Remote Sensing Needs and Capabilities In West Africa
(A Case for Coastal and Ocean Monitoring)

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ABSTRACT

The greatest advantage of remote sensing over conventional measurements lies in the opportunity to carry out detailed spatio-temporal analysis of land and ocean features on a very frequent basis. This paper analyses the contribution of satellite imagery to atmospheric, geophysical and ocean studies and management in West Africa since the early 1980s. The detailed application of data from optical sensors (e.g. Meteosat, NOAA/AVHRR, SPOT, Landsat TM, etc.) for weather prediction, hydrogeological, landuse/cover and cartographic studies has been acknowledged. However, the use of microwave (e.g. SAR) and optical data for ocean monitoring and studies in the sub-region is still very limited. Even though sufficient remote sensing expertise and infrastructure is perceived in the region, no clearly defined networking or database exists.

1. INTRODUCTION

Satellite remote sensing for atmospheric and land applications in West Africa became more relevant after the regional droughts of the early 1980s. Hitherto, surface mapping and cartographic activities were executed using conventional land surveying and geophysical measurements. As a result, mapping outputs from institutions like the Ghana Survey Department, Regional Centre for Training in Aerospace Surveys (RECTAS, Nigeria), Centre

National de Télédetection du Benin (CENATEL) and Commission du Bassin du Lac Tchad were predominantly, in analogue form. Classically, applications included visual and stereoscopic aerial photo-interpretation, photogrammetry and cartography (Agyepong, 1983; 1989; Amamoo-Otchere, 1994; Bekoe, 1994, etc.).

Widespread and detailed digital processing, analysis and interpretation of optical images started after the establishment of regional/national institutions like RECTAS, CENATAL, Senegalese Centre de Suivi Ecologique (CSE) and Remote Sensing Applications Unit (now Centre for Remote Sensing & GIS) (CERGIS) at the University of Ghana. Many of the institutions were established between 1980 and 1993. Since then, the potential of remote sensing for spatio-temporal analysis of land features has been demonstrated in several reports including Agyepong (1992); Camara (1995); Opoku-Duah et al. (1999), etc. In this article, an overview of remote sensing development in West Africa since 1980 is presented.

The specific objectives of the paper are as follows:

(a) To highlight the contribution of satellite imagery to regional atmospheric, land and ocean studies and management.
(b) To describe the current remote sensing needs and capabilities for natural resources assessment and management.
(c) To present a framework for improved remote sensing capacity building and institutional networking based on the Regional Framework for Geo-spatial Information Management (REFGIM) concept.

Section 1 of the paper presents a brief historical background of remote sensing application in West Africa. Section 2 describes the major institutions that are involved in the application of remote sensing. The section also gives an overview of satellite image application to atmospheric, land and ocean studies and management. A description of regional remote sensing needs and capabilities is also presented in Section 3. A framework for improved capacity building via regional institutional networking is presented in Section 4. The last part (Section 5) presents the study conclusions and recommendations.

2. REMOTE SENSING APPLICATIONS IN WEST AFRICA

Remote sensing applications are usually grouped under such headings as agricultural and land use planning, forest management, soil resources, water resources and coastal problems, geologic and mineral survey, cartography and environmental protection (Nduaguba, 1983). The use of remote sensing in weather forecasting, climatology and communication is well known

2.1 Land & Atmospheric Applications

The most prolific applicants of satellite in West Africa include such institutions like RECTAS (Nigeria), CENATEL (Benin), Commission du Bassin du Lac Tchad (CBLT), National Water Resources Research Institute (NWRRI, Nigeria), CSE (Senegal) and the Centre for Remote Sensing and Geographical Information Systems (CERGIS, Ghana). Nearly all the Surveying and Meteorological Services Departments of West African countries are also involved in the application of remote sensing. There are a few private cartographic and engineering survey agencies involved in remote sensing, e.g. RUDAN Engineering Works in Ghana.

RECTAS (Nigeria)

The prime goal of RECTAS (set up in 1988) is remote sensing education and training in West Africa. The activities of RECTAS are supported by the UN-OOSA and French Government. The Centre provides 12-18 months training for African technicians, technologists and professionals in remote sensing application and space cartography. Recently, the Centre's work was expanded to cover consultancy projects in the processing and interpretation of satellite images for land and ocean applications (Amamoo-Otchere, 1994).

CSE (Senegal)

The Centre de Suivi Ecologique (CSE) started as a pilot project executed by the FAO in response to the disastrous effects of drought that occurred in Senegal in the 1970s. The Centre was thus, mainly concerned with the inventory and monitoring the Sahelian pastoral ecosystem (Camara, 1995). With the help of the Global Inventory Monitoring and Modelling

System (GIMMS) and the Earth Resources Section of NASA (USA), primary production was routinely monitored and evaluated applying a synergy between NOAA/AVHRR and field data. Image data was made available through the ILCA receiving station in Bamako (Mali). Eventually, the synergistic integration of Meteosat and AVHRR data assisted in evaluating accumulated rainfall, thus, improving correlation between rainfall occurrences and NDVI. Using a similar approach, bush fire monitoring was facilitated in Senegal.

Even before the establishment of CSE, rainfall monitoring and evaluation was done based on Meteosat data. Satellite images and processing equipment were donated as part of a collaborative project between the Senegalese Direction Nationale de Meteorologie (DNM) and the Tropical Agricultural Meteorology Using Satellites (TAMSAT) Unit of the University of Reading, UK (Camara, 1995).

(CERGIS, Ghana)

There are about 250 institutions and agencies related with remote sensing applications in Ghana; Table 1 gives an overview of the main institutions and agencies. Their applications range from teaching to production of maps for natural resources management. CERGIS was established at the Department of Geography, University of Ghana, Legon in 1993. In the mid-1990s, the centre made substantial contribution to a World Bank sponsored Ghana Environmental Resources Management Project (GERMP). They produced a comprehensive landuse/landcover map for Ghana. Also, through a World Bank-assisted Fisheries Subsector Capacity Building Project, CERGIS has produced GIS maps of the Volta Lake from data collected in a frame survey of canoes and fishing units for the assessment of fish production in the lake.

Offshoots of the above and other commissioned projects continue to make CERGIS the largest single user of satellite data derived from optical sensors (mainly SPOT, Landsat TM and NOAA-AVHRR) in Ghana.

Table 1: Main Institutions and Agencies Involved in Remote Sensing Applications in Ghana.

No.	Name and Address	Remarks
1.	Centre for Remote Sensing & Geographical Information Systems (CERGIS) Dept. of Geography and Resource Development University of Ghana, Legon, Accra	The most equipped remote sensing/GIS laboratory in Ghana. The staff calibre is very high. CERGIS was established in 1993. The mandate of CERGIS involves rendering academic, research and advisory services to the University of Ghana, public and private agencies needing remotely sensed data to contribute to national development.
2.	Remote Sensing Laboratory Dept. of Geography University of Cape Coast Ghana	This is a small unit still under development.
3.	Meteorological Services Department (Headquarters) P. O. Box 87 Legon, Accra	The MSD through the WMO/FAO applies data from several meteorological satellites (e.g. NOAA, GOES, MSG). Their main client is the Ghana Civil Aviation Authority.
4.	Ghana Survey Department (Min. of Lands & Forestry) P. O. Box GP 191 Accra	The mandate of Survey Department encompasses the application of remote sensing for landsurveying, digital mapping, photogrammetry and so on. The remote sensing unit is properly staffed and has sufficient hard and software with support from the JICA, World Bank and the Government of Ghana.
5.	Forestry Department (Min. of Lands & Forestry) P. O. Box 520 Achimota Forest, Accra	The remote sensing unit of the Forestry Department is only equipped to interpret image data via GIS tools. Much of their forest mapping assignments are carried out at CERGIS
6.	Water Research Institute (CSIR) P. O. Box M. 32 Accra	The remote sensing laboratory of the CSIR-WRI was to mainly support hydrological research of the Institute. The unit was set up in 2000 with financial and technical support from the European Space Agency (ESA/ESRIN, Frascati, Italy).

7.	Soil Research Institute (CSIR) Private Mail Bag Kwadaso Kumasi	The remote sensing/GIS unit of SRI was set up in the early 1990s as part of a capacity building programme within the Ghana Environmental Resources Management Project (GERMP) with sponsorship from the World Bank and UNDP.
8.	RUDAN Engineering Works Ltd. Plot 5 Kwabenya Road P. O. Box C828 Cantonments, Accra	RUDAN is private firm with support from DANDA
9.	Dutch Engineering Company Ltd. No. 5a Ringway Close Osu-RE Accra	The Dutch Engineering firm is also a private Dutch investment specialised in aero-surveys and air photographic mapping and interpretation.
10.	Dept. of Mining and Mineral Engineering Faculty of Engineering Kwame Nkrumah University of Science & Technology Kumasi	Facilities (hard and software) to process remotely sensed data are lacking. However, some expertise to analyse satellite images exists (e.g. for mining and hydro-geological investigations).
11.	Dept. of Electric & Electronic Engineering Faculty of Engineering Kwame Nkrumah University of Science & Technology Kumasi	-do-

It is important to note that most of the remote sensing institutions in West Africa have very little experience in the application of microwave (e.g. satellite radar) data. The only exception being agencies that have collaborative research projects with radar image producers, e.g. European Space Agency (ESA). For example, the Ghana Water Research Institute (WRI) recently applied the Earth Resources Satellite Synthetic Aperture Radar (ERS/SAR) as part of their contribution to the German government sponsored regional Volta basin hydrological research project (GLOWA-Volta Project).

Since the early 1980s, the Meteorological Services Department of Ghana has contributed to the WMO/FAO sponsored agro-environmental projects e.g. Global Information and Early Warning System (GIEWS), Centralised Desert Locust Reporting and Forecasting and Africa Real Time Environmental Monitoring Information System (ARTEMIS). Meteosat, Landsat TM and NOAA/AVHRR data were the data types used in these projects.

2.2 Applications in Coastal and Marine Environments

The use of remote sensing for marine weather forecasting, sea-state climatology, sea-state forecasting and communication is well known (ESA, 1996). Remote sensing applications in marine sciences have also been in the areas of marine environmental studies (including mapping areas of ecological importance), fish stock assessment, fish migration and fishing operations (Koranteng, 1999). Identification of potential sites for aquaculture may also be done through remote sensing.

Data from ERS-SAR and ATSR instruments have been used to improve accuracy and coverage of weather and sea-state forecast services. Again, global observation systems like JERS-1, Radarsat, etc. are known to offer consistent and geographically homogenous data, filling the gaps in existing conventional observation that results in economic gain. For example, a cost-benefit analysis done in ship routing (North and South Pacific Ocean) showed that optimum ship routing can typically save up to 10% in transit time on long voyages, with corresponding savings in fuel costs (ESA, 1996).

2.3 Access to Satellite Data

Satellite images are available in West Africa via four main ways: 1. Direct transmission through receiving stations. 2. Commercially packaged pre-processed CD-ROMs. 3. Free packages arising from collaborative and joint-research projects with bi- and/or multi-national agencies. 4. Free access to images displayed on the Internet (i.e. public domain output).

Africa utilises remote sensing technology less than any other continent (Amamoo-Otchere, 1994; Bekoe, 1994). The marketing of remote sensing data, equipment and software, is thus, non-lucrative on the continent. In Ghana for example, SAMBUS Company Ltd., is probably the only viable commercial distributor of satellite images, operating as representatives of a number of American and European companies, e.g. ERDAS Inc., Environmental Systems Research Institute (ESRI), European Image Company (EURIMAGE), etc.
Acquisition of satellite data is obviously technologically sophisticated and expensive. The most complex component is engineering design, construction and launching of satellites. This is currently feasible, only in technologically advanced economies, e.g. USA (NOAA), Europe (European Space Agency), Canada (Canadian Space Agency), Japan (Japanese Earth Resources Satellite), etc.

At present, pre-processed images can be obtained via satellite receiving stations in only a few African countries e.g. Tunisia, Egypt, Gabon and South Africa. But the successful operation of the ILCA receiving station in Bamako (Mali), télédetection station of the Centre AGRHYMET (Niger) and the recent telecommunication network of ECOWAS member states is some indication of the region's capacity for future image acquisition.

3. REMOTE SENSING NEEDS & CAPABILITIES IN WEST AFRICA

3.1 Remote Sensing Needs

As stated above, remote sensing for atmospheric and bio-/geophysical applications in West Africa is currently on the ascendancy. Nevertheless, there are three basic interrelated needs: institutional networking, national capacity building and establishment of an ocean-monitoring programme. It must be noted that remote sensing workshops initiated by the United Nations

Office for Outer Space Affairs (Vienna) (Agyepong et al., 1989; UN-OOSA, 1993a, b, etc.) culminated in the establishment of the RECTAS, CERGIS and other remote sensing units in West Africa.

However, since 1996, no clear follow-up action for assessing national needs, institutional networking and capacity building has taken place. In Ghana, a national remote sensing applications workshop held in 1989 (Agyepong, 1989b; Agyepong *et al*., 1989) resulted in the establishment of CERGIS (formerly called Remote Sensing Applications Unit) in 1993. Since 1995, however, no clear follow-up action for assessing national needs, institutional networking and capacity building has taken place.

The main objectives of institutional networking can be recognised in the opportunity to harmonise expertise and for the establishment of a regional remote sensing database. The greatest advantage of an efficient database would be the assurance of verifiable information for national, regional and global environmental studies and projects such as the GLOWA-Volta Project. Scientific experience arising from FAO-sponsored GIEWS and ARTEMIS projects emphasises the need for national and regional networking in terms of manpower training, image data acquisition and exchange, and dissemination and review of output. This thus, calls for the expansion of existing training opportunities at RECTAS (Nigeria) and CERGIS (Ghana).

Furthermore, the involvement of the Association of African Remote Sensing Experts (AARSE) in the construction and development of national associations has become increasingly important, cognisant of the contribution of remote sensing to national and regional socio-economic development.

In West Africa, one of the most important needs is ocean monitoring. The oceans, which cover more than 66% of the earth's surface have important influences on global weather and climate, yet they represent a natural resource about which comparatively, little is known (Lillesand & Keifer, 1994). Satellite imaging can provide synoptic views of the oceans over large areas and extended time periods. This task is virtually impossible to accomplish with traditional oceanographic measurement techniques. Remote sensing, thus, offers an excellent opportunity.

In the past, the Coastal Zone Colour Scanner (CSCS) borne on the Seasat, had capacity to measure the colour and temperature of coastal zones. Recently, Prince et al. (1998); Roerink et al. (2000), etc. have succeeded in extracting sea surface temperatures (SST) from the thermal bands (10.8 – 13.4μm) of Meteosat and NOAA-AVHRR. The value of SST is its contribution to the determination of global climate and weather prediction. Lichtenegger (1993) describes the European Space Agency ERS-1/2 as ocean monitoring satellites based on their low bit rate instruments, namely, Scatterometer, Wave Mode SAR, Alitmeter and ATSR. The current low resolution of the Canadian Radasat and ENVISAT image provides a large swath allowing full coverage of several latitudes within a few days.

For coastal and ocean monitoring, ERS Synthetic Aperture Radar (SAR) can be used to detect current shears and wave deflections, a potentially dangerous high sea state. At a Norwegian coast, for instance, the Scatterometer was successfully used to measure wind field, thus, enabling the institution of warning for weather hazard (Lichtenegger, 1993).

The analysis of sea surface features, however, is very complex, thus, requiring specialised image processing and interpretation skills in tandem with computer hard and software. The greatest scientific challenge remains the development of processing algorithms and assimilation procedures that could ensure an integration of image data into marine-based numerical models for solving specific environmental problems.

3.2 Remote Sensing Capabilities

Building sufficient manpower and infrastructure capacity in remote sensing is inherently costly and time dependent. Nevertheless, institutions like RECTAS, CERGIS, CENATEL, etc. have accelerated the development of expertise in the sub-region. The UN-OOSA, ESA, CNES, French and Danish Governments are credited for their contribution to remote sensing knowledge in West Africa.

It is difficult to present accurate statistics on remote sensing experts in the sub-region. But in Ghana, for example, about 325 professionals, technicians and students have benefited (locally) from remote sensing and GIS knowledge since 1995 (CERGIS, 1999). A number of

professionals have also received advanced training from various international institutions and universities.

At present, there is capacity to operationalise satellite images in several sectors of the African economy, e.g. weather prediction, agriculture, forestry, geology, mineral and oil exploration and hydrology and water management.

Apart from the importance of real time meteorological images for weather update and forecasting, the capabilities of near-real time images for detecting and analysing oil spillage, forest fire mapping, urban and forest floods, locust monitoring, deforestation and illegal deforestation (logging & lumbering) is an important matter for consideration. Here, the most important challenge is the cost, availability and timely acquisition of images. For example, there is little use in images that have no time bearing on forest fires or urban floods.

4. DEVELOPMENT OF REMOTE SENSING: THE REFGIM APPROACH

4.1 The REFGIM Concept

The Regional Framework of Geo-spatial Information Management (REFGIM) is proposed to provide the infrastructure needed to support the collection, maintenance and utilisation of spatial information in West Africa. Spatial information refers to data that is referenced to space or has a clearly definable position in space. REFGIM is planned to be inter-disciplinary such as to embrace all institutions that produce and/or use spatial data and information.

REFGIM is a regional extension of the National Framework of Geo-spatial Information Management (NAFGIM) project in Ghana. NAFGIM has become necessary as a follow-up action to the recent Ghana Environmental Resources Management Project (GERMP) and Information Project Operations Committee (LIPOC). NAFGIM is an inter-disciplinary and inter-agency Spatial Data Infrastructure (SDI) initiative that embraces all institutions that produce and/or use spatial data and information. The concept recognises remote sensing as major contributor of spatial data for national and regional development and planning. However, the greatest challenge is the integration of remotely sensed data into GIS. Part of

the solution lies in efficient networking of expertise, infrastructure and data exchange development of specific integration algorithms.

4.2 Framework for Developing RS Infrastructure and Expertise

Figure 1 illustrates a simplified framework for developing remote sensing infrastructure and expertise in West Africa. The only regional remote sensing centre is RECTAS (Nigeria). The CERGIS (Ghana), CSE (Senegal) and CENATEL (Benin) are national in character. But the most important difficulty associated with these institutions is that they are either operated on foreign budget or structured (e.g. CERGIS) for profit making. The cost of training therefore presents a handicap to human resources development.

The above notwithstanding, Fig. 1 proposes a clearing-house mechanism that aims at establishing an image (digital) database for West Africa. There are two main possibilities to guarantee this. Firstly, a REFGIM Secretariat can be set up. Secondly, a unit can be dedicated at the RECTAS, CERGIS, CENATEL, or CSE to serve national, regional and global interests.

The need for strengthening national and international networking of experts and data is emphasised. The co-ordinating role of the REFGIM scheme to ensure data exchange among the stakeholders is worth exploring. In particular, two things are relevant: 1. There is the need for system and software standardisation. 2. There is the need to connect remote sensing institutions to the Internet. The second point has been emphasised in scientific workshops (UN-OOSA, 1996). In Ghana, this has been addressed by the NAFGIM Steering Committee, espoused at the Environmental Protection Agency.

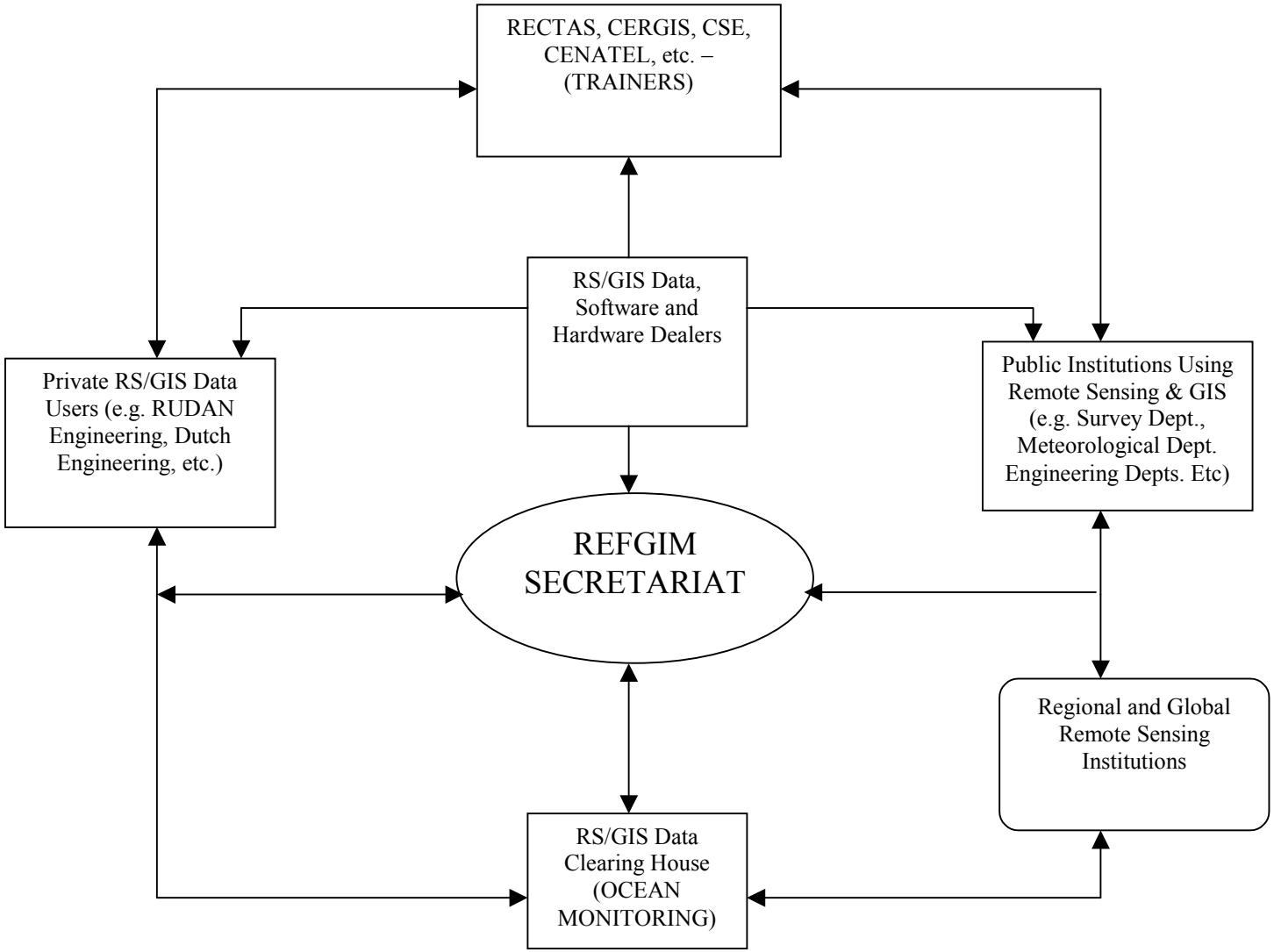

Fig. 1: Framework for Developing Remote Sensing in West Africa

5. CONCLUSION & RECOMMENDATIONS

Remote sensing (RS) for atmospheric and land applications in West Africa has intensified in recent times. With the establishment of such institutions like RECTAS (Nigeria), CERGIS (Ghana), CENATEL (Benin), AGRHYMET (Niger), CSE (Senegal), etc. many professionals, technicians and students have become aware of the exploits of remote sensing for environmental studies and the management of natural resources.

Despite the established potential of remote sensing, its application for coastal and ocean monitoring in West Africa is extremely minimal. This paper presents an innovative framework for ocean monitoring and the development of RS infrastructure and expertise in the sub-region.

To contribute to national and regional policy action the following recommendations are presented for consideration:

1. The Regional Framework for Geo-spatial Information Management is an excellent platform for building infrastructure and human resources capacity concerning remote sensing applications.

2. A remote sensing data clearing house (database) should be established at the proposed REFGIM Secretariat or in an existing institution (e.g. RECTAS, CERGIS, CENATEL, CSE, etc.) to facilitate national, regional and global networking and data exchange. By this, West Africa would be equipped to adequately contribute to global projects like climate change, SST monitoring, desertification, early warning system for locusts, etc.

3. There is an urgent need for an RS-based ocean-monitoring programme along the Gulf of Guinea.

4. Information & Communication Technology (ICT) should be institutionalised and networked at all RS-based agencies in the sub-region.

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