Japan International Cooperation Agency(JICA)

Geographical Institute of Burkina (IGB)
Ministry of Infrastructure, Housing and Urban Planning

THE STUDY ON THE NATIONAL TOPOGRAPHIC MAPPING OF THE SOUTHWESTERN AREA IN BURKINA FASO

MAIN REPORT

MARCH 2001

Aero Asahi Corporation

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PREFACE

In response to a request from the Government of Burkina Faso, the Government of Japan decided to conduct a development study concerned of the national topographic mapping in the southwestern area of Burukina Faso and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA dispatched a study team headed by Mr. Kokichi Kimura of the Aero Asahi Cooperation four times between November 1998 and February 2001.

The team held discussions with the officials concerned of the Government of Burkina Faso and conducted field surveys at the study area. Upon returning to Japan, the team conducted further studies and prepared this final report.

I hope that this report will contribute to the promotion of this project and to enhancement of friendly relationship between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the study for their close cooperation and supporting to the Study.

March 2001

Kunihiko Saito
President
Japan International Cooperation Agency

March 2001

Mr. Kunihiko Saito
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Mr. Saito,

Letter of Transmittal

We are pleased to submit to you the Study Report on the National Topographic Mapping of the Southwestern Area in Burkina Faso. The report contains the advice and suggestions of the authorities concerned of the Government of Japan and your Agency as well as the formulation of the mentioned project. Also included are comments made by the Geographic Institute of Burkina, Ministry of Infrastructure, Housing and Urban Planning of His Majesty's Government of Burkina Faso during technical discussions on the draft report which were held in Ouagadougou.

This Study had the objectives to develop the 1/50,000-scale national topographic maps covering the southwestern area of 20,600 square kilometers that is important for the economic development of Burkina Faso and to conduct the transfer of the national topographic mapping technology.

To fulfill these objectives, the topographic mapping method was improved from the conventional analog mapping system into a digital mapping system. The technical standards for it were also established and the mapping equipment, the digital topographic mapping data and the national topographic maps were developed. Further, the GIS basic data was produced from the digital topographic data and the presentation of a pilot GIS was made at a seminar.

Based on the results of this Study, we recommend the following points: The extensive use of the GIS using the GIS basic data will contribute to the higher efficiency of services in the policy-making agencies and promotion of the sustainable development policies to cope with the increasing pressure of desertification. It is also expected that the development of the national topographic maps and GIS basic data to cover the entire country will be promoted through operating the developed national digital topographic mapping system.

We wish to take this opportunity to express our sincere gratitude to your Agency, the Ministry of Foreign Affairs, the Ministry of Land, Infrastructure and Transport. We also wish to express our deep gratitude to the Geographic Institute of Burkina, Ministry of Infrastructure, Housing and Urban Planning of His Majesty's Government of Burkina Faso for the close cooperation and assistance extended to us during study.

Very truly yours,

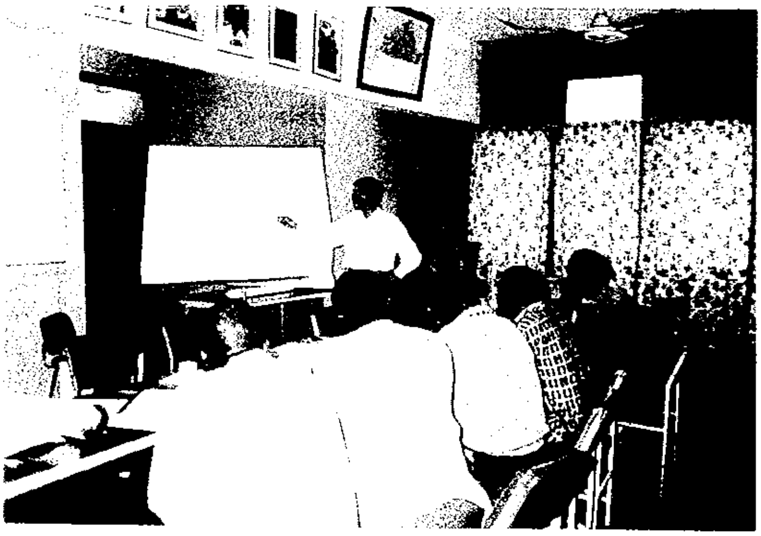
Kokichi Kimura
Team Leader
Study Team on the Study of the
National Topographic Mapping of the
Southwestern Area in Burkina Faso

Exchange of the minutes with signature

Management Council in IGB

Management Council in IGB

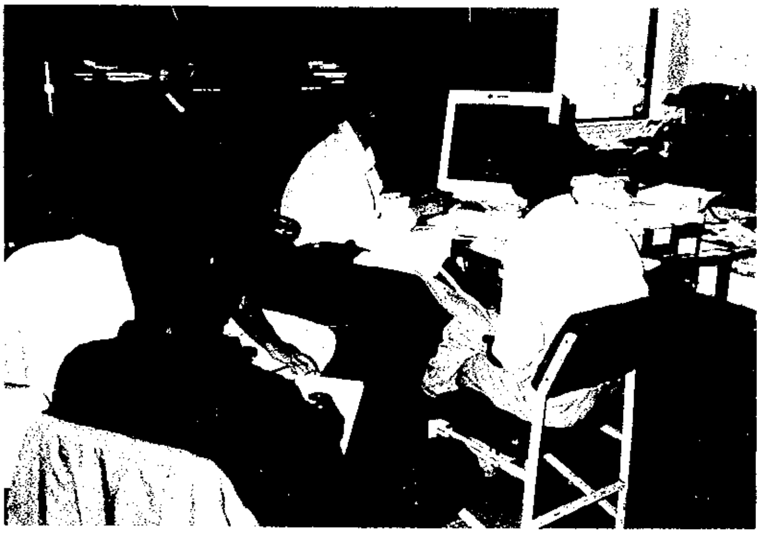
A scenery in the study area



Technological consultation on levelling

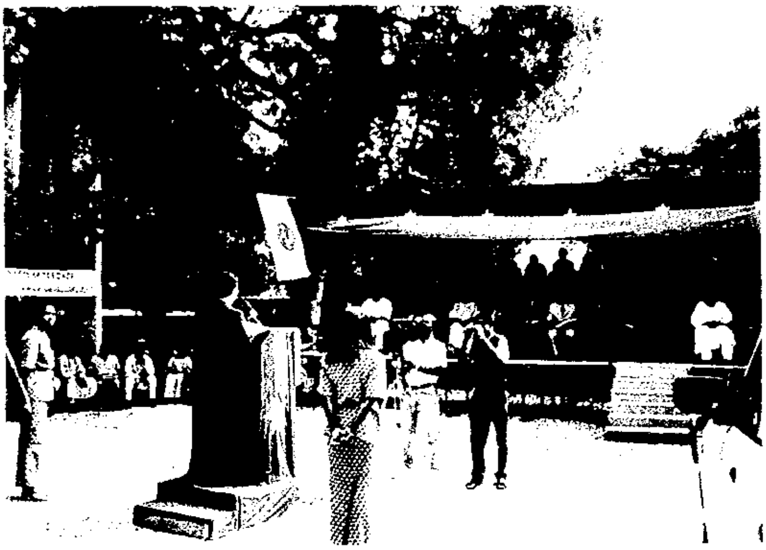
A scenery of levelling observation

Explanation of the established equipment

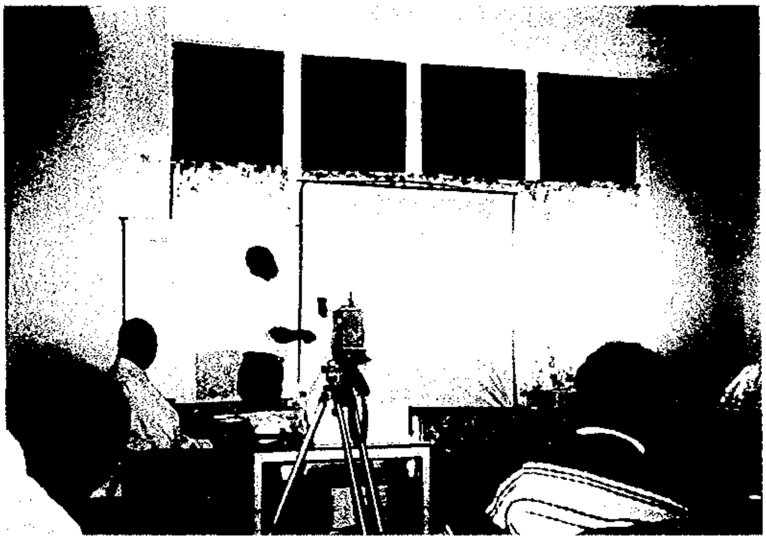


OJT of digital plotting

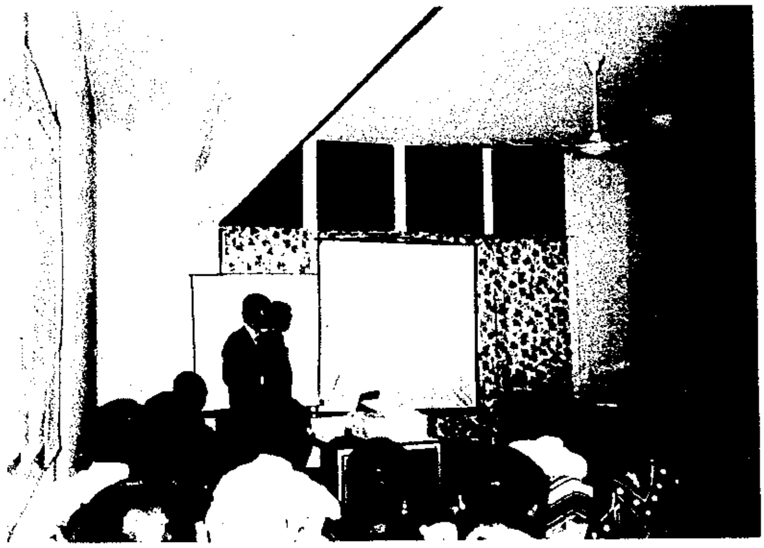
Technological consultation of field identification



Seminar opening ceremony



Technological presentation of a counter personal in the seminar



Technological presentation of a member of the study team in the seminar

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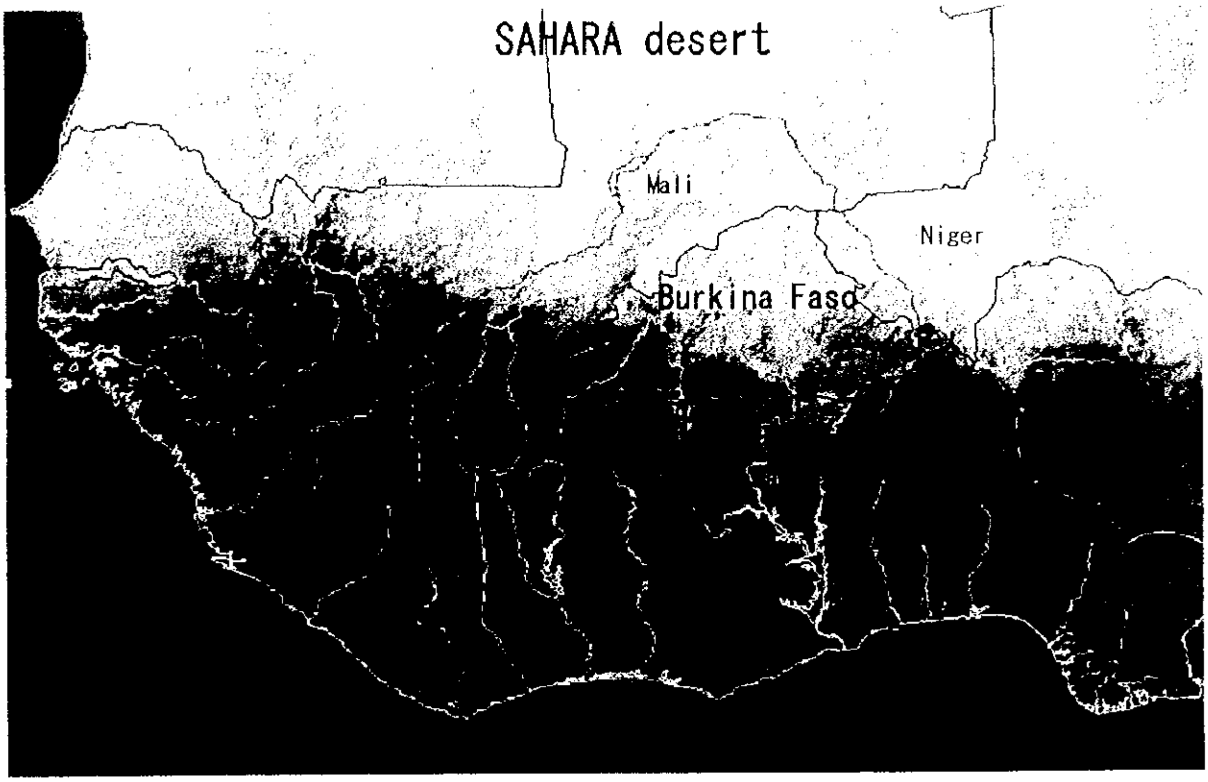

Figure 1　Study area in Burkina Faso

Mean annual rainfall (in mm)
over a 30-year period, 1966-1995

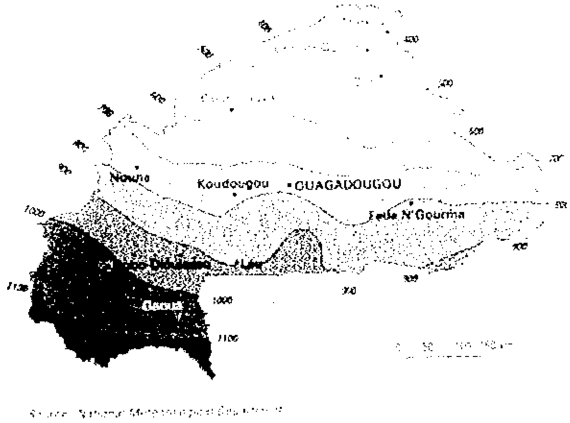

Figure 2　Rainfall distribution and project area

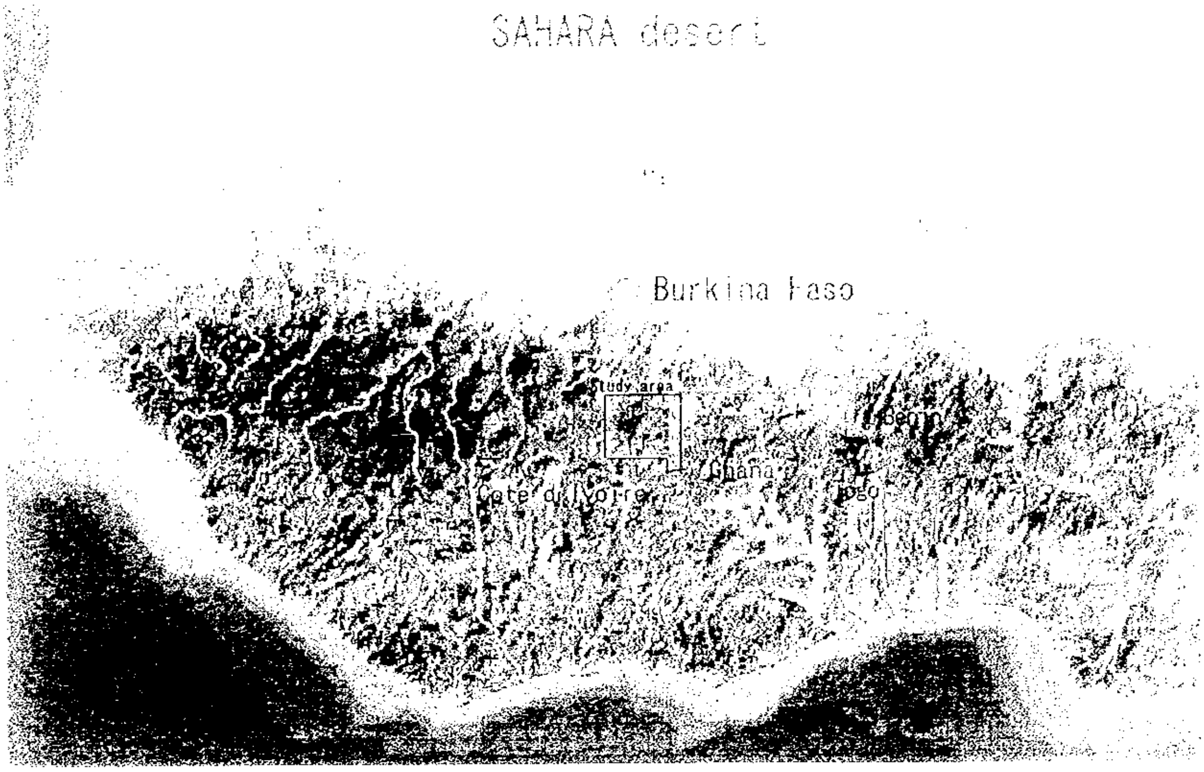

Figure 1 Study area in Burkina Faso

Figure 2 Rainfall distribution and project area

1. INTRODUCTION

1.1. Background to the Study

Burkina Faso is an inland country of West Africa that is located at the south end of the Sahara and its natural environment and its agricultural and stock raising industry, an economic core, are seriously affected by the pressure of desertification. (Refer to Figure 1.) The Government of Burkina Faso has been promoting the comprehensive development and maintenance of its national land under "the Second Five-Year National Land Development Plan". However, it has faced the necessity of acquiring the comprehensive information on the national land space in order to promote the sustainable economic development in harmony with the environment. The Government has therefore established the "Schema Directeur de Cartographie et Territoire (SDCT)", which is now being executed.

The study area located in the southwestern part of Burkina Faso belongs to the Sudan-type tropical climate zone and is relatively rich in water resources, but this area is retarded in development because it is inadequate for residence due to endemics such as Guinea worm, trypanosomiasis and onchocerciasis. The Government of Burkina Faso has promoted the campaign against endemics under the assistance of the United Nations. As a result, this policy has been effectively executed to cause the movement of the population to the southwestern area and propel the agricultural development. The GDP of Burkina Faso has been enhanced in the long term though it has depended upon drought and rainy seasons, and it has been highly evaluated as a brilliant achievement in the Sahel region where the agriculture is generally inactive.

The Government of Burkina Faso continues to promote the studies for the water resources dam construction plan and the development of the alluvial plain (Bas Fonds) that is suited for rice and other farming. This means that the Government faces the task to enhance this area up to the sustainable higher development level harmonized with the natural environment. For this purpose, the Government of Burkina Faso has made a request to the Government of Japan for technical cooperation in the national topographic mapping study of this study area.

1.2.Objective of the Study

Based on the results of the preliminary study, the Scope of Work agreement was signed and became effective between the preliminary study team and IGB. The study has the following two objectives:

(1) To produce the 1/50,000-scale national topographic maps for the southwestern area of approximately 20,600 km^2, Burkina Faso.
(2) To transfer the technology to the counterparts on the Burkina Faso side through this study.

The work processes to be carried out to improve the conventional technology in the practical work are as follows:

(1) Plotting process

In the plotting process, 1/50,000 digital topographic map data is created in the 10m contour line intervals.

(2) Compilation process and structuralization process

The digital topographic data is structuralized in phase.

The total period of the study will be about 30 months.

1.3. Final output configuration of the Study

The final output configuration of the study is shown in Figure 3.

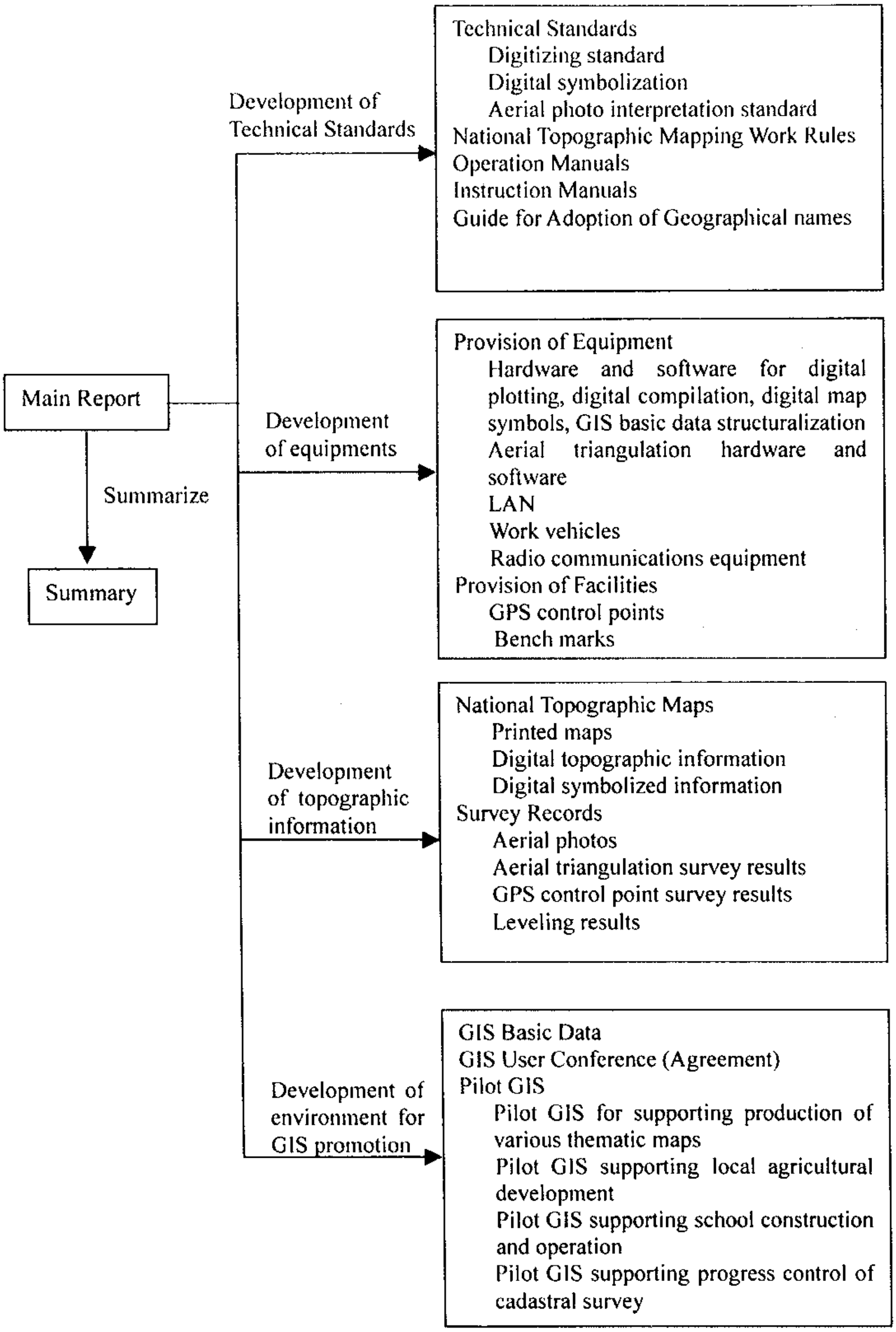

Figure 3 Final output configuration of the study

2. OUTLINE OF THE STUDY AREA AND TECHNICAL CONDITION

2.1. Priority of the National Topographic Mapping in the Southwestern Area

2.1.1. Economic trend and role of the southwestern area in Burkina Faso

Burkina Faso is one of the poorest countries that is ranked at the 18th of 160 countries in the world in the evaluation method based on the GDP per person according to the "World Development Report 1991" issued by the World Bank. As the rank was the 7th in 1989, its situation has been remarkably improving.

In Burkina Faso, about 85% of the total labor population is engaged in agriculture and livestock raising. Agriculture occupies about 30% of the GDP and the export of agricultural products shares over 60% of foreign currency income.

Since the country largely depends upon the self-supporting and self-sufficient rain-fed farming, it suffered a hard hit due to a long drought from 1972 to 1973. After that, the long drought from 1983 to 1984 caused severe damage to the agricultural production of this country.

In the rainy years of 1984 to 1985, the economy was recovered remarkably and the GDP recorded a growth of 10.5% in yearly average. However, the start of the rainy season was delayed in 1987 and the GDP growth rate decreased to 7%. In 1989, the agricultural production was sluggish due to drought and the GDP growth rate was minus 0.4%.

However, the long-term GDP growth rate for a period of 1982 to 1990 exceeded 3% of population growth rate. The real growth rate was 3.7% in yearly average. This high growth rate was due to the positive promotion of the campaign against onchocerciasis, the endemic disease in the southwestern area, that the Government of Burkina Faso and the United Nations were coping with. This policy was effectively executed to ensure the cultivation of the fertile southwestern area that is relatively rich in water resources. As a result, the agricultural production in the southwestern area increased and accordingly increased the national agricultural production and GDP. The rainfall characteristics in the southwestern area will be seen from Figure 2.

2.1.2. Advanced development stage and necessity of early development

The development plan in Burkina Faso was executed from the first to the fourth phase during the period of 1967 to 1986. For the period of 1986 to 1990, the New First Five-Year

National Development Plan was executed with the individual targets:

① Priority investment on agricultural sector and water resource development for self-supply and livelihood improvement (43.8% of total investment);

② Prevention of desertification through forest conservation;

③ Suppression of trade deficit;

The Second Five-Year National Development Plan (1991-1996) is aimed at:

① Increase of agricultural and livestock-raising production keeping the environmental and social balance;

② Activation of business activities through improvement of investment environment in the private sector;

③ Reduction and efficiency of the public sector;

④ Activation of human resources through reinforcement of elementary education and insurance service for grassroots.

The development concept and plan for the southwestern area could be seen in the more detailed levels in the request. However it is necessary to grasp that the development level was different in quality from the development stage in which the movement of population has made progress after the epidemics has been stamped out, so that the farmland has been expanded. Although the load of the cultivated farmland on the natural environment is large even at the present stage, the future development plans will be of larger scale through introduction of up-to-date technologies. Therefore, it is necessary to grasp the comprehensive national land space information, and make plans and execute the development from a higher point of view in order to promote sustainable production in harmony with the natural environment.

The southwestern area has not only a yearly rainfall of over 1,000mm but also fortunate topographic conditions in which the alluvial plain formed with fertile soil by the floods from the Mouhoun and the Komoe rivers is extended. It is clear that the development of this area capable of cultivating money-convertible rice has a high priority to Burkina Faso including the Sahel region.

At present, the study of the alluvial plain is in progress under the guidance of the U.N. in order to realize the development concept. As there is no 1/50,000 national topographic map, the 1/200,000 topographic maps have been developed to the 1/100,000 scale, the alluvial plain has been interpreted from the 1/50,000 aerial photos, and the interpreted maps have been developed to the 1/100,000 scale and digitized. (Refer to Figure 4) These processes will be simplified in interpretation, plotting and digitization of 1/50,000 national topographic maps in the plotting process. Therefore, it is desired to provide 1/50,000 national topographic maps as soon as possible.

In addition, 1/100,000 soil maps are being prepared for the regional agricultural development plan in a similar method, but 1/50,000 national topographic maps should also be provided for this plan as soon as possible.

Most of on-going development plans are in similar unfavorable conditions because there is no 1/50,000 national topographic map, resulting in lower study accuracy, duplicate costs and delay in the study.

Figure 4 Alluvial plain study work conditions (a, b)

2.2. National Topographic Maps and Others Materials Available in Burkina Faso

The agency for managing national topographic maps in Burkina Faso is the Geographical Institute of Burkina Faso (Institute Geographique du Burkina: IGB) that belongs to the Ministry of Infrastructure, Housing and Urban Planning (Ministre des Infrastructures de l'Habitat et de l'Urbanisme).

2.2.1. 1/200,000 national topographic maps

The national basic maps covering the entire country of Burkina Faso are the 1/200,000-scale national topographic maps that IGN France produced as part of the West African maps in the colonial time. In Burkina Faso, aerial photography was carried out for a period of 1956 to 1960. The entire country is covered with 34 map sheets. The contours are represented in 40m intervals and where the neat lines have intervals of 1° in latitude and longitude.

2.2.2. 1/500,000 national topographic maps

The 1/500,000 national topographic maps were produced by compilation in scale of the 1/200,000 topographic maps. The organization that produced these maps was IGN France. Figure 5 shows the map indexes of the 1/200,000 and the 1/500,000 national topographic maps.

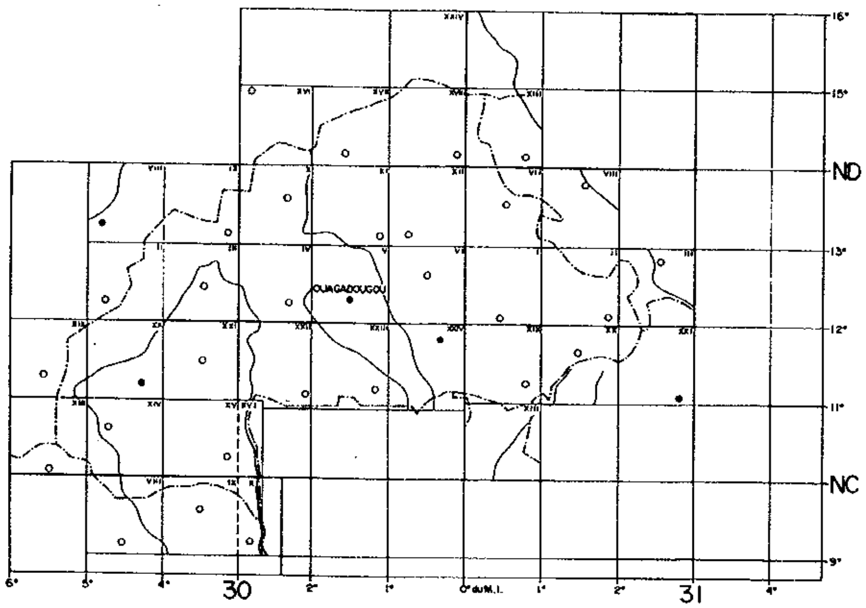

Figure 5 Map indexes of the 1/200,000 and the 1/500,000 national topographic maps

2.2.3. 1/50,000 national topographic maps

The 1/50,000 national topographic maps were produced by dividing the 1/200,000 national topographic maps into 4 parts for each of latitudinal and longitudinal directions in 15-minute neat lines. The actual area of each map sheet is approximately 740 square km.

The 1/50,000 national topographic maps produced by dividing the 1/200,000 national topographic maps into 4 parts are numbered 1, 2, 3 and 4 from the bottom-left as shown in Figure 6 1/50,000 national topographic map development plan and each part is further divided into 4 sub-parts and marked with a, b, c and d as shown in Figure 6.

Figure 6 shows the index maps and the produced map sheets of the 1/50,000 national topographic maps under planning. These national topographic maps have been produced through the following events:

① Supply of equipment for a period of 1976 to 1983 by the Netherlands, the largest donor at the time of foundation of IGB and training of engineers at ITC.
② Fund assistance by Switzerland for GPS survey including supply of 2 GPS receivers for geodetic net development and technical training.
③ 1/50,000 national topographic map production project in joint work with CLIDE, LTD, UK under the fund assistance (loan) by Islamic Development Bank.

2.2.4. Various thematic maps and other maps

IGB has produced various thematic maps in addition to various national topographic maps. The main maps are as follows:

- Maps for administrative use: 1/1,000,000 maps and 1/500,000 regional maps
- Provincial maps: 1/200,000 provincial maps
- Language maps: Produced in cooperation with CRNST.
- Wall maps for school use
- Metropolitan guide map

In 1993, the World Bank offered a fund assistance to introduce a GIS in Burkina Faso and provided the equipment including a digitizer, a plotter and GIS basic software. In addition, a short-term training course was carried out in Canada in order to create the 1/200,000 national topographic database (BNDT). Although there are not so many cases, it seems that the use of the GIS has been growing.

2.3 National Topographic Map Development Plan

2.3.1 1/50,000 national topographic mapping plan

The national topographic mapping plan of Burkina Faso has been executed under the National Topographic Map Development Master Plan (SDCT) that was resolved at the Cabinet meeting in 1990 as a high-priority plan in the Second Five-Year National Development Plan. For the resolution at the Cabinet meeting, this plan was put into the priority order and deliberated in detail in accordance with the rules for national topographic map production in African countries adopted by ECA, and based on the questionnaire study covering the organizations using the national topographic maps in Burkina Faso.

The most important plan in SDCT was the 1/50,000 national topographic mapping plan, the detail of which is shown in Figure 6. Figure 6 shows additionally the map sheets produced in the Study.

BURKINA FASO

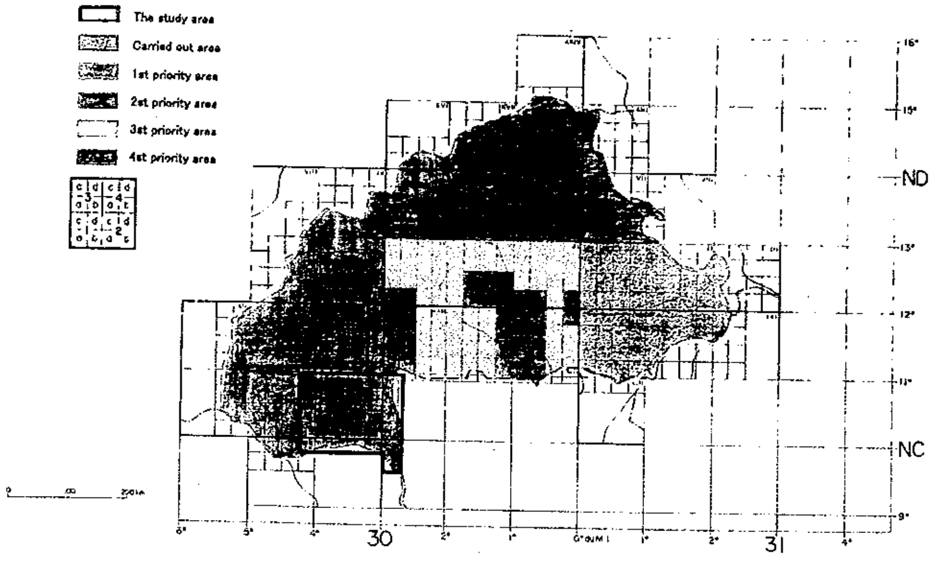

Figure 6 1/50,000 national topographic mapping plan

2.4. National Topographic Mapping Capacity of Burkina Faso

2.4.1. Geodetic survey standards

The standards for horizontal positioning and leveling can be guaranteed by the national control points and leveling net. In Burkina Faso, the geodetic datum and the original point of leveling are appropriately defined and the national control points and leveling net are provided as in Figure 7 and Figure 8. In the study area, it is necessary to increase the second-order GPS control points and the third-order bench marks.

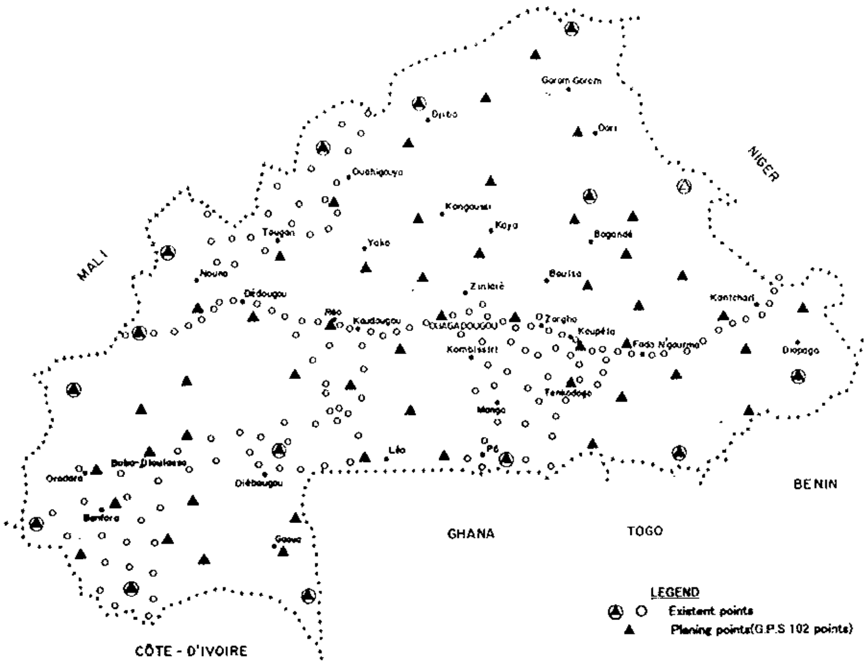

Figure 7 Control point location map

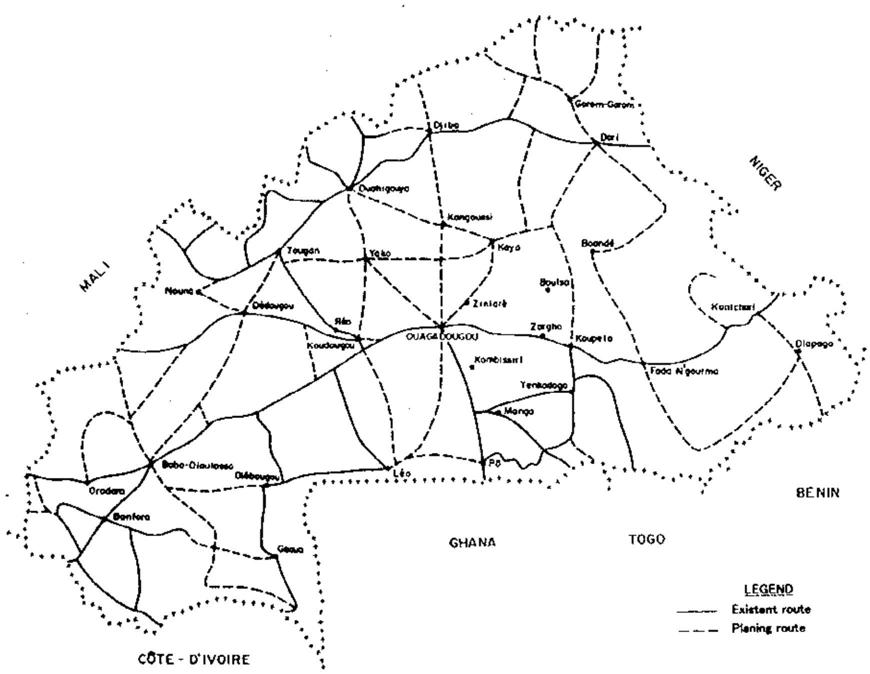

Figure 8 Benchmark network map

2.4.2. Technical capability of engineers

In response to the request for technology transfer, the technical capability of IGB engineers concerned with the development work of the 1/50,000 national topographic maps has been examined in the oral question method. The evaluation consists of tow groups: group A for which technical advice and instructions are required and group B is requiring technical training for new technologies. The results of examination are shown in Table 1.

Table 1 Technical capability of technical personnel

Work Process	Evaluation	Remarks
Aerial photo signal installation	A	The work performed by IGB by itself is sufficient.
GPS control point survey	A	2 engineers were trained in Switzerland. The engineers dispatched by Lausanne Polytechnic, a Swiss confederation survey public corporation, trained the IGB engineers. IGB's independent survey was also made with sufficient results.
Leveling	A	IGB's independent survey was made with sufficient results.
Aerial triangulation	B	One engineer had experience in studying at ITC, the Netherlands. 5 engineers were engaged in this work. IGB had the PATM386 software, but no experience in block adjustment. Photo control point survey was made for each model for orientation because the software version was too old and not installable.
Digital plotting	B	One engineer had experience in studying at ITC, the Netherlands and at an educational organization of Ministry of Elementary Education, France. 2 engineers were trained for digital plotting in Canada. 3 other engineers were engaged in this work. They are experienced in many contract works, but it is necessary to train them for the new system customized for national topographic mapping.
Field identification	A	IGB had an achievement of joint work with CLIDE LTD., UK.
Digital information processing	B	One engineer was trained at a private French company. 4 engineers were trained in Canada. One engineer was trained in Belgium. IGB had great achievements of GIS data digitized from the 1/200,000 national topographic maps and analysis of land use change for 1970 to 1990 using satellite images. However, it is necessary to train them for the new system customized for 1/50,000 national topographic maps.

2.4.3. IGB's own equipment and materials

The survey equipment and materials that IGB possesses are shown in Table 2.

Table 2 IGB's own survey equipment and materials

Survey equipment/material	Quantity	Remarks
(1) Geodetic and topographic survey equipment		
• Theodolite	15 units	
• Level	9 units	
• RDS (Range detection system)	2 units	
• MICROFIX	6 sets	
• D15	1 unit	
• GPS receiver (Leica 2000)	2 units	
• GPS receiver (Leica 3000)	2 units	
• Base line analysis software (SAI-Ver.2.1)	1 set	
(2) Photogrammetric equipment		
• Plotter (A10)	1 unit	Repaired in the study.
• Plotter (B8S)	2 units	With one encoder.
• Plotter (B8S)	1 unit	Modified to analyzing plotter.
• Planicarte	1 unit	Out of order
• PUG-4	1	
• MicroStationVer.5(digitizing software, English)	1 1	
• 3DD (digitizing software – French)	1	
• PAT-M386 (aerial triangulation software)		
(3) Photograph process equipment		
• Developer (FE120)	1 unit	
• Printer	2 units	
• Enlarger	1 unit	
• Film dryer (TG-24)	1 unit	
(4) Information processing/digitizing equipment		
• Workstation (SUN)	3 sets	
• Scanner (A0 color: CT-3600)	1 unit	
• Digitizer (A0)	1 unit	
• Plotter (HP755MC)	1 unit	
• Plotter (MH MX)	1 unit	
• PC586	5 units	
• PC486	7 units	
• Software (ARCINFO PC)	3	
• Software (ARCVIEW)	12	
• Software (Arc view UNIX)	2	
(1) Map editing equipment		
• Map reproduction camera (KLIMSCH)	1 unit	
• Continuous developer (KLIMSCH)	1 unit	
• KARGL correction projector	1 unit	
• Contact print vacuum printer	1 unit	
(2) Work vehicles		
• Toyota BJ45	1 unit	
• Toyota BJ60	1 unit	
• Toyota double-cabin	1 unit	
• Peugeot	1 unit	

3. PLAN OF THE STUDY

3.1. Approach to the objectives

As the result of analysis of the conditions necessary to attain the two objectives as agreed upon in the S/W, the two objectives are broken down into 4 approaches as described below.

3.1.1. Development of 1/50,000 national topographic digital mapping system

(1) Cost-effective system with high-speed processing

In comparison in the practical technology, the cost of digital mapping is 20% lower than that of analog mapping and the map production period is 40% shorter. Especially, analog mapping requires more experience and continuous mental concentration and higher skills in compilation drafting and scribing and a longer time to train technical staves. Therefore, a digital mapping system will be designed and developed from the point of view of mapping cost and speed and training of technical staves.

(2) Information society-oriented system for creating GIS basic data

As the advanced information technology and the development of infrastructure for it is making progress, the value of digital information has drastically been enhanced also in Burkina Faso. In particular, the digital topographic mapping information on the national basic maps as universal GIS basic data has become the base of the spatial information in relation to all the social activities including administration, which will be the center of the society in an era in which decision-making must be faster and more comprehensive from the high-level point of view, allowing information to create new values. For this purpose, a digital mapping system that can be directly connected to a system to produce GIS basic data is called for. Digital information would be obsolete and the information operation method would be forgotten if the data is not always used without added or corrected changes of data. Therefore, a system that can not only store the data for future use, but a system that allows the data to readily be used will be developed.

(3) System adaptable to the policy, technology and economic strength

In Burkina Faso, development in harmony with the environment is desired. It is also called for to develop the 1/50,000 national topographic maps in an economical and urgent way and as independently as possible and to develop the system of the level and scale which they can operate and maintain by themselves using the technical capability acquired for a long time.

(4) Basic design diagram of 1/50,000 national topographic digital mapping system

The basic design diagram of the 1/50,000 national topographic digital mapping system is shown in Figure 9.

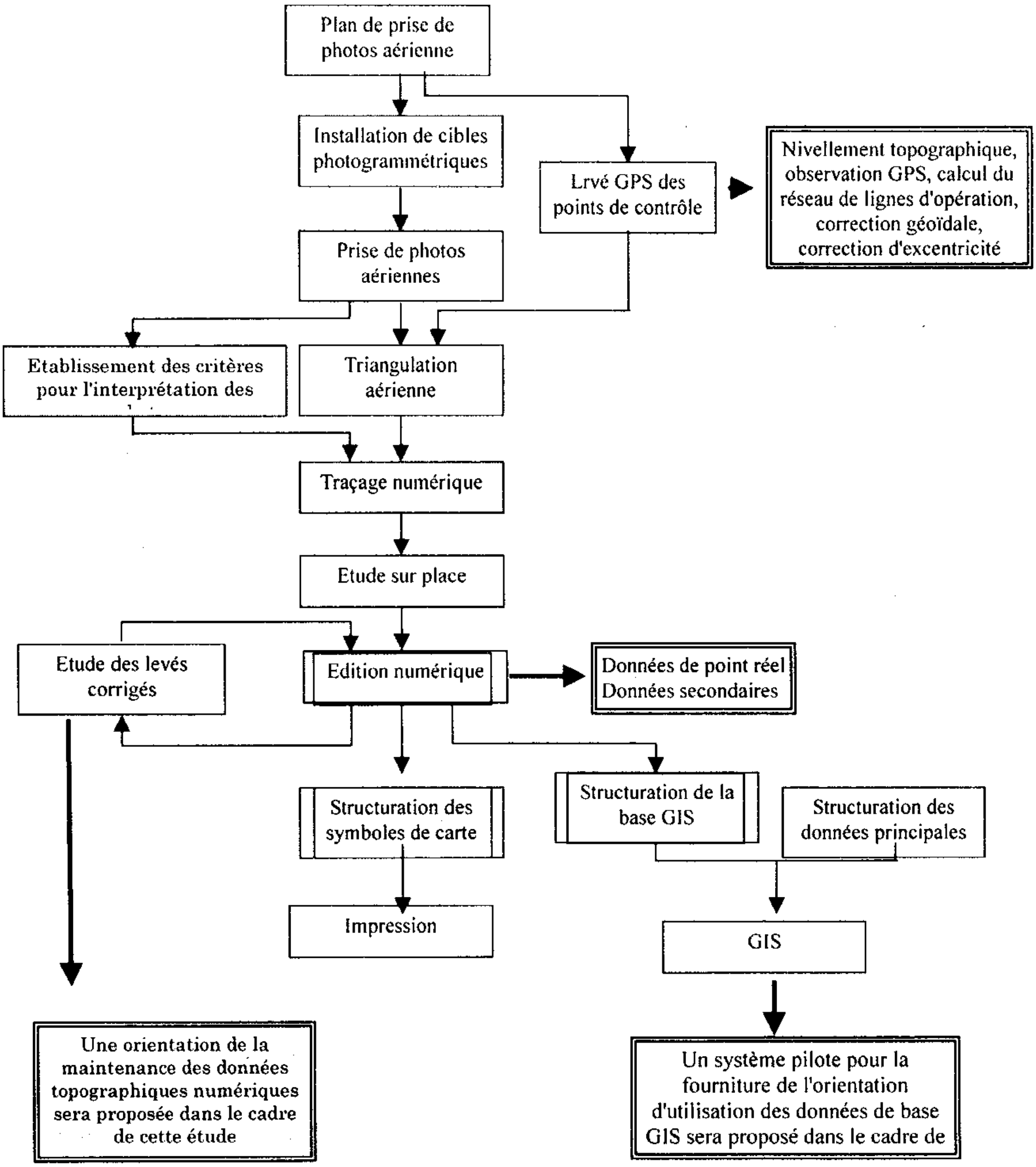

Figure 9 Basic design diagram of 1/50,000 national topographic digital mapping system

3.1.2. Training of technical staff for 1/50,000 national topographic mapping system

It is called for by IGB to educate its technical personnel for operation and maintenance of the 1/50,000 national topographic mapping system and its technical leaders for future improvement of the system after the completion of development under the study

3.1.3.Development of 1/50,000 national topographic maps and digital mapping information of the southwestern area

The large-scale development study of the 1/50,000 printed national topographic maps, digital topographic mapping information and GIS basic data covering the southwestern area of 20,600km^2 is now in progress and it is desired to complete the development as early as possible (within about 29 months).

3.1.4. Development of Pilot GIS using the GIS basic data

The measures in which the digital topographic mapping data developed in this study can be operated as GIS basic data in an effective, immediate and practical way will be recommended.

3.2. Operational plan of the Study

3.2.1. Work process and flowchart of the Study

The work process and flowchart of this study are shown in Figure 36.

In Figure 36, the process indicated with a tag number affixed to the work process number is an additional process under the additional request determined through mutual discussions in each year.

3.2.2. Survey design

(1) Survey of second-order GPS control points and photo control points

The design diagram of second-order GPS control point survey and photo control point survey are shown in Figure 37.

(2)Third-order leveling

The third-order leveling design diagram is shown in Figure 38.

(3)Aerial photography

The aerial photography plan diagram is shown in Figure 39.

3.3. Management Plan

3.3.1. Establishment of Management Council

In regard to the operation of this study, IGB and the study team established the Management Council with the purpose of executing this study in close cooperation of both. The Management Council consist of the Director General of IGB and the members appointed by the Director General depending upon the subject of discussions, and the study team leader and the members appointed by the study team leader. The chairman of the Management Council was the IGB Director General, and if the Director General can not attend the meeting, the study team leader was the chairman. If both of the IGB Director General and the study team leader could not attend the meeting, a proxy who was given the right to chair the meeting is assigned through a written notice send to the above. At the operation meeting, the minutes of meeting were prepared and signed by the duly appointed representatives of both parties.

3.3.2. Nomination of coordinator

The Director General of IGB or the study team leader appointed the coordinator for each process to assure mutual communication and coordination on the works shared by each party in order to ensure thorough communication and coordination in the implementation stage.

3.3.3. Formation of GIS basic data user conference

IGB and the study team organized the GIS basic data user conference consisting of related organizations in order to mutually cooperate in collection of related information, construction of the pilot GIS and operation of the pilot GIS based on the policy of operating the digital topographic data developed in the study,.

4.DESCRIPTION OF THE STUDY

4.1. Development of 1/50,000 National Topographic Digital Mapping System

4.1.1. Functional improvement design of 1/50,000 national topographic digital mapping system

It was studied and designed how the functions of each work process of the system are to be improved based on the basic design diagram and the design concept as described in 3.1.1. The overview of the functional improvement design is illustrated in Figure 10.

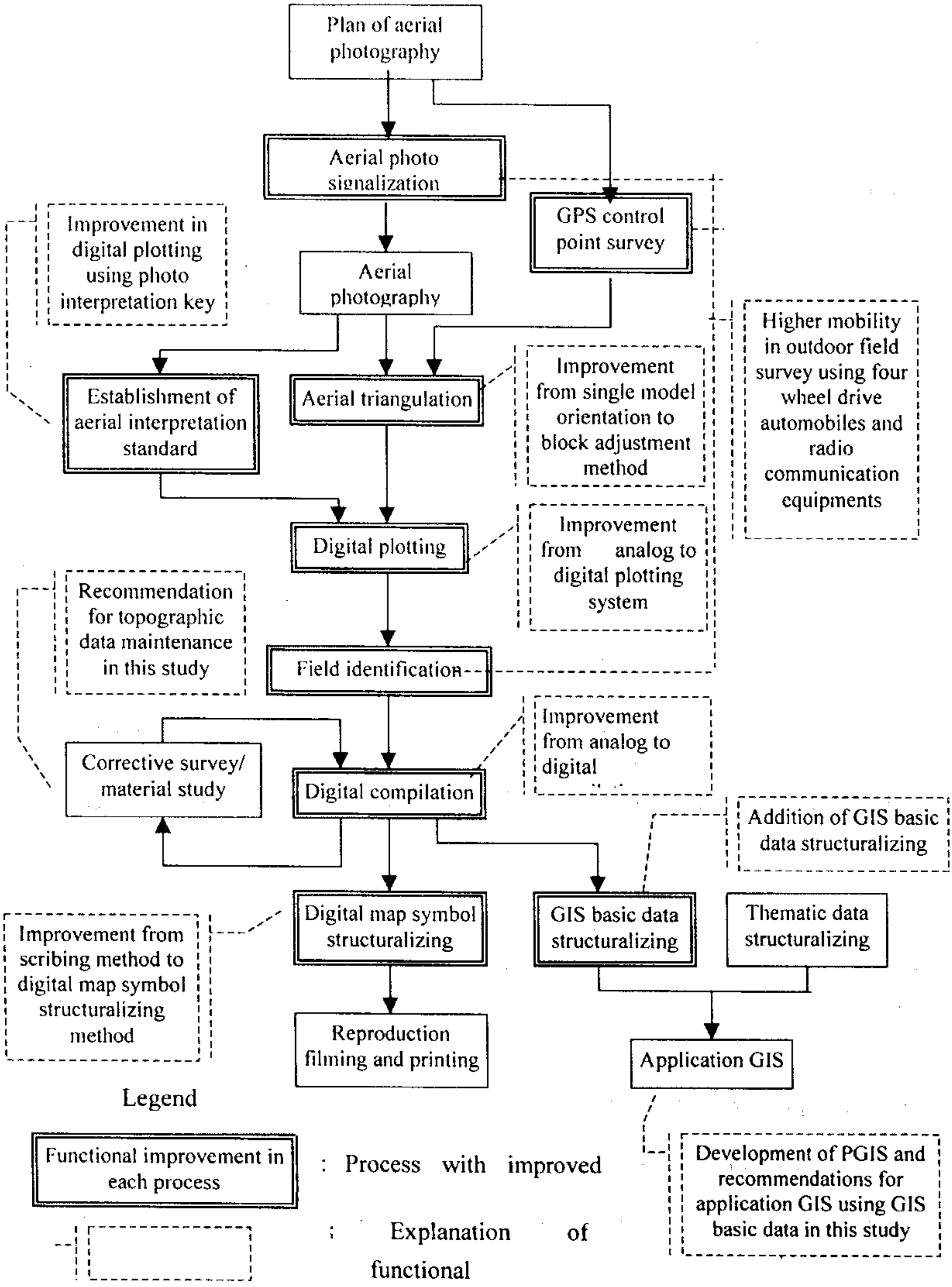

Figure 10 Functional improvement of 1/50,000 national topographic digital mapping system

4.1.2. Design and equipment of aerial triangulation process

(1) Existing equipment in aerial triangulation process

Equipment of aerial triangulation was introduced in 1992 in IGB. The contents of equipment were shown in Figure 11.

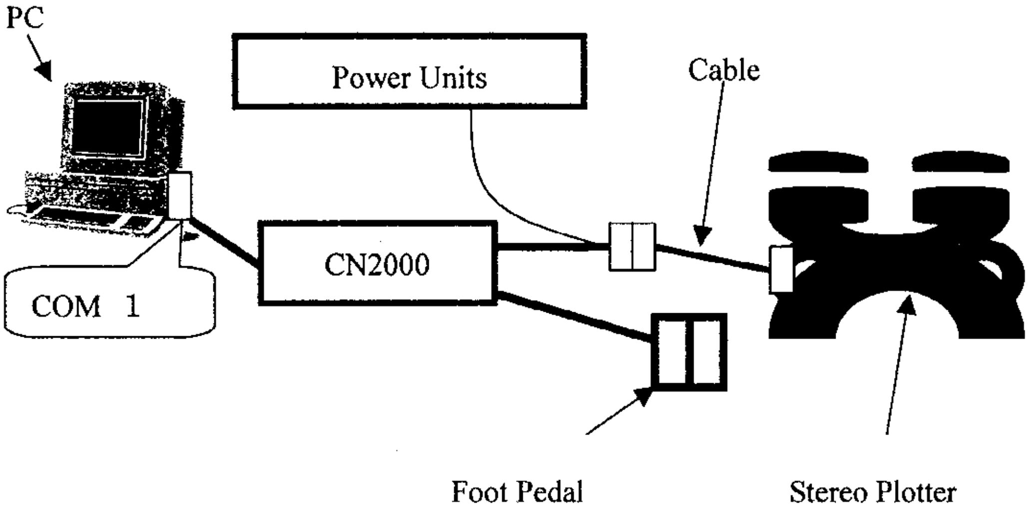

Figure 11 Existing and improved equipment in aerial triangulation process

Of the existing equipment used in the aerial triangulation process, the pricker PUG was usable after cleaning and adjustment. However the class 1 plotter WILD A10 was not operable due to mechanical troubles in the analog drawer joint section and the digital coordinate recording section does not work due to the failure in the magnetic tape recorder. In addition, the aerial triangulation block adjustment program PATM-386 was of the version to run on the MS-DOS operation system. As such, the operators could not operate it smoothly because they were familiar with the dominating operation system Windows.

(2) Improvement of equipment for aerial triangulation process

The improvement of the equipment for aerial triangulation process was made as follows. It had been reported that a repair company diagnosed the mechanical troubles in the class 1 plotter WILD A10 as unrepairable, but one of the study team members tried to inquire into the causes of the mechanical troubles and succeeded in repairing those. On the other hand, the genuine parts for the digital coordinate recording section and the printout section were expensive. The magnetic tape mechanism had many mechanical parts that were easy to cause troubles and the magnetic tape reader was required on the data receiving side.

Therefore, it was determined that the purchase of genuine parts was inadequate in this case. Under these circumstances, the digital pulse-type coordinate converter was manufactured. The software with the functions of accuracy control of model coordinate measurement values and creating PATM-386 input files on a PC was newly developed and the new PATM-386 version was provided as shown in Figure 11. Figure 12 shows an example of window of accuracy control of model to coordinate measurement values.

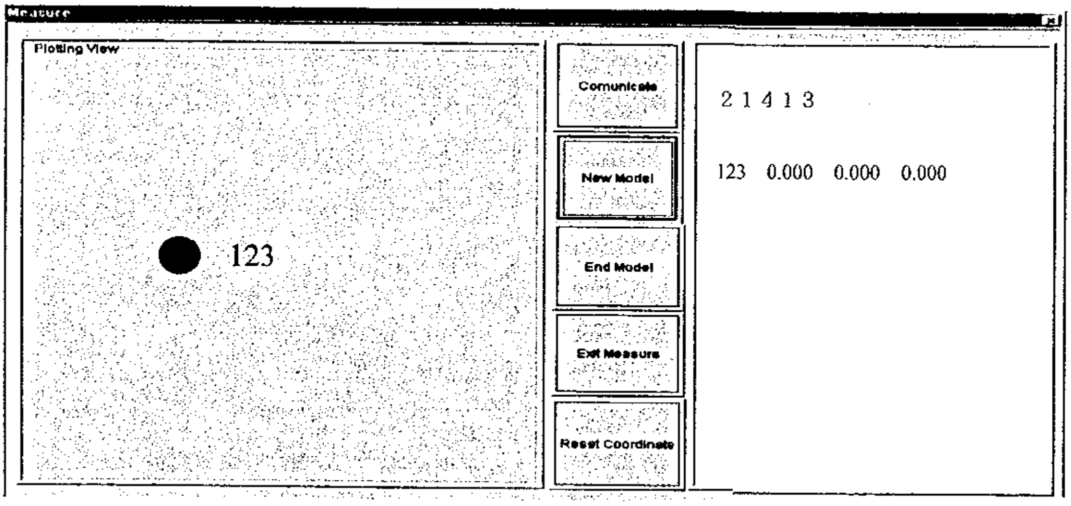

Figure 12 Example of window of accuracy control of model coordinate measurement values

4.1.3. Design and equipment improvement of digital plotting process

(1) Selection of digital plotting system

The photogrammetric technology has made fast progress from analog mapping to digital mapping. In this study, it was necessary to design an optimum system to ensure the successive operating effect in considering the political requirements and economic and technical conditions in Burkina Faso.

Of the photogrammetric technologies that are changing from the analog to digital system, the commercially available systems are mainly divided into the following three types:

(a) Digitizing at analog plotting output section

In this digitizing method, the mechanical analog plotting outputs that are obtained from analog photo images through a precision optical system and a precision mechanical analysis system in the existing plotter are digitized in the plotting output stage using a three-axis encoder. This system can be realized by adding the three-axis encoder and basic plotting software to the class 2 plotter Wild B8S that IGB possesses.

(b) Digitizing at precision optical analysis section

In this digitizing system, the mechanical analog plotting outputs that are available from analog photo images through a precision optical system and a precision mechanical analysis system in the existing plotter are digitized in the precision optical and mechanical analysis stages and most of the precision mechanical analysis functions and the functions of the mechanical analog plotting output system are processed using a computer. This type of system can be realized by adding the digitizing mechanism to the precision optical and precision mechanical analysis systems in the class 2 plotter Wild B8S and providing it with the PC and plotting analysis software and digital plotting software. The mechanical analysis system and the mechanical analog plotting output system have few errors compared with the method of digitizing at the analog plotting output section, ensuring higher accuracy.

(c) Digitized image analysis system

The digitized image analysis system is essentially different from the conventional plotting system. It requires no precision optical system or precision mechanical analysis system, because it provides stereo matching of the digitized aerial photos using computer technology. Therefore, this system is very inexpensive. If this system is newly introduced, it is evaluated to be superior in the introduction and running costs, but if compared with that of the existing plotter improved for digitizing, the introduction cost will be higher.

In addition, this system is still under development and the accessory software necessary for practical operation is still insufficient. Therefore, it is necessary to develop and customize the necessary practical detailed software in parallel with the actual work. These developments are not suited to the purpose of this study in which the urgent task is early development of the national topographic maps.

As described above, the three digitizing systems have advantages and disadvantages, but the system for digitizing at the analog plotting output section was adopted by adding some improvements from the viewpoint of accuracy. The plotting efficiency is more important than the accuracy in plotting work because the basic accuracy is determined by aerial triangulation survey.

When IGB plans to improve the version of the plotter in the national topographic digital mapping system in several years, the digitized image analysis system will be first examined. However at this moment of the study, it was evaluated that the method of digitizing at the analog plotting output section was the best.

(2) Improvement of digital plotting equipment

Since the method of digitizing at the analog plotting output section was adopted for digital plotting, the pulse signal generation mechanism using a three-axis encoder was added to each of two sets of class 2 plotter WILD B8S that IGB possesses. The pulse signal outputs from the encoder are digitized. For digital plotting, the PC and basic software KORK as shown in Figure 13 was also provided.

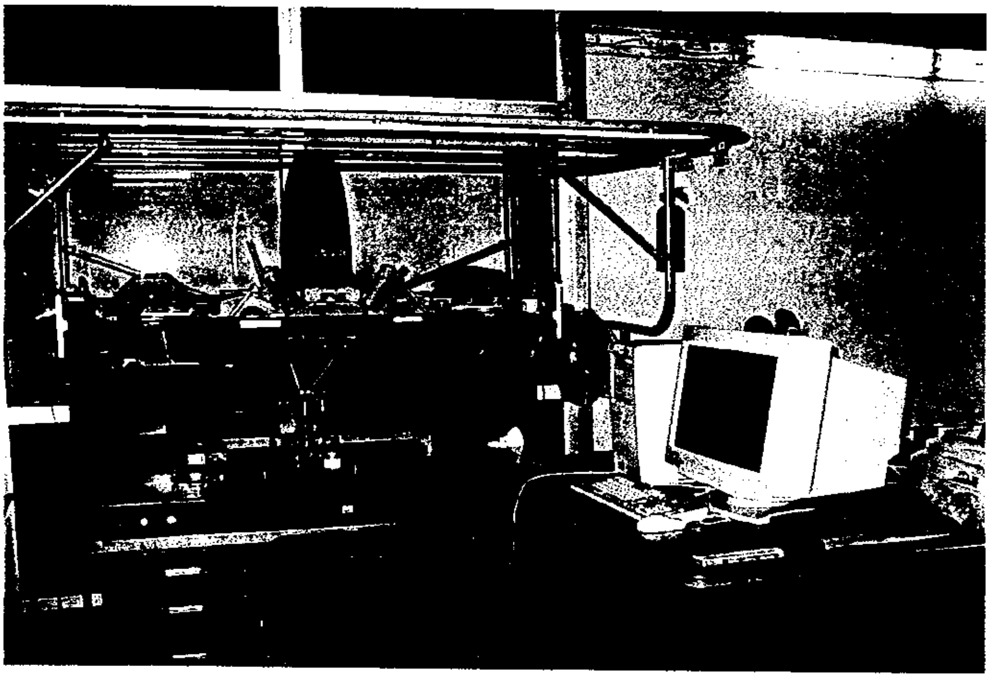

Figure 13 Equipment improvement in digital plotting process

4.1.4. Introduction of Equipment for Digital Compilation, Symbol Structuralization and GIS Basic Data Structuralizing Processes

The digital compilation, symbol structuralization and GIS basic data structuralizing processes require the introduction fore new equipment because there is no existing equipment at IGB and to use the computer information processing technology. The main equipment including personal computers and basic software was introduced as shown in Figure 14.

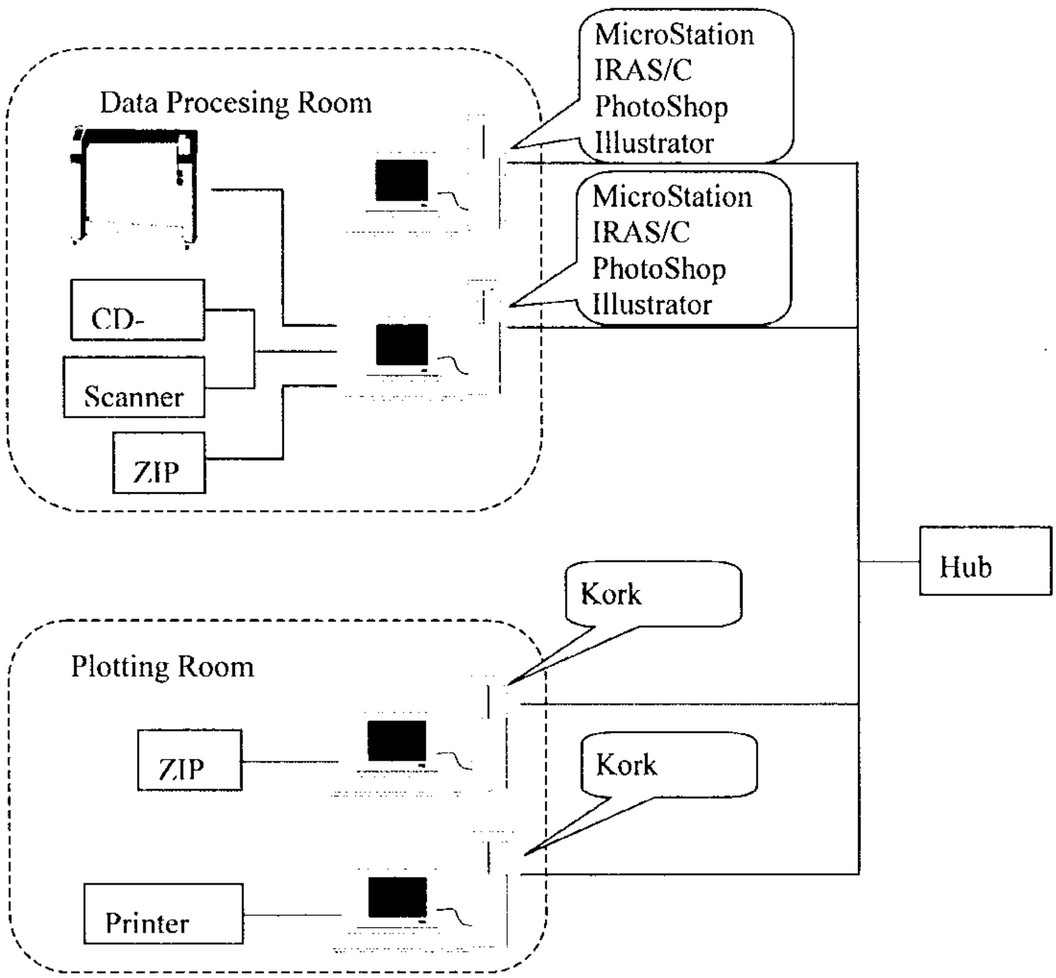

Figure 14 Introduction of equipment for digital compilation, symbol structuralization and GIS basic data structuralizing processes

4.1.5.Customizing of digital plotting and compilation, and map symbol and GIS basic data structuralization

(1) Basic software

In this study, the equipment and technology for the 1/50,000 national topographic digital mapping system were made available from those possessed by IGB as a rule. Insofar as possible, the basic software was also procured from the general-purpose software that was commercially available.

IGB had introduced the software SysteMap using the U.S.-made MicroStation as its engine for the class 2 plotter WILD B8S. However, the development of the SysteMap had been stopped and it was impossible to upgrade its version.

The digital plotting process was designed on the U.S.-made software KORK and the digital compilation, symbol structuralization and GIS basic data structuralization were designed on the MicroStation as their basic software. In addition, the reproduction film production process was designed to use PhotoShop as its basic software. The configuration of the basic software is shown in Figure 15.

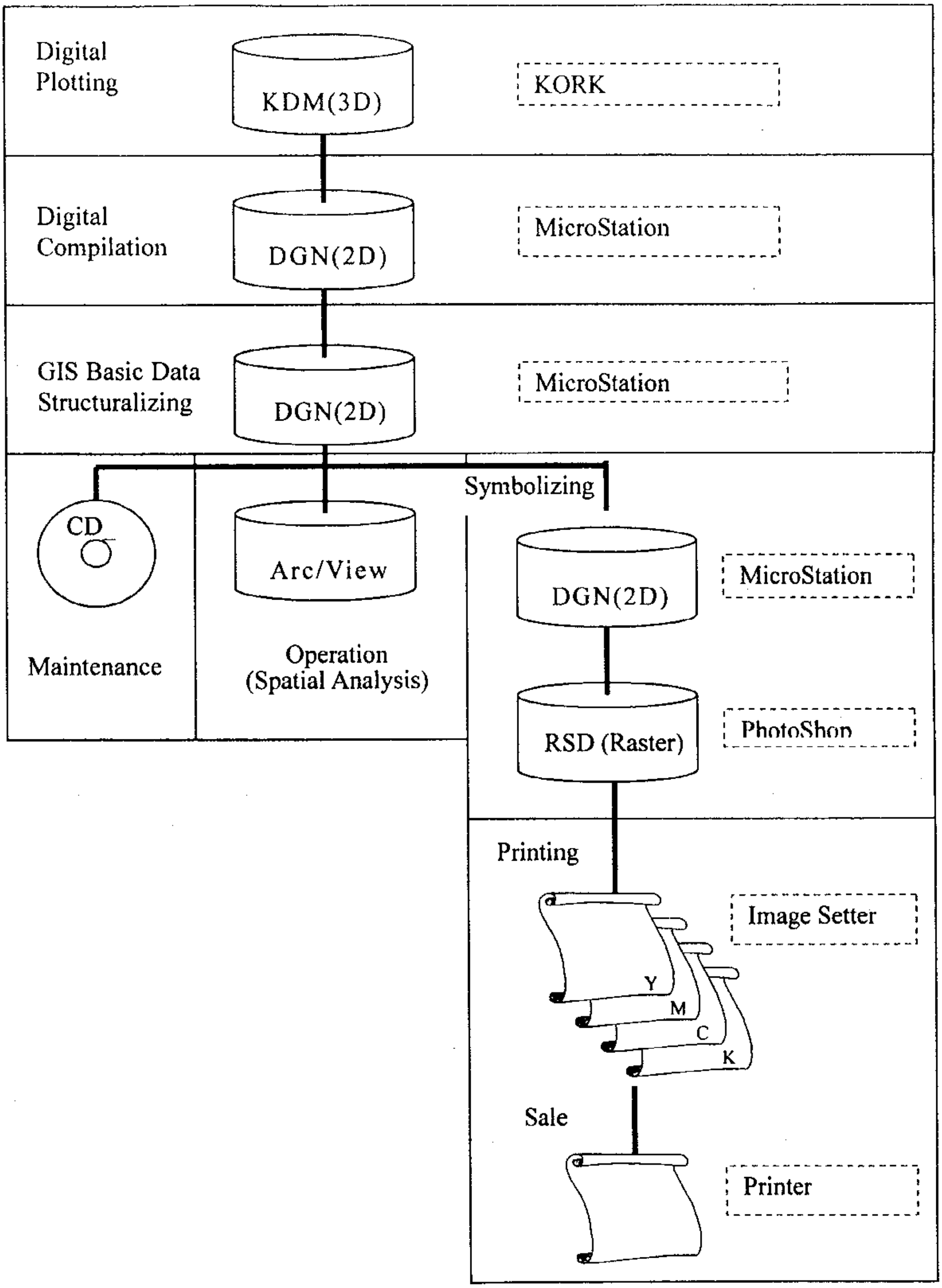

Figure 15 Basic software configuration for digital plotting, digital compilation, symbol structuralization and GIS basic data structuralization

(2) Customizing of digital plotting process

In the digital plotting process, the method of information acquisition was established based on the symbols and their numbers proposed by IGB in order to customize the functions of allocating the symbols and line types to each of the information to be stored. For this purpose, the symbol numbers were adopted as the representation category.

In addition, automatic control of connections and their ranges were customized as macro software in order to connect the lines of the same information or join the related information in a smooth manner. The coordinate thin-out macro software was also customized for automatic optimization of the vector coordinate density of line information.

(3) Customizing of digital compilation process

The digital compilation process was customized to create digital topographic data in accordance with digital compilation representation standard using the symbol numbers that were affixed to the digital information and symbols acquired in the digital plotting process.

(a) Customizing based on field survey

In this study, the field identification was made after the digital plotting process in accordance with the order of processes adopted by IGB. Therefore, the symbol representation category had to be applied to the planimetric features in the digital plotting process after photo interpretation of the features was made. The symbol representation categorization must have involved uncertainty in the photo interpretation. It was necessary to identify and correct uncertain features through the field identification.

To make the correction work effective, the functions of changing the line representation category codes, symbols and parts of the planimetric features were customized. Figure 16 shows the menu view of the symbol replacing function.

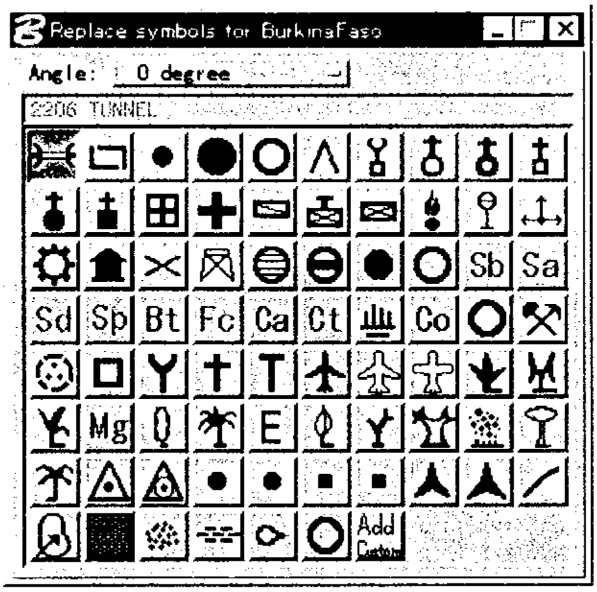

Figure 16 Menu view of symbol replacing function

(b)Customizing of digital compilation under digital compilation representation standard

The symbols used for digital compilation under the digital compilation representation standard were created based on the sample diagrams provided by IGB. As no detailed guidelines for line gauges and symbol shapes were indicated in the sample diagrams, the necessary symbols were read out of the sample diagrams arranged as a map symbol design diagram. Symbols were imported in the MicroStation in accordance with the symbol design diagram. For characters, Arial Narrow in Windows proposed by IGB was imported in the MicroStation as the font. The registered fonts are shown in Table 3.

Table 3 Registered fonts

Item	Font Number	Remarks
Symbols	No. 102	
Characters	No. 189	Arial Narrow

In addition, the main input menu, sub-input menu, annotation-input menu and compilation support functions were customized to carry out the digital compilation work effectively. This customization allowed instructions from field survey, correction of irrational points such as inconsistent points between contour lines and single elevation points, and the relational positions of roads, water channels and buildings, and entry of annotations and administrative boundaries to be compiled effectively. (Refere to Figure 17, 18, 19)

Figure 17 Main input menu

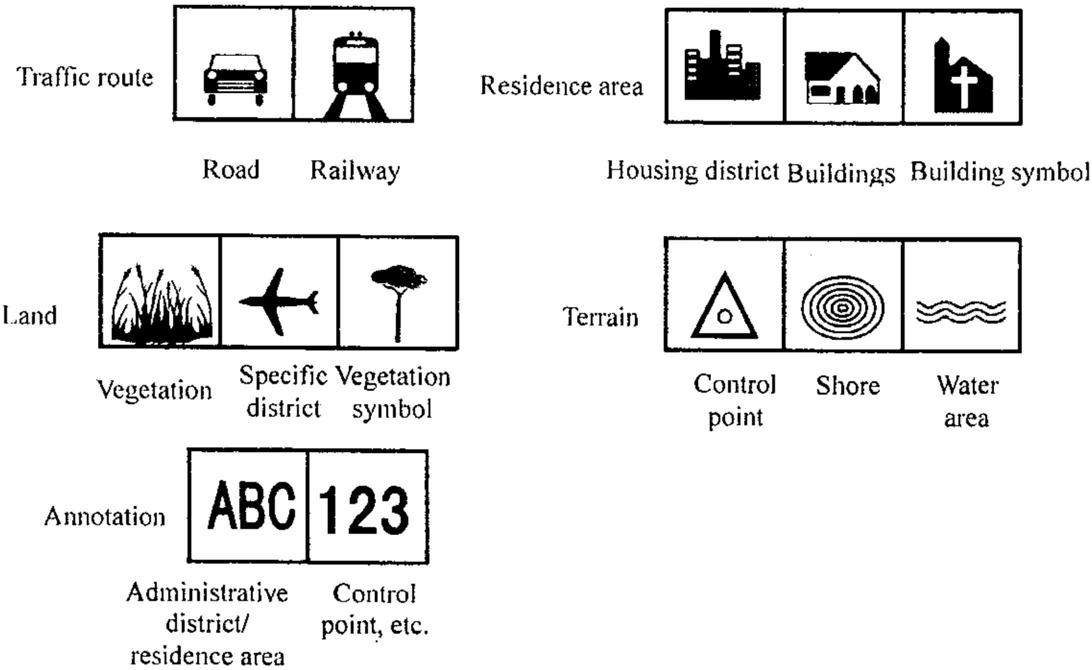

Figure 18 Sub-input menu

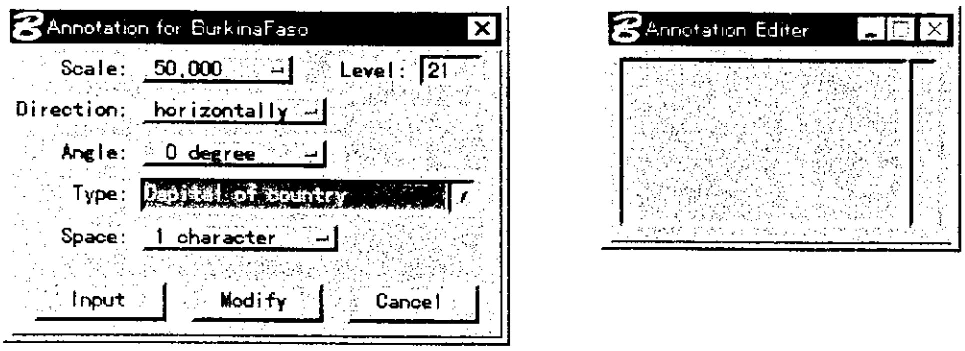

Figure 19 Annotation input menu

Digital compilation should be distinctly separated from structuralizing. The data to allow the map symbol structuralizing data and the GIS structuralizing data to be converted through program processing in a smooth manner was created and stored in the core files for future data management and updating.

(4) Customizing of GIS basic data structuralizing process

To make spatial analysis in the GIS, the strict mathematical relation of spatial information has to be established. It is important to connect the lines and form them as a single line for the planimetric features to configure the networks such as roads, water channels and railways. For the planimetric features to be represented as planes such as vegetation, it is necessary to configure planes and affix them with their attribute information to indicate the meaning of each plane.

For this purpose, the functions of connecting lines, single-line formation, plane generation and affixing attributes to the planes were customized. In addition, any illogical points in the data were automatically detected to reduce the errors in operation of GIS basic data structuralization and to diminish the stress and fatigue of operators.

(5) Customizing of map symbol structuralizing process

In printing maps from the digital topographic data, in general, the digital topographic data is imported in the image processing software such as typically Illustrator to symbolize the data in interactive mode. Therefore, it is necessary for the operator to be familiar with the operation of the digital topographic data imported in the image processing software. However, this method makes the map symbol structuralizing process complicated and give more stress to the operator, resulting in an inefficient work. This method will also cause the cost to be increased in the maintenance of the system because the digital topographic data has to be symbolized in interactive mode after the revision survey is made.

In this study, the software for map symbol structuralization through semi-automatic processing of the digital topographic data was customized. The symbol structuralization processing was divided into compound lines symbolizing, stick-up symbolizing, plane symbolizing and symbol and character outlining. After that they are processed in the vector mode and arranged in the priority order and converted into the raster mode in order to allow the 4-colors offset print reproduction output.

The compound line symbolizing is a process to extract the plane information from the

information of compound lines. In this process, plural planes such as external and internal planes are generated depending upon the compound grade of the line information. The more internal planes are in the higher layer of printing.
Stick-up symbolizing is a process of sticking up element symbols to the lines.
Plane symbolizing is a process of developing the element symbols in the planes. The more internal of compound planes are in the higher layer of printing.
Symbol and character outlining is a process of converting the registered symbols and characters to the vector mode. In this case, if compound plains are made the more internal plain is highest layer of printing.

(6) List of functions and types of customizing software

The functions and types of customizing software are shown in Table 4.

Table 4 Functions and types of customizing software

Process	Function	Type
Digital plotting	Editing/plotting menu, etc.	Macro
	Conversion of digital plotting data to digital compilation data	Batch
Field identification	Change in attributes	MDL
	Replacement of symbols	MDL
	Partial change in planimetric features (stged1)	MDL
Digital compilation	Development of representation category codes	Batch
	Input menu	MDL
	Annotation input menu	MDL
	Form adjustment	Batch
	Attribute copy	MDL
GIS basic data structuralization	Line connection	Batch
	Single-line forming	Batch
	Intersected line dividing	Batch
	Plane creation	Batch
	Check on integrity of planes with attribute symbols	Batch
Map symbolizing	Compound line symbolizing	Batch
	Line stick-up symbolizing	Batch
	Plane development symbolizing	Batch
	Character/symbol outlining	Batch
	Data arrangement in printing order	Batch
	Rasterization of printing	Batch

4.1.6. Improvement of digital topographic information network and installation of stabilized power supply equipment within IGB

(1) Digital topographic information network within IGB

The national topographic digital mapping system developed in the study had a relation with each department, for which it was necessary to provide information and communication equipment for efficient information processing. Under the equipment installation plan, each of the newly introduced personal computers were equipped with a 100BASE-TX network board to be connected to a 100BASE-TX HUB. During the construction work, it was not found in the equipment study that a local area network (LAN) connecting the IGB departments and sections had been installed, but the IGB staff did not understand the application method of the LAN.

The existing LAN was provided with 10BASE-TX HUB to allow connections to the existing PCs with a 10BASE-TX network board.
In this study, it was planned to connect the existing PCs and the newly installed PCs to the existing LAN for operation for the time being because ① the volume of information communications was not so high, and ② the existing PCs were capable of communication. For future increase of the communications volume and the rate of PCs with the 100BASE-TX network board, it was planned to provide the existing PCs with the 100BASE-TX network board to upgrade those and replace the LAN's HUB with the 100BASE-TX HUB.

(2) Installation of stabilized power supply equipment

In Ouagadougou, Burkina Faso, the public electric power supply has relatively been stabilized compared with other developing countries, but power failure and voltage fluctuations due to lightning and any other cause have often occurred.

If any trouble such as power failure occurs during operation of the national topographic digital mapping system, the information in operation may be damaged and the recovery cost would be a huge loss. To prevent this problem, the system was equipped with stabilized power supply equipment. The system was also designed to ensure that if power failure occurs, the information could be evacuated while power is supplied from the battery.

4.1.7. Higher mobility in outdoor field Survey

(1) 4-wheel drive automobiles for outdoor field survey

Four (4)-wheel drive automobiles for outdoor field survey were provided to reinforce the mobility in the photo control point survey process (GPS control point survey, leveling and aerial photo signalization) and in the field identification that served for the 1/50,000 national topographic digital mapping system.

(2) Radio communications equipment for outdoor field survey

The radio communications equipment for outdoor field survey was provided, which consisted of mobile radios installed on 4-wheel drive automobiles and the key station located at the IGB facility. The radio communications equipment was intended not only to reinforce the mobility in the outdoor field survey in general, but also to facilitate the movements over the long distances between survey points and to serve for scheduling of survey times. This has resulted in higher efficiency in using the relative positioning method in which several GPS receivers are operated for simultaneous GPS survey. The shortening of the period of outdoor field survey with lodging was very important to slash the development cost of national topographic mapping.

4.1.8. Improvement of geographical naming system

The geographical naming system in Burkina Faso has to be determined through the deliberation of the National Geographical Name Committee. The mission of the National Geographical Name Committee is to revise those geographical names that are deemed to impair the dignity and independence of the nation out of the names under long-time influence of the colonization by France. This work might bring vain confusion and ineffective results if it was not executed with deliberate considerations. The Committee was required to investigate the names based on the historical and linguistic research for many years. It was feared that such work might hinder the progress of the schedule of this study. Therefore, the study team proposed to improve the geographical naming system through various case studies and discussions. As a result, this system was improved as described below.

The mission of the National Geographical Name Committee is important in respecting the dignity and independence of the nation as described above. On the other hand, the national topographic mapping work is also an important factor for the economic and cultural development of Burkina Faso. To satisfy both requirements, the IGB geographical naming committee was established within IGB to hear the opinions of the authorities in various fields and discuss this naming issue with them on the principle of "locally used names" in order to adopt the necessity names for the national topographic maps promptly.

The results of this work were reported to the National Geographical Name Committee immediately to contribute to prompt deliberation of the National Geographical Name Committee. In this system, some geographical names that the IGB geographical naming committee adopted might be rejected by the National Geographical Name Committee , but the digital mapping system allowed those names to promptly corrected in a simple way.

4.1.9. Preparation of 1/50,000 digital mapping system technical standard and work specifications

(1) Symbols

IGB investigated the symbols that had been used in the past and arranged them systematically. In the process of establishing the photo interpretation standard in this study, the symbol of a telephone antenna tower was added.

The recent telephone networks in Burkina Faso has been configured using radio, and the antennas are considered to be useful as key points for reading maps. Therefore, the conventional symbol of telephone line was abolished and a new symbol of telephone antenna was adopted.

(2) Digital data acquisition standard

The digital data acquisition standard was established to define the standard for data acquisition in digital plotting and digital compilation and the data creation procedures.

(3) Work specifications for 1/50,000 national topographic digital mapping

The work specifications for 1/50,000 national topographic digital mapping was established to make integrated maintenance and operation of the 1/50,000 national topographic digital mapping system, keep the integrity of all processes and secure the quality of the products.

The above is explained in detail to the separate volume No.1.

4.2.Training of Management and Operation Personnel for 1/50,000 National

Topographic Digital Mapping System

4.2.1. Training of operating personnel for 1/50,000 national topographic digital mapping system

(1) Objectives of training

In this study, the system operation personnel to have charge of one or two processes to produce part of the national topographic maps for the southwestern area using the 1/50,000 national topographic digital mapping system improved in this study and continue to operate the system in a sustainable and effect manner after completion of this study.

(2) Training method

For the improvement of the 1/50,000 national topographic digital mapping system, the method to evaluate the existing technical processes in accordance with the basic policies of this study and introduce new technical processes effectively while using the existing excellent technical processes was adopted. Therefore, it was claimed for that the operating personnel would be trained using the method of evaluating the technical details in each process to be adapted to its purpose.

Many of IGB engineers had a high level of general technical knowledge because they had obtained the professional education and studied in ITC in the Netherlands and educational institutes in France. Notwithstanding, their technical capability was complete in some of the processes implemented in the joint venture with some donor countries using the equipment procured under the assistance of the donors, because in addition of the financial problems, the engineers could not have sufficient experience in systematic execution of the work to take the initiative in the national project.

Taking this into account, the personnel in charge of technical advice and support of progress and quality control of this study was assigned to the processes using existing technologies, and the scheme of preparing manuals and on-the-job training was adopted for training the operating personnel for the 1/50,000 national topographic digital mapping system.

The manuals were prepared to support the operation of the system and to be used as the training materials for training new personnel after completion of the technical cooperation. In these manuals, stress was not placed on the general theory though some engineers needed such general knowledge. As many reference documents on the general theory were available, it was thought the trainees should study general knowledge by themselves. It was also deemed that the on-the-job training would support their understanding of the general theory in their self-study. The manuals are shown in the separate volume No.2.

(3) Contents of training

(a) Personnel training method, study team members in charge, periods and manuals by work process

The personnel training method by work process, study team members in charge, periods and manuals are listed in Table 5.

Table 5 Personnel training method, study team members in charge, periods and manuals by work process

Work process	Training method	Member in charge	Period	Manuals and others
Aerial photography plan	Advice, etc.	Katsuyuki Hatakeyama	1998.11.21. ~1998.11.24.	
Aerial photo signalization	Advice, etc.	Dr.Bandula Senakasiri	1998.11.21. ~1999.02.03.	
Control point survey	Advice	Dr.Bandula Senakasiri Yoshikazu Ogasawawara	1998.11.21. ~1999.02.03.	Geoidal correction manual
Aerial photography	Advice	Katsuyuki Hatakeyama	1998.11.21. ~1999.01.20.	Subcontract
Preparation of photo interpretation standard	Advice, etc.	Kentaro Usuda	1999.03.02. ~1999.03.21.	Photo interpretation is a newly introduced technology.
Aerial triangulation	OJT	Seiji Nakanishi	1999.07.25. ~1999.09.22.	Aerial triangulation manual
		Kosuke Tsuru	2000.06.12. ~2000.07.11.	
Digital plotting	OJT	Takashi Tomura	1999.09.22. ~1999.12.20.	Digital plotting manual
Field identification	Advice, etc.	Kentaro Usuda	1999.10.31. ~1999.12.05.	
Digital compilation	OJT	Masami Yoshimoto	2000.06.12. ~2000.07.20.	Digital compilation manual
Digital symbol structuralization	OJT	Masami Yoshimoto	2000.07.21. ~2000.08.15.	Digital symbol structuralization manual
GIS basic data structuralization	OJT	Masami Yoshimoto	2000.08.16. ~2000.09.09.	GIS basic data structuralization manual
Reproduction film production and printing	Advice, etc.	Katsuyuki Hatakeyama	2001.01.23. ~2001.02.18.	Subcontract in Japan

Note:For the manuals, refer to the separate volume No.2.

(b) Technical personnel receiving OJT

The personnel for OJT were appointed after making discussions on the conditions of IGB's engineers and the future scale of the national topographic mapping improvement project. The list of OJT trainees is shown in Table 6.

Table 6 List of OJT trainees

Work No.	Item of Training	Number of trainees		System manager	Trainee
		Chief	Members		
[5-1]	Correction of geoidal undulation in GPS survey	1	2	SAWADOGO Jean	ZIO Issa SANOU Yaya
[21]	Aerial triangulation 2	1	3	COMPAORE Désiré	TOURE Ladji NIKIEMA Sagado
[22]	Digital plotting 2	1	5	COMPAORE Désiré	TOURE Ladji NIKIEMA Sagado KOUDOUGOU Sibiri J SANOGO Sié
[35]	Digital compilation & structuralization 2	1	6	KABORE Salifou	SOMDA Lucie KIEMA Béatrice YAGO Idrissa BOULSA Charles BOLLY Ahamadou BAKOUAN Hortense ☆COMPAORE Désiré
[36]	Map symbol structuralization 2	1	6	KABORE Salifou	SOMDA Lucie KIEMA Béatrice YAGO Idrissa BOULSA Charles BOLLY Ahamadou BAKOUAN Hortense ☆COMPAORE Désiré
[37]	GIS basic data structuralization 2	1	4	KABORE Salifou	TAPSOBA Martine OUEDDOUDA Rosalie PARE Françis BOLLY Ahamadou ☆COMPAORE Désiré
[47]	Pilot GIS operation		4	KABORE Salifou	DEMBELE Ousmane YAGO Idrissa BOLLY Ahamadou ☆COMPAORE Désiré

4.2.2. Training of system managers for 1/50,000 national topographic digital mapping system

(1) Objectives of training

The manager in a work process of the system was appointed as the system manager of the work process. The system manager has the role of instructing any proper measures for any problem in system operation and giving a solution to it after completion of this study.

(2) Training method

As the training method, the following procedures were taken on the details of management of the 1/50,000 national topographic digital mapping system:

(a) All the system managers attend the Management Council of this study to experience the problems and solutions to those in the system operation through this study.

(b) The system managers for the work of introduction of new technologies participate in the necessary part of OJT.

(c) The system managers for the work processes of aerial triangulation and digital plotting participate in the long-term collective training "Planning and Management of National Mapping and Surveying Course" in Japan.

(3) Contents of training

(a) For the system managers that participated in the Management Council.

(b) For the system managers for the work process of introduction of new technologies that participated in OJT.

(c) The participant and training period of the long-term group training "Planning and Management of National Mapping and Surveying Course" held in Geographical Survey Institute, Japan.

Participant: Mr. COMPAORE Désiré (Chief of Aerial Triangulation and Digital Plotting Work Processes)

Training period: October 2, 2000 to July 29, 2001

4.2.3. Training for GIS design and configuration method using GIS basic data

(1) Objectives of training

In the S/W of this study, the technology concerning the GIS is poised as recommendations for effective use of digital topographic data produced in this study. The study team recommended the development of pilot GIS as one of the recommendation schemes. In response to the recommendation, the members of the "GIS Users Conference", which consists of the delegates of IGB and other related governmental agencies, strongly requested the study team for transfer of technology in the GIS design and configuration using GIS basic data, which was adopted and added to the third-year work.

(2) Training method

The Training Method was as follows:
(a) The GIS development department was newly established in IGB and the development manager received the individual training in Japan.
(b) Preparation of pilot GIS operation manual and operational training of the IGB's GIS engineers and the members of GIS User Conference in charge of pilot GIS work.
(c) The seminar on GIS design and configuration using GIS basic data was held for the members of GIS Users Conference and IGB's GIS engineers.

(3) Contents of training

(a) Individual training of GIS development department manager in Japan
Participant: Mr. BOLLY Ahamadou (IGB's GIS development department manager)
Training period: September 27, 2000 to October 28, 2000
(b) Training for Pilot GIS operation
Participants: Members of GIS Users Conference in charge of pilot GIS work and IGB's GIS engineers
Training period: February 1, 2001 to February 14, 2001.

4.2.4. Training of IGB's High-Level Management

For the purpose of studying the actual conditions of the National Survey Projects of Japan having many years of achievements and smooth promotion of technical cooperation between Japan and Burkina Faso, Mr. Ousseny TARNANGUIDA, the General Director of IGB visited Japan between June 21 to July 3, 1999 and Mr. Claude Obin TAPSOBA, the Technical

Director, between June 21 to July 16, 1999 respectively to study and discussions at Geographical Survey Institute, various survey education organizations, survey-equipment manufacturers, survey-related organizations and companies in Japan.

4.2.5. Seminar

A seminar for the concerned members was held within IGB's facility on February 8 and 9, 2001 to confirm the achievements of the friendly technical cooperation between Japan and Burkina Faso, and to contribute to the improvement of administrative service and the sustainable development for the key issues such as nation-wide promotion of the national digital topographic data and the application of GIS using GIS basic data in harmony with the natural environment in Burkina Faso.

The contents of the seminars are as follows:

(1) Ceremony of delivery of various products such as equipment of the 1/50,000 national topographic digital mapping system, the national basic maps for the southwestern area, the digital topographic mapping data and GIS basic data and also the presentation of the pilot GIS etc, in which the Ministers of the Government of Burkina Faso and the representative of Japanese Embassy participated.

(2) Seminar for promoting the GIS using GIS basic data for the members of the GIS Users Conference consisting of delegates of GIS-related governmental agencies, and IGB's GIS engineers.

(3) Seminar for explaining the general products of this study for the officials of the agencies as users of the national topographic maps and IGB's staff

4.3. Development of 1/50,000 National Topographic Maps for Southwestern Area and Digital Topographic Information

4.3.1. Technical standard for topographic mapping

The technical standard for topographic mapping will be outlined as follows:

Reference ellipsoid:	Clarke 1880
Radius of the equator:	6,378,249 m
Flatting rate:	1/293.4663
Unit:	Meter
Map projection:	UTM
Map scale:	1/50,000
Contour line interval:	10 m
Neat line:	15' x 15'

The outline standards of the symbols and digital data acquisition are shown in Figure 41.

4.3.2. GB's production method of 1/50,000 national topographic digital mapping

IGB's production method of the 1/50,000 national topographic digital mapping is designed in consideration of investment efficiency and other factors in establishing the technical environment in Burkina Faso and providing IGB with necessary equipment for each production process.

In the work processes of aerial photography and map printing, aircraft and aerial camera as well as rotary press printing machine were required for production in IGB, and the initial investment was large. In addition, the costs of personnel including pilots, aircraft maintenance crew and printing technicians were constantly required. Under these conditions, the production by an external contractor was determined as adequate and the system design and these work processes were also implemented under a contract.

For other work processes, the production system within IGB was deemed to be adequate because any industry having the function of producing national basic maps has not developed in Burkina Faso.

4.3.3. Restrictive production conditions and early development of national topographic maps for southwestern area and digital topographic information

The 1/50,000 national topographic digital mapping system was designed and developed in a production scale to be fulfilled by two plotters focusing on the plotting as the core process of the development as described in 4.1. Therefore, the quantities of production in Burkina Faso of the national basic maps for the southwestern area was restricted by the scale of equipment installations.

For introduction of the new technologies, the production through OJT was restricted in the speed of production as described in 4.2.

On the other hand, it was required that the national topographic maps for the southwestern area and digital topographic data had to be developed early under the S/W as described in 2.1.2.
Based on the above, the production through OJT was carried out in the work processes of digital plotting, digital compilation, digital symbol structuralization and GIS basic data structuralization and some of the work processes were implemented in Japan in accordance with the requirements for efficient technology transfer.

All the aerial triangulation process was implemented in Japan in order to keep the uniform accuracy and minimize the cost of control point survey, while the production of maps for some of areas underwent technology transfer in Burkina Faso. In addition, the work for Banfora area was implemented through OJT to promote the technology transfer and the IGB project.

4.3.4. Processes of study works and work procedures

In the development of the 1/50,000 topographic digital mapping system, the subcontract method was adopted for the processes of aerial photography and map printing in considering the technical conditions in Burkina Faso. The aerial photography process was subcontracted to CINTEC and the map printing process was originally planned to be subcontracted to any company in the neighboring country Côte d'Ivoire, but it was subcontracted to Nakasha Creative Co., Ltd. in Japan because of the unstable political conditions the recommendation for forbidden entry into the country.

The IGB's 1/50,000 digital mapping system consisted of 2 sets of digital plotter. In addition, the processes of digital plotting, digital compilation, map symbol structuralization and GIS basic data structuralization that were the new technology introduced in this Study were implemented through OJT (on-the-job training), so that the production pace was limited. In consideration of the above circumstances, some portions of these processes were implemented in Japan. The study work processes are shown in Figure 20.

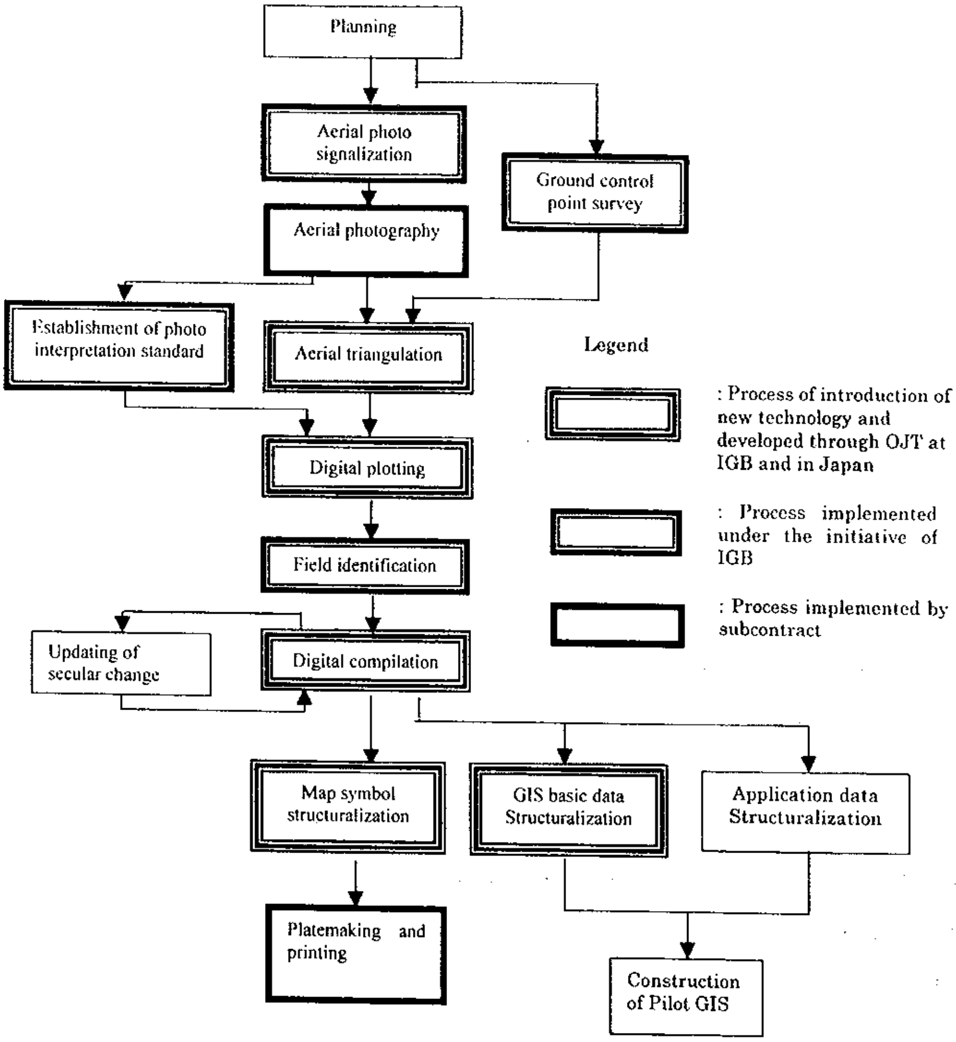

Figure 20 Processes of production of topographic maps and digital topographic data and study implementation procedures

4.3.5. Work details of topographic mapping process

(1) Process of installation of aerial photo signals

For absolute orientation for the aerial photography, signals were installed. The signal structure was designed as shown in Figure 21. The material of the signal was made of locally available, white-painted stones of 10 to 20 cm diameter laid on the ground. The sites of signal installation and the quantities of those are shown in Figure 37 and Table 7 respectively.

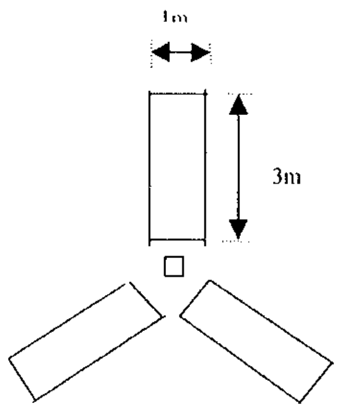

Figure 21 Structure of aerial photo signal

(2) Process of ground control point survey

The observation of GPS survey for the second-order ground control points was carried out for 2 hours per session. The net adjustment was performed based on the first-order ground control points as known points. To indicate a point as its elevation value, the correction using the local geoid method was made.

To obtain the high elevation accuracy, the leveling route was set through the third order leveling and pricking was carried out. The points for which these works were made and the work volumes are shown in Figure 37 and Table 7 respectively.

(3) Aerial photography

As a result of investigation of the technical capability and price and other conditions of candidate companies, the aerial photography process was subcontracted to CINTEC as the most appropriate subcontractor. The photography base was posted at Bobo Dioulasso Airport. The discussions with IGB, the contract with CINTEC and the installation work of aerial signals preceded so that all the process of aerial photography could be finished before harmattan hit this area.

Aircraft:	Cheftain Navajo
Aerial camera:	RC-10 (f = 88.01 mm)
Film:	AGFA AVIPHOT PAN 200 PEI
Photography scale:	1/50,000

The photographing courses are shown in Figure 39.

After their processing, the photographs were subject to inspection under the same specifications as the JICA Work Specifications and it was verified that those photographs satisfied the inspection criteria.

(4) Aerial triangulation process

To obtain the integrity in accuracy, aerial triangulation survey of all models were conducted using the block adjustment method, separately from the OJT products.

① Main equipment

Pricker:	PUG II/IV type (Wild)
Coordinate observation equipment:	Stecometer (Carl Zeiss Jena)
Computer:	ACOS PX 7800 (NEC)

② Work details

1) 5 path points were selected for each photo taking into account the photography using the super-wide angle camera.
2) 2 tie points were selected for each model for higher connectivity.
3) The ground control points were actually checked by stereoscopic observation in accordance with the detailed description sheets of ground control points and transferred.
4) The benchmarks were observed on the basis of the quadruple-enlarged photo, pricked photo materials and the points were transferred.
5) The coordinate observation was made twice independently and the major errors due to discrepancies were checked and rechecked in the polynomial expression method.
6) The block adjustment was made using the bundle method.

③ Results of adjustment

1) Number of used ground control points: 52 points (horizontal)

128 points (elevation)

2) Standard deviation presumed from the residuals of ground control points:

±0.616 m (horizontal)

±0.633 m (elevation)

3) Standard deviation of path points and tie points:

±6.56 μ (coordinate component)

(5) Photo interpretation standards establishment process

In the digital plotting process, the aerial photos were interpreted in an appropriate way to standardize the accuracy, so that the information under the map symbol specifications was not different depending upon the interpreters.

The interpretation standards were made up on the basis of the map symbol specifications by arranging the applicable criteria, aerial photo samples, ground photo samples and the representation method in digital plotting and compilation in order to obtain easy to read photos.

The target features are as follows:

Road type
River and seasonal river
Village and its extent
Vegetation
Terrain

(6) Digital plotting process

In the digital plotting process, the photo models were oriented using the results of aerial triangulation. Then, the information to be acquired was interpreted in accordance with the photo interpretation standards and the planimetric features, vegetation and other topographic data to be represented as line and positional data were plotted and fitted with attribute symbols in accordance with the data acquisition standard.

In the data acquisition in the digital plotting process, the plotting work proceeded in an efficient and systematic manner in accordance with the customized map symbol representation specifications. The area of 2,150 square kilometers that IGB undertook was digitally plotted through OJT.

(7) Field identification process

The output maps from the digital plotting process were carried to the field to identify and acquire the geographic names and planimetric features that were not acquired by aerial photography and to correct the omissions in data acquisition and the errors of interpretation. For the geographic names that were local language was recorded on the tape recorder in order to acquire the right notation in French. And they ware decided through careful inspection by IGB Toponymy Committee.

(8) Digital compilation process

In the field identification, the lacking data in the checked digital plot information was additionally plotted and the errors were corrected. Further, the line data, connected line and closures of polygonal data that were incompatible with the digital data acquisition standard were corrected. The geographical names, annotations of planimetric features and administrative boundaries were also compiled.

The compilation work was conducted efficiently using the customized digital compilation software to perform automatic logical check and to cause no oversight in checking.

The area of 1,500 square kilometers that was undertaken by IGB was digitally compiled through OJT.

(9) Map symbol structuralizing process

In the map symbol structuralizing process, the data such as line and plane information, planimetric features and vegetations that were compiled in the digital compilation process were symbolized in accordance with the map symbol specifications in order to output those on printed maps. Vector-type data was also converted into raster-type data. The symbolized data was divided into color-separated layers. This process was performed in a semi-automatic procedure using customized map symbol structuralizing software.

The area of 1,500 square kilometers that was undertaken by IGB was processed through OJT.

(10) GIS basic data structuralizing process

In the GIS basic data structuralizing process, the geographic data compiled in the digital compilation process was structuralized as the logical structures that were adequate for spatial operation to generate GIS basic data. This process was performed in a semi-automatic procedure using customized GIS data structuralizing software.

The area of 1,500 square kilometers that was undertaken by IGB was processed through OJT.

(11) Platemaking and map printing process

In the platemaking and map printing process, the structuralized map symbol data was separated into 4 colors of green, orange, blue and black and reproduction films and plates were produced. Then, the maps were printed from those plates.

Originally, it was planned to subcontract this filming and printing process to a subcontractor in the neighboring country, Côte d'Ivoire, but the political conditions became unstable during the period for implementing this process and the forbidden entry into the country was recommended. Thus, this process was implemented in Japan.

4.3.6. Work schedule by work process in development of national topographic maps for southwestern area and digital topographic information

In general consideration of the restrictive conditions of production such as the production equipment scale for the 1/50,000 national topographic digital mapping system improved by IGB and the production through OJT in the new technology introduction process, the work schedule for development of the national topographic maps for the southwestern area and the digital topographic maps was planned and implemented as planned. (Refer to Figure 35)

4.3.7. Areas for production through OJT

In the work process of new technology introduction, the areas for producing maps through OJT will be described.

(1) Aerial triangulation

The areas for aerial triangulation implemented through OJT are shown in Figure 22.

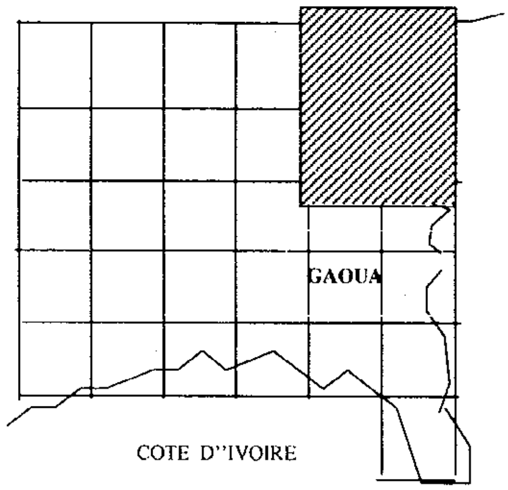

Figure 22 Areas for aerial triangulation implemented through OJT

(2) Digital plotting

The areas for digital plotting implemented through OJT are shown in Figure 23.

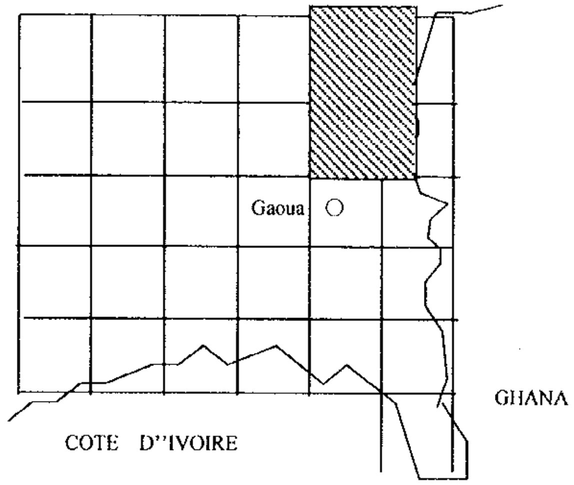

Figure 23 Areas for digital plotting implemented through OJT

(3) Areas for digital compilation, digital symbol structuralization and GIS basic data structuralization implemented through OJT

Originally, the areas for digital compilation, digital symbol structuralization and GIS basic data structuralization to be implemented through OJT was planned to be the same as those for digital plotting through OJT. However, IGB requested to increase the hours of explanatory education in the OJT. Therefore, the work areas were decreased as shown in Figure 24 in order to obtain a higher educational effect within the planned work schedule.

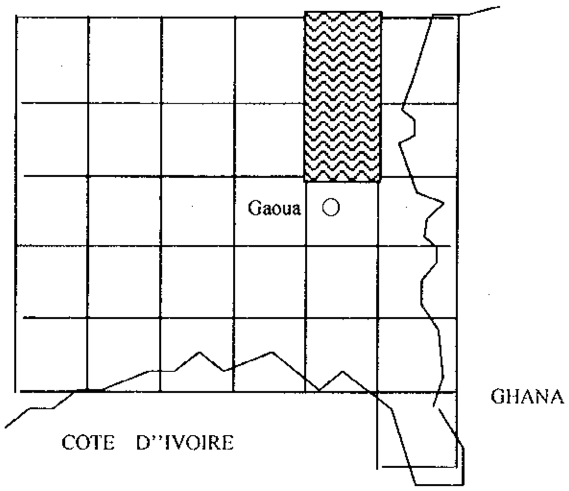

Figure24 Areas for digital compilation, digital symbol structuralization and GIS basic data structuralization implemented through OJT

4.3.8. Quality Control of National Topographic Maps for Southwestern Area and Digital Topographic Information

The quality control of the national topographic maps for the southwestern area and the digital topographic information was implemented in two types; quality control by work process carried out by the personnel in charge of production and the inspection of the results carried out by the external inspection organization, the Technical Center of Japanese Association of Surveyors.

(1) Quality control in each processes

The quality control in each processes ware carried out by the producers in charge. The quality control procedures ware executed in the way of photo management method, limitation of discrepancy such as difference in back-and-forth leveling, allowable error due to standard deviation of average values in net adjustment computation etc.

For the quality control items in each processes and their management method, refer to the separate volume No.1.

The measured values exceeding the allowable error were adequately processed after the causes were investigated and the re-measurement was carried out.

(2) Inspection of the results by Japanese Association of Surveyors

The results of the survey ware inspected by the Technical Center of Japanese Association of Surveyors that is the external inspection organization in order to inspect the results in an impartial position.

In this inspection, the general quality is inspected in accordance with the inspection procedures established by the Technical Center of Japan Survey Association. The inspection procedures are taken for a wide range of tests such as the logical test for automatic detection of logical errors in the digital maps using a program, appropriateness of map generalization method, errors in annotations, and verification of survey records with accuracy control tables. For the results that successfully passed the inspections, the inspection record and the certification are issued.

4.3.9 Items of Development and Work Volume of 1/50,000 National Topographic Maps for Southwestern Area and Digital Topographic Information

The items of development and work volume of the national topographic maps and digital topographic information are shown in Table 7.

Table 7 Items of development and work volume of 1/50,000 national topographic maps for southwestern area and digital topographic information

Items	Quantity	Description	In charge of work		
			JICA	IGB	Com.
Results of survey					
Establish. of aerial photo signal	51Points			○	
GPS survey	69Points			○	
Leveling & GPS leveling	521km	2 GPS leveling		○	
Aerial photography	20600k ㎡	1/50000scale			○
Photo interpretation standard	1set		○	○	
Aerial triangulation	618models	180models OJT	○	○	
Digital plotting	18450k ㎡	2150k ㎡ OJT	○	○	
Field identification	20600k ㎡		○	○	
Digital compilation	19100k ㎡	1500k ㎡ OJT	○	○	
Map symbol structuralization	19100k ㎡	1500k ㎡ OJT	○	○	
GIS basic data structuralization	19100k ㎡	1500k ㎡ OJT	○	○	
Make up film & map printing	32sets				○
Documents					
Technical standard & specification	1set	Fr,	○	◎	
System operation manuals	1set	Fr,	○	◎	
Inception report	1set	En	○	◎	
Progress report 1	1set	En	○	◎	
Progress report 2	1set	En	○	◎	
Draft final report (Main,Summary)	1set	En,Fr,Jp	○	◎	
Final report(Main,Summary)	1set	En,Fr,Jp	○	◎	

◎ : Conference

4.3.10. 1/50,000 national topographic maps produced

The printed 1/50,000 national topographic maps are produced using the customized software for automatic processing to perform the map symbol structuralizing process efficiently. Compared with the maps for which the map symbols are structuralized with any drawing software, these produced maps features the uniformity and high mechanical accuracy. Although a few people familiarized with the manually drawn maps had objections, the management committee made the overall evaluation that the customized semi-automatic map drawing software absolutely contributed to the superior products. The index map of the printed 1/50,000 national topographic maps is shown in Figure 40.

4.4. Development of Pilot GIS

4.4.1. GIS Users Conference

The "GIS Users Conference" consisting of delegates from various related agencies and organizations was formed to promote the GIS applications using GIS basic data. The Agreement for the GIS Users Conference is shown in Appendix 10. In this study, the full-scale GIS application systems were not be configured because those are not included in the S/W, but two types of pilot GIS using GIS basic data were configured through the discussions at the GIS Users Conference in the initial stage in order to promote the effective use of the developed digital topographic information resources. The pilot GIS's are the pilot GIS for support of the regional agricultural development and that for support of elementary school construction, management and operation. In addition, some agencies requested to configure pilot GIS systems based on important ideas, which regrettably could not be configured within the S/W.

The GIS Users Conference is expected to play the important roles as a users' body to make various recommendations for administrative policies and technical issues and as a joint development body together with IGB.

4.4.2. Configuration of pilot GIS

(1) Simple GIS

The simple GIS is a system in which the GIS basic data configured from the 1/50,000 national topographic information including not less than 150 types of huge geographic information is operated with the GIS engines commercially available. The promotion of simple GIS applications in which necessary information can be retrieved from the GIS basic data by theme is very important for promotion of GIS.

The GIS applications such as display of cultivated lands within any administrative district and calculation of the areas of those lands to obtain the rate of land cultivation, retrieval of road networks to produce road maps, and production and use of water system maps are the important keys to promote the GIS to the people who do not fully understand it. The commercially available GIS engines are so easy to purchase that the simple GIS applications with popular PCs will be promoted among the people having interest in taking a GIS in their work.

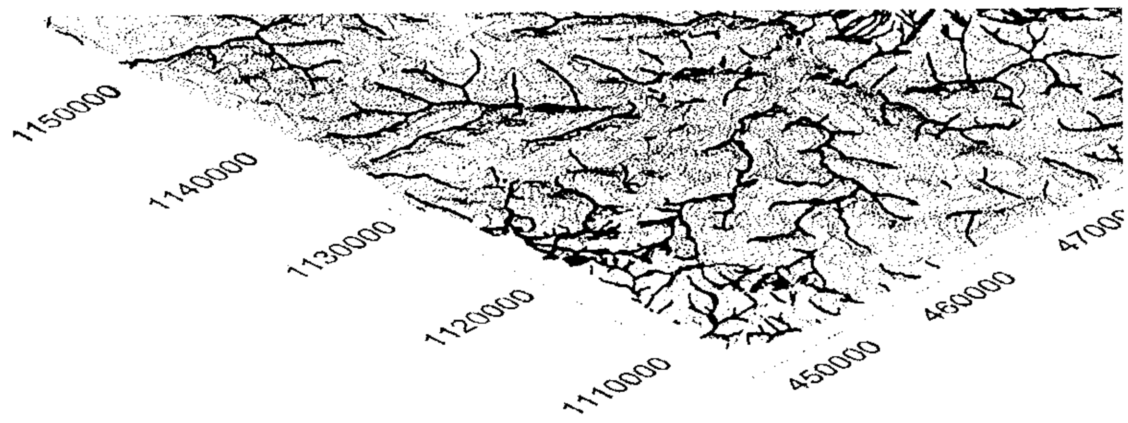

Figure 25 Example of water system map produced using a simple GIS

(2) Pilot GIS for support of regional agricultural development

This pilot GIS system has the following functions to contribute to formulating the master plan for regional agricultural development:

①Indication of topographic features

In the southwestern area of Burkina Faso, there are a few topographical undulations in general, but many alluvial plains (Bas Fonds) formed with fertile soil owing to the floods from the Mouhoun and the Komoe rivers. The alluvial plains have a high water conserving capacity suitable for rice farming and a high potential for agricultural development.

As Burkina Faso has a few topographical undulations, the 1/50,000 national topographic maps are represented with 10m contour lines (generally, having many terrains with 20m contours). The interpretation of alluvial plains is very highly accurate in the maps with 10m contours. However, the topographic features can be clearly indicated by creating the 3-dimensional topographic models with the GIS, enlarging the scale of elevation components and displaying the map in a bird eye's view.

②Addition of vegetation information in aerial photos

If the aerial photos containing a wealth of vegetation information are pasted on the 3-dimensional topographic model and a bird's eye map is displayed, the extent of alluvial plains can accurately be interpreted.

③Accurate acquisition of alluvial plains

If the alluvial plains extracted from the 1/50,000 national topographic maps are corrected on the bird's eye map, the accurate information of alluvial plains can be acquired.

④Evaluation of water resources, etc.

By calculating the water collection area at a developed site and multiplying it with a monthly rainfall, the water resource evaluation is partly available.

⑤Support of evaluation of land use and development infrastructure

By overlaying roads, villages and cultivated farms on the alluvial plain districts, the development infrastructure and land use conditions can be evaluated.

For the detail, refer to the separate volume No.2. The bird's eye photo with enlarged scale for interpretation of alluvial plains is shown in Figure 26. The map of overlay of cultivated lands, roads and villages extracted around alluvial plains is shown in Figure 27.

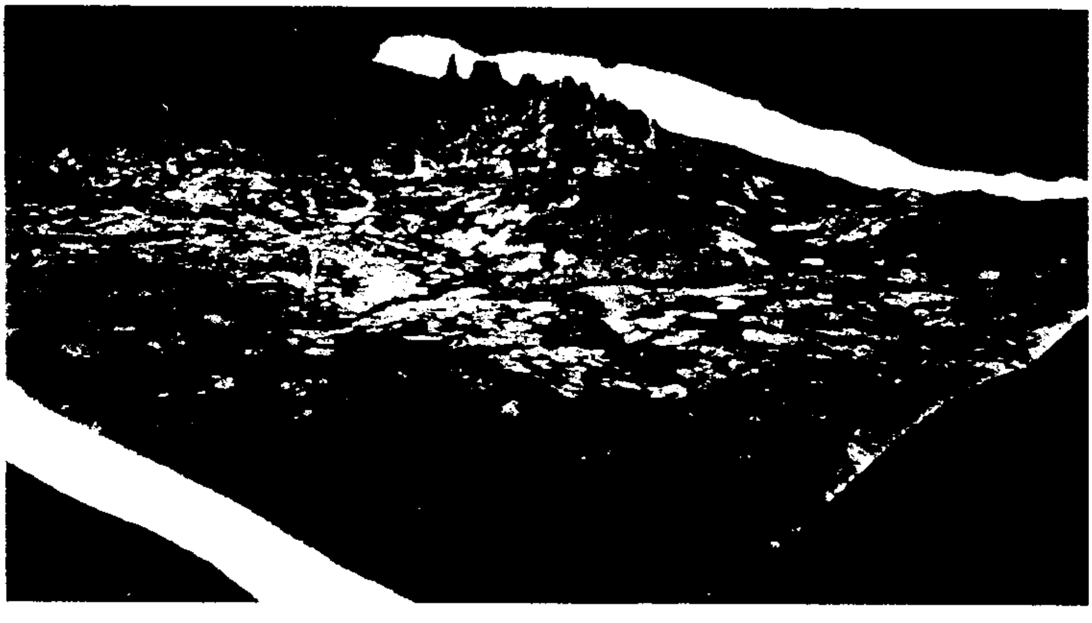

Figure 26 Bird's eye photomap for interpretation of alluvial plains

Figure 27 Conditions of roads and villages around alluvial plains

(3) Pilot GIS for support of elementary school construction, management and operation

This system is a pilot GIS to support the new or additional construction, maintenance, management and operation of elementary schools. Its major functions are as follows:

① Presumptive local distribution of children

A target area is divided into 500m grid meshes and the number of houses per mesh is counted. In this case, the number of generalized representation of built up areas are corrected. For example, in a city area, the number of houses per mesh is assumed to be 100 houses. If the field survey is available, the surveyed values are used.

The total number of children is obtained for each possibly small administrative area from the statistic of population, and the number of children per mesh in the administrative area is counted assuming that the number of children per mesh is proportional to the number of houses per mesh in the administrative area.

② Support of plan for additional construction to existing elementary schools

The children in a mesh within a 4km range from an existing school are deemed to be the children within an area to be provided with a school. Which school is the nearest from each mesh within such school-satisfied area is determined and the mesh nearest to the school is deemed to be the nearest mesh to school.

Assuming that the children attend the nearest school, the number of children within each mesh near a school is counted to obtain the total child capacity of each school. Then, the rate of children's attendance to school for a near future is estimated and the total number of children for each school is multiplied by this rate to plan the total number of children for a school. If it is necessary to increase the current total child capacity of a school in order to admit the planned total number of children, a plan of additional construction is made as given by the following number of children: Planned total number of children – current child capacity = number of children for additional construction.

③ Support of construction of new school

The children within meshes outside of the 4km coverage of an existing school are those requiring a new school. For these children, an efficient school distribution is designed under the Christaller theory to count the number of children to be admitted in a new school as the standard number of children for a new school construction plan. Then, this plan is corrected in compliance with the surrounding conditions by overlaying roads, rivers and other topographic features.

④ School information

This pilot GIS provides the image information to offer visual displays of major structures such as school buildings and text information such as school facilities, teachers and children. If the location of a school on a map is clicked, the school is displayed and the information on the management and operation of the school is also supported.

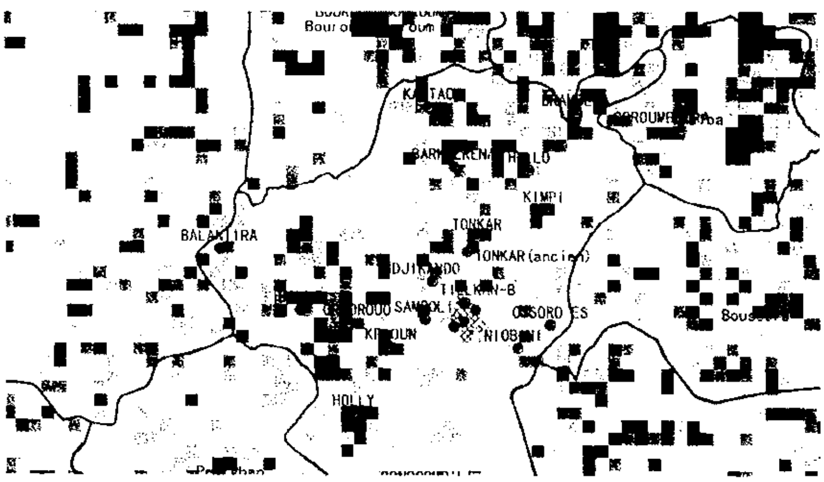

Figure 28 Child distribution by mesh in Gaoua rural district and its environs

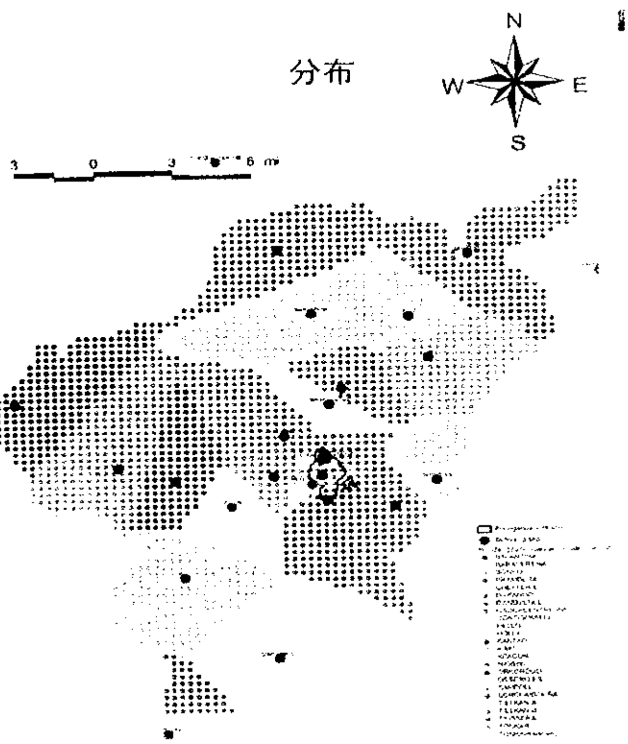

Figure 29 Meshes near the existing schools in Gaoua rural district

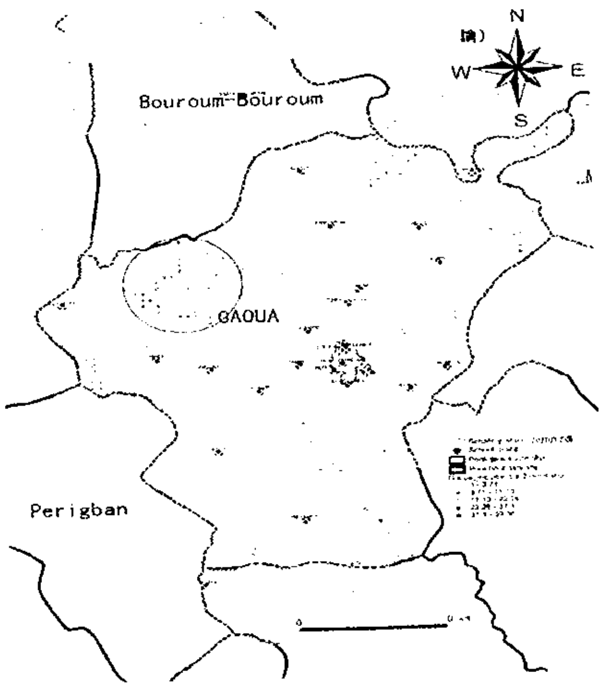

Figure 30 Selection of new school construction sites under the Christaller theory

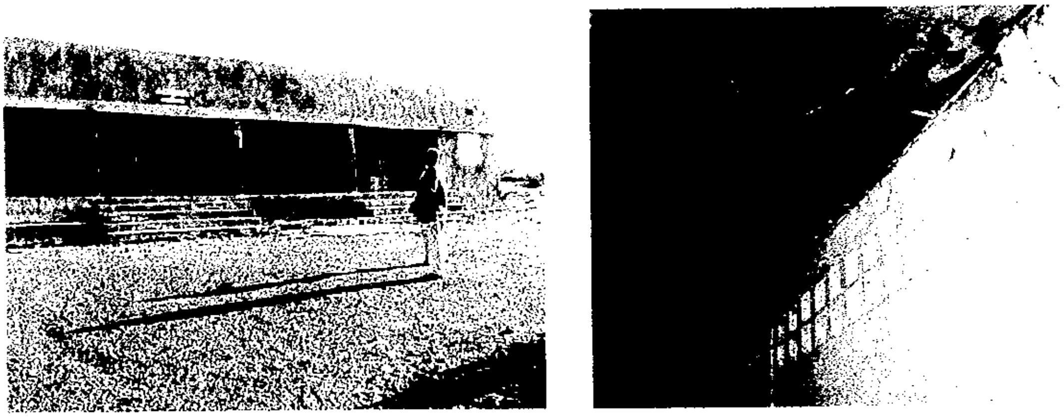

Figure 31 Image information on school buildings

There were many agencies that requested to configure pilot GIS systems, but those requests could not be realized within the S/W.

The system plan requested by the Institute of Agricultural Environment Research relates to a appropriate geographic distribution of test areas in which the ecological changes of microorganisms are regularly observed and recorded. The symptoms of desertification such as decrease of organic materials in soil, deterioration of physical and chemical soil properties and change of vegetation distribution are also observed, offering important indexes. By clicking a test area on a digital topographic map, these records can be retrieved as time-series data including image data.

The system plan requested by the Seeds Institute relates to observation and recording of the appropriate conditions for seeds to analyze those in connection with the geographic locations and the surrounding topographic environment.

The system plan requested by the Cadastral Office relates to a system to digitize cadastral maps measured in the local coordinates system, convert the maps into the national geodetic control system and manage the progress of cadastral survey on the 1/50,000 national topographic maps produced in the same coordinates system. As these cadastral maps can be used for the land use and other plans in the same coordinates system in future, the utility value of the information will be high.

It is expected that these system plans will be realized in a near future.