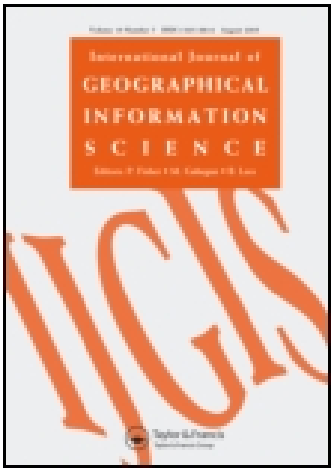

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GIS in Africa: problems, challenges and opportunities for co-operation

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GIS in Africa: problems, challenges and opportunities for co-operation

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Abstract. African countries have unique challenges for the development and use of geographic information systems (GIS), resulting from their history, culture, politics, economies, needs and resources. Many of these challenges are similar for other pioneering activities in Africa and elsewhere. These challenges can be eased by more thorough considerations by systems developers, such as in improved software functionality, integration, user interface, documentation and training aids. Increased contact with other GIS facilities in Africa and elsewhere is also important, both in person and through exchanges of publications. Aid agencies can also modify their programmes to make implementation of GIS more successful in Africa. Specific examples and improvements are cited in this article.

1. Introduction

GIS activities began developing in Africa over 15 years ago, mostly from desires to apply computer technology to cartography, remote sensing, data management and environmental assessments. Specialists in GIS in Africa note that few GIS installations are very active but that activity is increasing quite rapidly.

Although it is virtually impossible to characterize a continent without some stereotyping, it is worth noting a few observations (or perceptions) about Africa that influence the development of GIS on that continent. Most of these observations are synthesized from unpublished conversations with people active in GIS and related technology in Africa, and upon over six years' living and working in Africa.

From observations of media reporting and discussions with colleagues in that continent and elsewhere, Africa is generally considered the poorest, least-developed continent, with great wealth of resources. Outside Africa, one hears too often of the harm inflicted by repressive regimes, with inadequate credit given the many governments that are working to develop their countries. Styles of government may differ among countries, but many African countries give their people great personal freedom so long as they obey the rules. Some people obey the rules, others exploit conditions by breaking them, including planning or zoning ordinances or environmental regulations. As elsewhere, African organizations can benefit from GIS in developing and enforcing such policies. Differences as well as similarities can be expected in these uses, problems and challenges for GIS facilities in Africa, compared with other continents.

Lacking the level of industrialization of other continents, and with urbanization being a relatively new phenomenon in many areas, Africa is often perceived as a continent where rational planning of development can contribute significantly to environmental protection as well as to the people's welfare. In brief, Africa is often viewed as a laboratory with unique opportunities to do something correctly from the beginning (or at least closer to the beginning than in most other areas). This increases the appeal to some organizations interested in implementing GIS. This missionary zeal often brings Africa unrequested problems, as well as requested assistance, and complicates the style as well as the substance of GIS developments.

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Like all other parts of the world, Africa and its countries have unique conditions which challenge the developers of this technology. We discuss some of these conditions/challenges in this paper, emphasizing those of importance to developers of GIS and to current and future collaborators with African GIS centres.

We must also remember that several major cultural groups have been active on the continent. Islamic, Christian and other religious groups, British, French, Portuguese, Turkish, Spanish, Belgian, Dutch, Italian, German and other colonial influences combined with complex physical and cultural conditions. Each of these influences has left its mark in innumerable ways that affect current activities, including the development of GIS.

2. Background

Africa has a complex social and political history, strongly influenced by external colonial powers until recently and still influenced by relations with former colonists and newer offerers of bilateral and multilateral aid. These external influences combine with unique internal distributions of cultures and resources. National boundaries often divide cultural groups and physiographic/resource zones.

Within many individual nations, colonial history combined with specific local considerations to influence governmental organization. Thus one often finds in anglophone nations (usually members of the Commonwealth) a traditional civil service, a newer 'Council for Scientific and Industrial Research (CSIR)' or a variant thereof, parastatal companies, research and teaching universities and private industry. The civil service may include a geological survey, forestry department, water resources department, agriculture ministry and other agencies, often in competition with the CSIR. The CSIR, with its Highway Research Institute (loosely paralleling the civil service Public Works Department), Crops Research Institute (loosely paralleling parts of the Agriculture Ministry), and so on, may have greater focus to its mission, often being more research and development oriented, with little of the basic information management and administrative responsibilities of the civil service equivalent. The CSIR probably has a higher salary scale, benefits and level of equipment, thus attracting talented people more easily than the civil service. Indeed, CSIRs often consider the civil service as a type of training ground, offering jobs to civil servants who have gained the appropriate experience. The universities, also, have a salary scale and lifestyle that attract talent. Private industry can also attract some of the best people with its opportunity for better compensation and working conditions. Similar conditions often exist in other countries, although francophone and other countries may use parastatal companies or other administrative creations in place of CSIRs.

The bewildering complexity of competition for human, financial and other resources is often not apparent to the inexperienced outsider. Foreign aid missions often try to help the most disadvantaged governmental organizations without adequately assessing the reason for the disadvantaged status of the organizations. For reasons that go beyond the scope of this paper, the conditions that shape the more disadvantaged (often civil service) organizations may be structural, intentional or otherwise, and beyond the ability of international assistance programmes to remedy in any substance.

However, it is often the traditional civil service that has operational mandates for gathering and providing information, such as on agricultural resources and production, geology and mineral resources, weather and climate, fisheries, planning and

development of infrastructure and other projects, trade, and the economy. These are often functionally the most logical homes for GIS activity, even if they are severely limited in their ability to support a highly technical programme requiring continuity of personnel and activities. Technological development programmes must address the issue of ensuring sufficient infrastructural support to keep the GIS effective long after its initial implementation. This is one of the greatest challenges to such efforts and a challenge that some GIS developers/suppliers do too little to resolve.

2.1. *Origins of GIS in Africa*

The United Nations Environment Programme (UNEP) was formed in the early 1970s, with its headquarters in Nairobi, Kenya. UNEP's Global Environmental Monitoring System (GEMS) was created to develop global environmental monitoring programmes, one of which is the Global Resource Information Database (GRID). GRID, which recently became operational after several years of prototype testing and efforts to promote public awareness, includes GIS for the production and application of spatial databases for global environmental study (Fanshawe 1985).

GRID was formally established in 1985. At this time, several other organizations were pursuing GIS development. A number of these facilities were remote sensing agencies which had been established over the previous 15 years and had introduced related technology to their host agencies.

In addition to UNEP's activities in its 'home' continent, several bilateral programmes have been developed between countries such as the United States of America, Germany, The Netherlands, the United Kingdom, France and Sweden to help individual organizations within African countries use GIS and related technology to monitor/manage their environments. Often growing out of remote sensing development programmes of the past twenty years, this GIS activity has been growing significantly since the mid-1980s.

Other than UNEP, the Food and Agriculture Organization and the United Nations Institute for Training and Research, among other UN agencies, are becoming active in GIS in Africa. The United Nations Development Programme is also becoming interested in GIS and related technology. In addition, the World Bank is gearing up in this area. Unfortunately, the United Nations Educational, Scientific and Cultural Organization, which was so effective in sponsoring meetings and compilations of scientific knowledge on Africa from the 1950s to the 1970s, has had a tumultuous decade in the 1980s, otherwise it would probably be a major contributor in this area.

2.2. *Development based on needs*

Africa has immense resources and a generally low but rapidly-growing population. The small community of natural resource scientists is generally spread very thin and needs tools to make better use of limited resources of personnel and equipment. As many African countries regained their independence over the past 40 years, they have produced large numbers of national and regional thematic maps of resources, such as topographic, geological/mineral, soils, climatic, land use and forest maps, often with accompanying reports. Many such projects have been undertaken, only to have the information lie fallow in storage rooms owing to an inability to use it fully. GIS is one collection of tools designed to help overcome this problem.

2.3. *Some African examples*

2.3.1. *Desert Research Institute, Egypt*

The Minerals, Petroleum and Groundwater Assessment Program (MPGAP), conducted by the Government of Egypt with the assistance of the US Agency for International Development (USAID), is an overall programme to improve the handling of information concerning geological resources in Egypt. The philosophy is that improved access to information through better libraries, spatial and tabular database management, and compilation of information will make it easier for these resources to be developed wisely. Remote sensing and GIS capabilities are considered important components of this effort. Of the original four Egyptian governmental organizations participating in MPGAP, all four expressed at least some interest in GIS, but only the Desert Research Institute (DRI), a civil service research laboratory in Cairo, has progressed to the point of implementing a system. Having a requirement for integrated remote sensing and GIS capabilities, DRI acquired raster and vector systems in early 1989. It has received training from a series of visiting specialists, with visits varying from a week to 6 weeks at a time. Continued training is planned until the official end of the project in September 1990, after which training may or may not continue with USAID assistance.

DRI has developed a new laboratory for its GIS activities, which are based on personal computers. This same laboratory contains additional PCs assisting database management and other scientific applications such as groundwater modelling. DRI has built a prototype database of an area in the Sinai peninsula. It also plans to build operational databases by digitizing existing cartographic information (largely using the capabilities of DRI's vector GIS), converting information from its database management systems to cartographic data within the GIS, and by analysing and interpreting satellite imagery in an image processing system linked with DRI's raster GIS.

DRI has the advantage of neighbours (see immediately below) with similar interests and compatible software environments, so that experience can be shared. It has already benefited from this interaction, as many African GIS laboratories will as GIS become more widespread on the continent.

DRI still has many challenges, such as building and maintaining a skilled staff with this combination of brief visits and local interaction, keeping its hardware running in a climate of ubiquitous dust, power fluctuations and other hazards; in one neighbourhood nearby, power maintenance crews reversed the polarity of the mains during routine maintenance, sending 220 volts to the ground and vice versa—destroying several layers of power conditioning but fortunately not destroying the newly-developed databases or the computers themselves.

Continued interaction with other GIS facilities is important to such laboratories. Some of this interaction may be possible through bilateral or multilateral aid, but long-term interaction outside of the umbrella of 'technical assistance' is vital for long-term vitality. DRI invites collaboration with other GIS facilities inside and outside of Egypt, as do many other GIS facilities on the continent.

2.3.2. *Egyptian Ministry of Irrigation, mapping water resources of the Nile Delta*

The Ministry of Irrigation has been receiving technical assistance from The Netherlands to understand better the hydrology of the Nile Delta. It has implemented the same vector GIS as the Desert Research Institute (by coincidence, not design) at a facility near the Nile Barrages just north of Cairo. Several members of the Ministry GIS team spent a year in The Netherlands receiving extensive training in the use of this

software for digital hydrologic mapping. After this training, The Netherlands sent two specialists to the Ministry to continue the training in an operational environment, as the Ministry develops the databases for editing into published maps. The Netherlands has world-famous expertise in hydrology and knows that the software being used is complex and user unfriendly, hence the extensive training. Currently the team is still learning but it is making progress in a production environment.

2.3.3. *Mersa Matruh, Egypt, regional planning*

The German government is providing technical assistance to the governmental authorities of this coastal city west of Alexandria. It has provided the same image processing/raster GIS system as used by the Desert Research Institute, again by coincidence rather than design. Its choice was based on the user friendliness of the system for image processing, as the original application was processing and interpreting satellite imagery to make thematic maps.

The German government has provided a specialist to the office at Mersa Matruh. On-site training was provided for over a year. On a visit of this group to the Desert Research Institute, the group decided that the raster GIS capabilities of the system already selected were adequate for their applications. Although some of the features of the vector system were attractive, particularly its digitizing environment and cartographic output, the user-unfriendliness and poor protection of data integrity were decided disadvantages. The group decided to continue with its original system, enhanced as much as possible for GIS application.

2.3.4. *Global Resource Information Database (GRID), Nairobi, Kenya*

UNEP/GEMS/GRID was established in 1985 'to give users access to harmonized and integrated geographical data sets of known quality' (UNEP 1988, p. 1). GRID underwent a pilot phase between 1985 and 1987, followed by an extensive review, and has recently become operational. GRID has two main installations, in Nairobi and Geneva, and is developing a system of 'nodes' in other locations. GRID has been working with organizations and individuals on all continents to implement its programme.

GRID has received significant donations of hardware and software, and uses raster and vector systems. It is using both commercial and educational software in its operations and training. GRID's expertise is formed by a small group of full-time staff members, short- to medium-term visiting experts, an advisory panel and colleagues. Compared to many other GIS efforts in Africa, GRID has had a high profile, which is a mixed blessing. Attention helps to build interest and collaboration in a programme, but it also brings to bear competing forces requesting more than an embryonic/pioneering programme can readily provide.

2.4. *Frequent problems of African GIS facilities*

The following characteristics obviously do not exist at all African GIS facilities. There are variations among facilities and many of these characteristics are common outside Africa.

Many laboratories were developed through combinations of outside technical and financial assistance with commitments of staff, office space, finances and infrastructure of the host institution itself. Neither contribution is negligible. The assisting external agency often requires commitment by the host agency and the host agency needs an infusion of capabilities unattainable by the agency alone. The image of a 'hand-out' is usually a serious distortion.

Nevertheless, many GIS laboratories are developed in technical environments that are not completely ready for GIS. Staff may have developed scientific and other methods that conflict with the development of a new, multidisciplinary high-tech facility that may suddenly become a popular target of attention, competing with established groups. New staff may be taken from existing groups, creating friction within the host organization. Combinations of factors (such as demonstrations by vendors and other protagonists of GIS) may create high expectations of the system that are not met. Thus, such features as internal jealously within the organization, basic training in computer technology, training in multidisciplinary thinking and data processing and the tedium of actually developing digital databases from scratch create organizational barriers that must be overcome. One only hopes that there is no major administrative change at the top of the organization, as such changes often result in the cancellation of new programmes that are not already proven successes to make room for the new administration's initiatives.

Database development must often begin with nothing available, with the possible exception of global-scale databases too generalized to be immediately useful for much local-scale work. With few or no other facilities in their countries, there are few data and experiences to share.

An agency's skill needs for applications often exceed the available software, or technical skills of the agency's staff. Database development often requires combinations of software packages that may not fit well together. For example, some base maps have limited coverage of topographic contours mixed with a limited distribution of point elevations, stream lines and sketch shaded relief from which a digital elevation model (DEM) must be derived. A customized methodology must be developed, or no DEM will be available. One can rarely plan for all such needs in the initial design of the system. Such problems may discourage all but the most highly-motivated and resourceful efforts.

At least some technical expertise is only borrowed, or is available only part-time. This is true for even some of the best-established, best-funded facilities. The temporary loss of a key person (such as the only person who knows how to configure the hardware or the software, or the manager of a suddenly corrupted database) can grind the lab to a halt. Back-up assistance through ties with colleagues can save the day for such laboratories. However, such assistance usually goes beyond the long-term abilities of aid agencies.

In many cases, selection of a system is based not on a complete study of needs but on one's impression from 'popular' GIS software. Often a combination of vector and raster capability plus other database development tools is needed to develop and edit databases from available maps, and to do sophisticated environmental modelling (such as cluster analysis, filtering and trend analysis), rather than mere overlay analysis. Often a system will be asked to perform combinations of functions, from environmental analysis to urban planning.

Although some software systems cater to beginners and experienced users alike, few have a complete balance. Systems that emphasize ease of learning often limit the sophisticated user, thus frustrating that user when he or she outgrows the system. Systems that provide the power without considering ease of learning frustrate the beginner to that system (even if that person is expert in GIS, having outgrown the easy-to-use system). Extra care is needed on the part of software developers interested in overseas marketing to overcome such problems.

Many laboratories are pioneers in their countries. They have the challenge of creating a critical mass of physical laboratory facilities, computer facilities, staff, data, applications skills, collaborators with whom to share experience, long-term funding for continued system support and development, and so on. They cannot rely on development support forever but must become operational. One thing that they most vitally need is protection from isolation when the developmental stage of their system is completed. Colleagues within their own countries are most valuable in this respect, but, in the beginning, there may not be such colleagues. International collaboration is often invaluable to the survival of such laboratories. Such collaborations must help to develop the facilities of the laboratory, not just 'do' favours for that laboratory that make it dependent on the outside collaborator. One of the authors has visited laboratories (not all in Africa) that have felt captive to universities in the 'north' that have provided services in exchange for data, but which have not actually helped to develop capabilities in the laboratory in the developing country. (Their impression was that the overseas university felt that it would have less leverage in obtaining data if it helped the developing laboratory to increase its own capabilities.) GIS laboratories need more substantial collaboration than this if they are to succeed. This is an area in which readers of this journal can provide immense help.

3. What can the GIS community do to assist the development of African GIS laboratories?

Several things can be done to assist the development of an African GIS community. The ideas listed here will also improve the development of the GIS community outside Africa, so no sacrifice of other priorities is needed.

3.1. *Improvements in software and user interfaces*

Great progress is currently being made to integrate raster and vector GIS capabilities, and to integrate image processing and GIS. These are major improvements in software integration that will help African GIS facilities. Additional systems integration, such as substantial capabilities for conversion from tabular to spatial data, analytical handling of multiple map scales (such as GRASS (CERL 1989) can now do), analytical handling of multiple combinations of ASCII and binary data as 8-bit byte, 16-bit integer and floating point real data (such as IDRISI (Eastman 1989) can now do) and indexing of data to speed windowed plots (such as the NOAA National Geophysical Data Center's GeoVu (NGDC 1989) software can now do with NGDC's spatial data on CD-ROMs) would reduce the frustration of users of African GIS facilities. Software developers in Toronto or Sunnyvale can get help if they need a quick fix to ingest a new database with the help of someone else's utility. This is not so easy in Bujumbura.

Software should be user-friendly but not at the expense of speedy operation. A combination of menus that the user can travel up and down, or skip directly to (by entering the menu name), or ignore altogether by entering the name of a command, provides such power and user assistance. ERDAS' system of windowing (ERDAS 1989), while leaving the user at a command line, greatly facilitates access to the system for beginners, casual users and power users alike. Another option is to have menu and command line versions of the user interface, perhaps with an intermediate version of each function that allows one to edit parameters and function settings interactively, such as is offered by GRASS.

Computers were created to take much of the drudgery out of repetitive processes. The power should be extended to the drudgery of memorizing command syntaxes. Many GIS still appear to disdain casual users who have other responsibilities in life than running their GIS. The lower the level of software training necessary to be productive (all else being equal), the better the GIS for African and other laboratories.

Computers should also help protect the user from foreseeable problems. These include protecting against loss of data from system malfunctions (like a disk failing to write) in the middle of a program by *not* overwriting the input data with the output data, avoiding incompatible file formats that unnecessarily impede the appropriate combination of different types of data, and ensuring that the output from one function produces data which are not incompatible for input into a logical next-step function. Many (most?) GIS are still deficient in such areas. These problems are much worse when they occur away from convenient telephone contact (e.g. because phones do not work, or merely because of 12 hour differences in time zone).

User interfaces could also consider linguistic differences. Words common to major languages, symbols, etc., could be used more than they currently are.

Incidentally, not all developments of user interfaces must be made by the developers of GIS software. One of the authors has experimented with the addition of a user-friendly menu system for IDRISI (before IDRISI had such a system of its own), using the shareware program Automenu (available from many bulletin boards, shareware distributors and directly from the developers (Magee 1988)). Although IDRISI and Automenu were not designed for each other, resulting in some limitations, the combination can result in a useful tool for first-time or casual users of the GIS.

3.2. *Improved software documentation and training materials*

Software documentation is often written unintelligibly in its original language—consider the person in Mozambique who tries to decipher it while trying to save a database from destruction.

Several public domain or low-cost educational packages have rather substantial documentation that also includes sample databases and training exercises. Many of these systems exceed far more expensive commercial systems in their consideration for the user's education. One vendor has produced a series of videotapes for use in training—but these tapes primarily give a very elementary overview of GIS. Anyone selecting a system should have passed through this stage already. Though the tapes may be useful, they do not sufficiently help the new user to become familiar with the software. Producing a training tape takes some care but is not particularly difficult. One tape on database digitizing, another on database integration, one or two on different aspects of processing, one on modelling and one on cartographic output can be little more than carefully orchestrated demonstrations that have been videotaped, spiced with important pointers and accompanied by books that repeat the information in print (with appropriate references to software documentation). Some materials are beginning to appear along these lines from third-party vendors.

GIS developers should consider the need for improved training in GIS techniques in the appropriate technical subject area. With the current shortage of textbooks, videos and written training exercises, for many systems, there is currently no replacement for long-term commitment of training personnel to new aid projects. It is interesting to note that public domain and low-cost (but sometimes substantial) systems may have more training materials available. This is a hint to developers of more expensive

commercial systems that they should catch up in this area, or risk having aid agencies choose public domain/inexpensive systems as more cost-beneficial for training and operations!

3.3. *Long-term commitments for training*

Development of a GIS facility involves competing pressures on limited budgets to maximize hardware and software capability, hire the best people, provide adequate training and support operations. In most cases, painful compromises are required.

Training is often one of the worst-hit parts of this process when budgets need to be met. When hardware and software are touted as 'easy-to-use and maintain', why should one need a long-term training commitment?

Those responsible for the most successful implementations of GIS in any area know that adequately-trained personnel are a fundamental requirement. Training specialists know that computer technology, particularly technology as sophisticated as GIS, may need considerable training time for people in less material/technological cultures than in countries that are exporting this technology.

One laboratory that has received a series of visiting specialists rather than long-term training, has had mixed benefits from this style of training. Several of the briefer 1–3 week visits have encountered a common problem. Some visiting specialists have come to find conditions different from those described, and wind up improvising solutions to immediate problems extending beyond their missions; alternatively, they stick to their contracted service, being less effective than hoped for because of competing problems. This problem may be compounded by the rigid schedules of consultants, preventing important extensions of their stay to provide the planned-for service as well as the unscheduled trouble-shooting. In addition, there may be inadequate time to consolidate the new knowledge (imparted hastily to meet a schedule) before the specialist leaves. Thus the desire for a wealth of specialists competes within a fixed budget with the desire for long-term support.

However, in developing its own GIS staff capabilities, this laboratory has been able to take advantage of local contract help hired as part of the development project. These people, who are not GIS specialists but have computer programming and database management skills, have been able to absorb the technology relatively quickly, and have provided continuity between the relatively short visits by foreign specialists.

Other laboratories that have received more long-term training commitments may not have been given such a variety of training; but they have an easier time obtaining a stable foundation in the technology.

3.4. *Continued technical input after training*

It is important for new facilities to receive a collection of textbooks and subscriptions to journals and newsletters. These may be overlooked by some providers of aid, at considerable cost to the recipient laboratory. Though there is a shortage of good textbooks, a few are available. This journal and few others are valuable references, provide case histories and keep readers current through their newsletters, reviews and advertising materials. GIS Newsletters are appearing, to keep readers current on developments and personalities in the field. Several software developers provide valuable newsletters to users of their systems. These can be useful even to users of competing systems. For example, *ARC News* on ARC/INFO, *ERDAS Monitor* and *GRASSClippings* on GRASS provide tips, examples and related product/data announcements that go beyond their own user communities for value.

3.5. *Improved collaboration with other GIS facilities*

As GIS spread in Africa, opportunities multiply for African GIS facilities to collaborate with others on the continent. Nothing substitutes for a local colleague with whom to share experience.

However, most facilities in Africa are still pioneers. Even when they mature, international collaboration will greatly help many activities. Indeed, local and international collaboration may be vital to the continued success of many African GIS facilities.

This need provides opportunities for overseas laboratories, particularly in universities. Is a university looking for good places to get its students experience, and perhaps thesis projects? Consider finding an African (or South American, Asian, or other) laboratory that uses the same software and has compatible technical interests. Many such laboratories would greatly appreciate collaboration that could provide medium-term technical visits, and possibly data and technology exchange. Some may be able to provide office facilities, some (particularly universities) may have temporary accommodation or other support. Such in-kind support often facilitates the arrangement of formal funding from third-party agencies. Try contacting the supplier of your GIS software to locate potential co-operators in Africa or elsewhere.

Software developers can help in this effort, and also provide some enhanced marketing, by having lists of users of their software (with addresses, names of key personnel, areas of activity and a comment field for solicitations of specific types of collaboration) who are interested in collaborative ventures. This list should not be restricted to Africa. African laboratories should be able to use such a list to solicit collaboration in Europe, South America or wherever.

4. Summary

Conditions in African GIS laboratories are influenced by the unique conditions of their own countries, plus many problems faced by GIS facilities in other parts of the world.

Many of the solutions to these problems are:

(*a*) in the hands of software developers—and such solutions would help other users as well as African users if they were achieved. Appropriate adjustment of development priorities would help the developers as much as the African users.

(*b*) in the hands of aid agencies—as their programmes mature, more thorough approaches to implementation can improve the effectiveness of their investments.

(*c*) in the hands of the GIS community outside the individual African laboratories. Other GIS laboratories can help themselves and their African colleagues by improving ties.

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