South Kordofan (W)	46	8	166	120	22	180	90	11	120
North Darfur (W)	402	48	119	800	80	100	900	68	75
South Darfur (W)	994	174	175	900	122	135	860	77	90
South Region (S)	85	14	162	85	13	150	50	8	150
Total Rainfed Trad.	2867	355	124	3980	388	97	3590	269	75
Grand Total	2886	363	125	4128	410	99	3626	285	79

1/ 5 - Year average includes 1980/81 to 1984/85 *Less than 1000 M. tons.

Groundnuts: Estimates of Area, Production, and Yield, 1986/87 Crop Season with comparisons.

Production Center ( ) = Region	5-Year Average 1/			Crop Season — 1985/86			Crop Season — 1986/87		
	Prod 000 MT	Area 000 Fed	Yield Kg/Fed	Area 000 Fed	Prod 000 MT	Yield Kg/Fed	Area 000 Fed	Prod 000 MT	Yield Kg/Fed
Irrigated									
Gezira & Managil (C)	169	104	614	103	77	750	149	115	775
Rahad (C)	63	49	775	40	16	400	58	46	800
Suki (C)	12	10	803	1	*	450	2	1	500
New Halfa (E)	37	27	749	2	1	650	24	24	1000
Total Irrigated	282	191	677	146	94	644	233	186	798
Rainfed Traditional									
Blue Nile (C)	17	8	494	5	1	180	5	1	180
White Nile (C)	41	11	275	10	2	180	10	2	180
North Kordofan (W)	594	128	216	130	26	200	206	52	250
South Kordofan (W)	31	7	227	30	8	250	83	25	300
North Darfur (W)	79	13	162	50	15	300	85	17	200
South Darfur (W)	704	140	198	460	106	230	500	105	210
Southern Region (S)	233	48	208	120	22	180	60	11	180
Total Rainfed Trad.	1699	347	222	805	180	224	949	213	224
Grand Total	1981	568	287	951	274	288	1182	399	338

1/ 5 – Year average includes 1980/81 to 1984/85. *Production less than one thousand M. tons.