Induction, development and impact of GIS/RS facility and applications in Karnataka Forest Department

Assessment of past and ongoing programmes and strategic planning for the future

Evaluation Project No.PCCF(EWPRT)/EVAL.PROJ/001/2005-06

P.J.Dilip Kumar, S.Nagaraj, Sharachchandra Lele and K.S.Shashidhar

Karnataka Forest Department, Bangalore

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Acronyms and abbreviations

ACF	Assistant Conservator of Forests
ADLR	Assistant Director of Land Records
CF	Conservator of Forests
CISED	Centre for Interdisciplinary Studies in Environment and Development, a centre of excellence of Institute for Social & Economic Change (ISEC), Bangalore
CoDMIS	Computerised Divisional Management Information System
CoRMIS	Computerised Range Management Information System
DCF	Deputy Conservator of Forests
DfID	Department for International Development (United Kingdom)
DGPS	Differential Global Positioning System
DSSLR	Directorate of Survey, Settlement & Land Records
FLIS	Forest Land Information System
FLS	Front Line Staff
FMIS	Forest Management Information System
FRG	Federal Republic of Germany (erstwhile West Germany)
FSI	Forest Survey of India
GIS	Geographical Information System
GoI	Government of India
GoK	Government of Karnataka
GPS	Global Positioning System
ICAR	Indian Council for Agricultural Research
ICFRE	Indian Council for Forestry Research & Education
IFS	Indian Forest Service
IS	Information System
ISEC	Institute for Social & Economic Change
ISRO	Indian Space Research Organisation
IWST	Institute of Wood Science & Technology, Bangalore
JBIC	Japan Bank for International Cooperation
JFPM	Joint Forest Planning & Management
KFD	Karnataka Forest Department
KSRSAC	Karnataka State Remote Sensing Application Centre
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LISS	Linear Imaging Self-Scanning Sensor
MIS	Management Information System
MSS	Multi-spectral Sensor
NRSA	National Remote Sensing Agency
PCCF	Principal Chief Conservator of Forests

PCCF(EWPRT)	Principal Chief Conservator of Forests (Evaluation, Working Plans, Research & Traininig)
PMU	Planning and Monitoring Unit
PPDP	Project Process Development Programme
PPST	Project Process Support Team
RAMIS	Range Management Information System
RAMPS	Range Management Planning System
RFO	Range Forest Officer
RRSSC	Regional Remote Sensing Service Centre
RS	Remote Sensing
SFR	State of Forest Report of the Forest Survey of India (FSI)
SOI	Survey of India
SSP	Site Specific Planning
TM	Thematic Mapper
ToR	Terms of Reference
VFC	Village Forest Committee
VFMP	Village Forest Management Plan
WGFP	Western Ghats Forestry (& Environmental) Project
WP	Working Plan, WPO Working Plan Officer
WPSP	Working Plans Support Programme

Units

Cum	cubic metre
ha	hectares
sq km	square kilometre
lakh	1,00,000 (= hundred thousand)
crore	1,00,00,000 (=ten million)

EXECUTIVE SUMMARY

Background, Objectives and Methods (Section 1)

In 1986, the Karnataka Forest Department (KFD) established a Remote Sensing Unit and thus embarked on the process of inducting Remote Sensing (RS) and Geographical Information System (GIS) technologies into its activities. While these technologies, along with that of Global Positioning Systems (GPS), have advanced enormously over the past two decades, the process of their induction and adaptation into the planning and management activities of KFD has been somewhat slow and haphazard.

This evaluation is an exercise to understand the current status and potential of this set of spatial information technologies (GIS/RS/GPS), to carefully review the past experience of KFD with them, and thereby to propose a strategy for the optimal utilization of the undoubted potential of these technologies in the workings of KFD. The guiding principles behind this exercise are: understanding the needs and constraints of the front-line staff, ensuring an optimal mix of internal capacity development and outsourcing, and drawing up a strategy for the future institutionalisation of these technologies and the required human resources in a phased manner over the next few years.

The evaluation was conducted in a short duration of May 2005 to August 2005 by a multi-disciplinary team consisting of KFD staff and outside experts. The team used a variety of methods and sources to assemble the necessary information in a short span of time.

KFD experience of using GIS/RS technology (Section 2)

GIS/RS/GPS is a package of three distinct but increasingly inter-related technologies. GIS is simply a tool for the overlaying and analysis of various *existing* map or pictorial (spatial) and tabular (non-spatial) data. RS and GPS are technologies for generating *new spatial data*. RS generates images of the earth's surface using cameras located on aircrafts and remote sensing satellites. GPS generates precise information on one's location on the earth's surface. These technologies, tools and available datasets are becoming more sophisticated, better integrated and generally cheaper by the day. Nevertheless, the hidden costs of using these technologies are still significant, due to the training required to use them properly, maintain them and understand their limits.

GIS/RS induction into KFD began back in 1986, but it has had a chequered path. Most of the focus has been on generating forest cover maps. Early efforts focused on coarse scale (1:250,000) and coarse category maps. A major push came under the DfID-funded Western Ghats Forestry Project (WGFP). Aerial photographs were commissioned and more detailed mapping activity in two circles was outsourced to the National Remote Sensing Agency (NRSA) in 1996, and the outputs were put to a limited use. Simultaneously, a pilot effort was made to set up Range-level and Division-level management information systems (RAMIS and CoRMIS) in Canara Circle that linked a variety of forestry, administrative and socio-economic data. But apart from data limitations, the idea of MIS-based decision-making and management failed to find acceptance as the systems were too complex, data-intensive and mismatched with actual processes. In 1998-99, under the Working Plans Support Programme (WPSP), a major effort was made to prepare a detailed forest-cover, physiographic and administrative

boundary database entirely in digital format for 18 forest divisions. Although in-house GIS capacity was built to some extent, and the outputs were used in preparing several Working Plans, equipment obtained during this phase is either inadequate to the task, or now lies unused asspecialists engaged for the period have left, and expertise and institutional memory of the WPSP seem to have evaporated.

The forest cover mapping effort, however, continued in 2002 in a different mode, with the complete outsourcing to KSRSAC of the task of developing a geo-spatial database for 19 forest divisions left out of the WPSP exercise. KSRSAC has used high resolution imagery along with ancillary information and generated detailed forest cover and many ancillary layers in digital and hard copy format by April 2005. Subsequently, KSRSAC has been requested to standardize the database of the 18 forest divisions prepared during the WPSP phase. The maps prepared by KSRSAC are generally of a high quality in terms of forest cover interpretation. However, they continue to have the weaknesses of earlier databases, viz., that the administrative and revenue boundary information they provide (being based on SOI toposheets and taluka level revenue maps only) is limited, incomplete and of poor positional accuracy. Several other layers also are constrained by the quality of source data.

Thus, the experience of GIS/RS induction in KFD so far may be summarised as follows:

1. The focus of most efforts has been on generating RS-based **forest cover maps**, usually without authenticated forest boundaries, and often at coarse scales (usually 1:50,000 or coarser). Such maps are useful for providing a broad overview of the forest cover to officers in the Headquarters, and for appending to the working plans, but of limited use to FLS daily operations or even in actual development of silvicultural prescriptions for the once-in-ten year exercise of writing Working Plans.
2. Complex databases that try to link physiographic features and administrative boundaries to other operational and socio-economic data turned out to be mismatched with the needs and capabilities of frontline staff.
3. While the internal capacity for GIS/RS work has developed inadequately, the policy of wholesale outsourcing, coupled with the regular transfers, has further undermined this capacity and increased the distance between the data producer and the user.
4. Lack of institutionalization and long-term planning has resulted in haphazard acquisition of sophisticated equipment such as Total Station and Differential GPS, which are not being used, while basic computer equipment that is in use suffers from lack of maintenance and threat of obsolescence.

Overall, the adoption of these technologies and tools seems to have been **supply-driven**, i.e., 'because the technology is there' and based upon many assumptions borrowed from the deployment of these technologies in the West, rather than being **demand-driven** or **need-driven** and cognisant of the organisational context in which they are being deployed.

Understanding the needs (Section 3)

The formulation of a strategy to add value to KFD staff's activities through GIS/RS/GPS technologies must be rooted in an understanding of how staff at different levels use spatial knowledge differently, their differential abilities to handle sophisticated technologies, and the databases already developed. Our needs assessment shows that:

1. Executive officers at DCF and higher levels in the territorial and wildlife wings find RS-based maps useful, because such maps provide a synoptic coverage of an area that is too large for the officers to get to know intimately through field work. Working Plan officers also need such maps at various points in working plan preparation. This need will now have been met when the full set KSRSAC maps become available. Given the background of these officers, they can, with minimal training, use these maps and databases. But this is offline use, requiring updating perhaps once in 10 years.
2. Frontline staff (FLS) generally have an intimate field knowledge of the terrain in which they operate, and given the complexity of GIS/RS technologies, they do not find forest cover maps of much use.
3. However, FLS in working plan and territorial wings are constantly engaged in *land management* activities such as monitoring encroachments or drawing up sec.4 proposals for notifying intent to constitute reserved forests, that requires constant reference to **village cadastral maps**, **forest survey maps** and **land records,** and also fresh surveying and map updating. These maps and records are currently in poor shape, and out of sync with Government of Karnataka's efforts to systematise land records through the Bhoomi project. Frontline staff would therefore need a technology and training package that would easily a) reproduce existing maps, b) speed up field surveying, c) link the survey data to these maps to facilitate cross-checking and updating, d) access reliable land tenure information related to the public land parcels that they manage.
4. Finally, this need for clarifying the legal status of various lands controlled by KFD finds resonance at KFD headquarters, where issues related to land regulation, notification for forming reserved forests and land transfers, have to be repeatedly addressed.

Presenting an alternate strategy (Section 4)

The above review and needs assessment lead to a strategy in which the essential elements are as follows:

1. The GIS facility in KFD should now focus on building up a digital collection of large scale maps like village maps and forest survey maps, with forest boundary details marked in relation to village boundaries and survey numbers. The department should accept that it may not be possible to put together all these individual maps in one composite geo-referenced map, but efforts can be made to develop a facility to put together a few adjoining villages to make a composite layout or view. Scanned and digitized versions of cadastral maps for the relevant villages could be obtained from the ongoing projects of KSRSAC or other agencies like SoI, state Department of Land Survey, etc.
2. These digital large scale maps can be linked to the existing 1:50,000 GIS to enable calling up of the relevant map images for specific purposes. This will amplify the utility of the existing GIS as well as the proposed large scale digital maps resources.
3. A parallel exercise is needed to build up a comprehensive database (which can be termed the **Forest Lands Information System,** FLIS) of forest lands, village-wise and survey number-wise, designed to be in concordance with the revenue land databases already developed in the state, i.e. Bhoomi. A concurrent exercise is to be taken up to rationalize the land database in collaboration with Bhoomi cell of Revenue Dept. and the Bhoomi software developers, i.e. NIC. The textual data connected to each forest parcel (may be just scanned images of documents) like the

forest notifications, boundary description, etc. may also be provided in the FLIS to provide a ready reference to these archival documents for each notified area.

4. In the immediate future, there need not be any massive exercise in building up management history or ecological data of each land parcel; development of such a larger, more elaborate and detailed **Forest Management Information System** (FMIS, for forest management purposes) can be thought of at a later stage, once the land database is stabilized.
5. The GIS and the proposed FLIS can be integrated at a later stage by providing suitable links in the software.
6. The Working Plans offices will be the nodal locations where the digital database (GIS/MIS) will be maintained during the developmental phase (anticipated to be the duration of the JBIC Phase-2 project). They will provide the respective territorial jurisdictions the relevant GIS/MIS services. A master GIS/MIS centre can be set up at HQ, and all centres can be linked to the land database (Bhoomi) of the State Data Centre.
7. Adequate technical staff will have to be provided to the Working Plans (nodal) offices and to the central unit. There will have to be at least one GIS specialist and one computer technician at each nodal location, and one senior GIS professional and two technicians at HQ. Adequate complement of draftsmen and surveyors (many posts of which are at present vacant) needs to be provided. These personnel will be the immediate users of the GIS, for preparing maps, entering data of local interest in specific cases, etc. The larger task of updating the GIS periodically, may however be entrusted to a professional organization (presently KSRSAC is meant to serve the whole state).
8. The post of Conservator of Forests (GIS & Evaluation) at HQ may be revived in order to give leadership to the technical staff, give proper orientation and momentum to the process of further developing the GIS programme, and above all for providing a medium of communication and interface between the rank and file of KFD on the one hand, and technical wing of the GIS in KFD, KSRSAC, and Bhoomi in the Revenue Department of Government.
9. The training given to surveyors and draftsmen located in territorial, wildlife and working plan offices, who are identified as the core clientele of the system, will be at professional, higher level to make them more efficient at using the GIS. Training to forest staff other than surveyors and draftsmen, and to officers at various levels, can be of shorter, general nature to familiarize them with the capabilities and uses of the GIS. Training opportunities should also be provided to the professional and technical personnel maintaining the GIS and computers, apart from providing adequate promotional opportunities in case they are provided permanent positions.
10. Upgradation of hardware and software will be done in stages based on present facilities and on capabilities of personnel using them, and future requirements. It will be sufficient to build up now on Windows-based GIS software, and with existing package like ArcView 3.2, which is considered sufficient for most of the functions that can be anticipated in the forest department in the near future. However, computer systems would need to be replaced urgently to have systems with extra memory, fast graphics, big screen etc.
11. A separate exercise is required to build up a proper data resources management system, including screening and cataloguing the existing data and map resources, and building up the metadata database, so as to minimize repetition of work already done, and make existing resources known and accessible to all potential users.

12. A mechanism may be put in place to take running decisions on technical issues, including quality control, maintenance of metadata, management of the data resources, avoiding repetition and minimizing costs, drawing up terms of reference and specifications, deciding or recommending award of contracts, etc.

It is believed that this strategy will ensure the adoption, adaptation and institutionalisation of these powerful emerging technologies and datasets in a way that adds significant value to the activities of KFD at various levels and ensures perpetuation of institutional memory and capabilities in KFD.

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1 Background, Objectives and Methods

Writing in the Foreword to an ISRO publication "Organising Spatial Information System around a GIS core" in 1994, Dr.K.Kasturirangan, then Chairman, ISRO and Secretary, Department of Space, stated that "The field of Geographical Information System (GIS) is relatively new and is rapidly developing. People new to the field and even many who have been working in it for some time are unsure about its capabilities and potentials". Ten years on, we are aware that a number of applied projects have been implemented using **Geographical Information System and Remote Sensing (GIS/RS)**[1] in various fields, including forestry, and capabilities are ever improving with advances in technology, launching of new and more capable satellites, enormous development in computer technology, etc. Dr.Kasturirangan concluded his preface by stating that "this report needs to be seen as a continuum and regularly updated by incorporating the advances in technology, applications and modeling and most important of all, user experiences that will be forthcoming in the future."

It is with this spirit in mind that it was proposed to assess and evaluate the experience with GIS/RS technology and applications in Karnataka Forest Department (KFD), and to suggest ways forward. A "concept note" of the proposed study was sent under letter No.PCCF(EWPRT)/ EVALPROJ/001/2005-06 dated 20th January 2005 to Government of Karnataka in the Department of Forests, Ecology & Environment, and after a discussion on 10th May 2005, Government have agreed to the proposal "in principle", as per Proceedings No.FEE 122 IFA 05 (A) dt.17.05.2005 of the Principal Secretary, Forests, Ecology & Environment Dept., Government of Karnataka.

Government have also made some suggestions while giving the above approval: that emphasis should be on building up of **institutional memory**, with care to avoid repetition and duplication; the objectives should be specific and relevant to front-line staff; possibility of developing expertise within KFD and also of outsourcing should be explored; a broad based strategy, which is not there at present, be developed on GIS, duly interacting with Karnataka State Remote Sensing Applications Centre (KSRSAC) regarding their recently approved GIS project for the entire state (with a view to exploring cost-saving linkages).

1.1 Objectives

Drawing from the issues to be addressed as per the concept note, the overall approach in this evaluation process is to develop a broad-based strategy for the adaptation and institutionalization of these technologies in ways that are relevant to the front-line management and planning staff.

The specific objectives of this evaluation-cum-strategy development exercise are:

1. To understand the GIS/RS/GPS technologies that are currently available and their potential in spatial analysis for planning, management, etc. in Karnataka Forest Department (KFD) and in forestry in general.

[1] During the course of the review, it was apparent that a third technology also needs to be addressed, viz. Global Positioning System (GPS). The subject of the study may therefore be more accurately termed GIS/RS/GPS.

2. To review the experience so far in KFD with the use and adaptation of these technologies in its activities at various levels (headquarters, working plans, territorial offices, etc.) and to understand the extent to which these activities have or have not benefited from these technologies and why.
3. To assess the actual needs for spatial information and analyses at various levels within KFD, the manner in which they are currently met, the possible contribution of GIS/RS/GPS technologies and methods for satisfying these needs over the long run, and the ancillary activities necessary for their optimal utilization.
4. To propose a strategy for such integration and institutionalization of these technologies and the associated human resources in a need-based and phased manner over the next few years, keeping in mind budgetary constraints and opportunities.

The guiding principles behind this exercise are: understanding the needs and constraints of the front-line staff, ensuring an optimal mix of internal capacity development and outsourcing, and developing an institutional framework that will ensure long-term stability of the system.

1.2 Methods and timeframe

The Government of Karnataka gave its consent to this evaluation exercise in May 2005, after which a multi-disciplinary team consisting of KFD staff and outside experts from Centre for Interdisciplinary Studies in Environment and Development (CISED, a centre of excellence of Institute of Social & Economic Change, ISEC), and Institute of Wood Science & Technology (IWST), was assembled and was charged with the task of generating an interim report by August 2005. A brief description of the team members is given in Appendix I.

The team used multiple methods, including

- consulting past KFD documents and consultancy reports,
- holding detailed discussions with a cross-section of staff associated with past GIS/RS activities,
- circulating a detailed questionnaire to all the Working Plan offices,
- visiting each Working Plan office and holding detailed discussions with all the Working Plan staff,
- commissioning additional needs assessment of territorial and working plan staff through an outside consultant, and
- holding detailed discussions with Karnataka State Remote Sensing Application Centre (KSRSAC) and Directorate of Survey, Settlement & Land Records (DSSLR).

A list of offices visited and persons consulted is given in Appendix I.

It was originally anticipated that the exercise would be conducted over a period of 6-9 months. However, as the Principal Secretary, Forests Ecology & Environment, expressed the need for a report very soon so as to initiate subsequent activities, the time line was shortened drastically and this report was finalized in early September 2005, i.e., barely 4 months after initiation of the exercise. This constraint should be kept in mind when reading this report.

This Review is a first attempt of the Evaluation wing of Karnataka Forest Department (KFD) to move from a works-based to a programme-oriented evaluation.

2 KFD experience of using GIS/RS technology

2.1 GIS/RS/GPS technology and tools and their application

Understanding the nature of the technologies is the first step in this exercise. GIS/RS/GPS is a package of three distinct but increasingly inter-related technologies. **GIS (Geographical Information System)** is simply a (computer-based) tool for the overlaying and analysis of various *existing* map (spatial) data and tabular (non-spatial) data. **RS (Remote Sensing)** and **GPS (Global Positioning System)**, on the other hand, are technologies for generating *new spatial data*.

GIS refers to a systematic organization of spatial data, that is information usually depicted on maps, and usually implies the use of computers to store and manipulate the data. Computer-based **GIS software** evolved initially somewhat independently of remote sensing technologies, being initially a tool to digitize and analyse hard copy maps prepared with conventional methods. Even after personal computers became popular in the late 1980s, it took a while for the complex GIS software to become available on PCs, and GIS became truly user-friendly and reasonably priced only in the 1990s. The ArcInfo/ArcView/ArcGIS series produced by ESRI dominate the market, while a few others such as MapInfo also exist. As RS imagery became available in digital (rather than hard copy) format, GIS software began to include modules for image processing, and vice-versa. IDRISI is a hybrid GIS-cum-image processing software, because it uses a raster-based GIS approach rather than the vector-based approach of ArcInfo.

Today, with the advent of high-speed computers, advanced graphics, and large hard disks and random access memories, the user has the ability to acquire and overlay data from different sources, thereby creating new maps or drawings. Various analyses such as buffering, clipping, distance calculation, surface interpolation, and routing can be performed, given suitable datasets, which would have been unthinkably tedious by hand. Nevertheless, the hidden costs of using these technologies are still significant, due to the training required to use them properly, maintain them and understand their limits.

It should be noted that converting existing maps into some digital format is always the first essential step in any GIS-based analysis. In India, the base maps are always those provided by the Survey of India (SOI). Over the past decade or so, different agencies have generated digital versions of base maps as well as additional layers (soil, slope, land-cover, watershed boundary, etc.) for different regions for different purposes. As described later, KFD itself has generated digital and hardcopy maps of various dates, types, and scales. However, many of the map layers generated by other agencies are not easily accessible. One of the tasks facing any organization is, therefore, to get access to and sort out the existing GIS data resources, assess their quality, build up a catalogue of their contents (area covered, parameters recorded, etc.), and attempt to reduce duplication while resolving any problems in using together data of different vintages (dates) and different sources. At the same time, non-availability of high resolution maps of administrative and revenue boundaries remains one of the biggest constraints in doing GIS-based analysis in India. This is particularly crucial in a situation where most of the

socio-economic and even operational information of government departments is organized around administrative units.

RS (Remote Sensing) generates images of the earth's surface (and to some extent subsurface) using cameras and other sensing devices located on aircraft and remote sensing satellites. These images were earlier available only in printed (hardcopy) format, and the scales of these images could be changed only using optical devices, and maps were prepared from them by tracing; now all these operations are done digitally on computers. The strength of RS lies in the fact that different sensors can capture different parts of the spectrum, and these can be examined and interpreted subsequently by technicians, or semi-automatically with the help of computers, to indicate among other things the type of vegetation or land use.

GPS GPS (Global Positioning System) generates precise information on one's location on the earth's surface, using a handheld receiver to capture signals from a network of 27 satellites that was launched by the U.S. Government. Further positional accuracy can be obtained by using a **Differential GPS (DGPS)**, wherein in a master station is located at a point whose location is known with a great deal of precision, and the handheld units operate as 'slave' units. By this method, an accuracy of better than 1m can be achieved, whereas the handheld receiver alone has an accuracy of about 5m under normal conditions and around 10m-15m in hilly terrain or under a dense tree canopy.

RS technology emerged earliest, with aerial photography being pioneered between the two World Wars. Aerial photography began in India with Survey of India and ISRO initiating aerial survey in the late 1960s using multi-data instruments and aircraft carrying a variety of image sensors, such as infrared scanners, multi-spectral scanners and radiometer for monitoring crop yields. Satellite-based remote sensing emerged with NASA (USA) launching LANDSAT-1 in 1972, thus paving the way for space data acquisition and assessment and monitoring of natural resources, especially forest resources. With the establishment of LANDSAT receiving station at the National Remote Sensing Agency (NRSA) in Hyderabad in 1979, opportunity was provided for quicker acquisition, interpretation and analysis of satellite data pertaining to the Indian subcontinent by Indian scientists. In March 1988, India's first indigenous remote sensing satellite, IRS-1A, was launched, soon to be followed by others in the series viz. IRS-1B (Aug 1991), IRS-P2 (Oct 1994), IRS-1C (Dec 1995), IRS-P3 (Apr 1996), IRS-P4 (OCEANSAT-1) (1996), IRS-1D (Sep 1997), ResourceSat-1 (2003), and IRS-P5 (CARTOSAT-1 in 2005). IRS-1D launched in Sep 1997 by Polar Satellite Launch Vehicle (PSLV) has three sensors: Panchromatic (PAN) with resolution of 5.2-5.8 m in visible spectrum, Linear Imaging Self-Scanning Sensor (LISS-III) providing multi-spectral data in four bands of visible near infrared (resolution 21.2-23.5m) and short wave infrared (resolution 63.6-70.5m), and wide field sensor (WiFS) with 2 bands and spatial resolution of 169-188m. IRS-P5 has an improved sensor system providing 2.5m resolution with stereo capability, catering to the needs of cartographers and terrain modeling applications, providing cadastral information up to 1:5000 scale and useful for making 2.5m contour maps. The trend has generally been toward higher resolution (e.g. the American IKONOS with 1 m resolution) and larger number of bands (100 or more).

The main advantage of RS lies in its synoptic and repetitive coverage, and in its providing data in a quantifiable manner, which makes it an effective tool for modifying the assessment of natural resources periodically, which can also be integrated within the

conventional data to assist decision making. Standard data products are available incorporating necessary radiometric and geometric correction. Analysis of satellite data is divided into **visual interpretation** and **digital processing**. Image interpretation uses the fact that different types of objects (e.g. vegetation) reflect different portions of the spectrum at different intensities, and hence if there is a sufficient number of bands in the RS data (i.e. if spectral resolution is good), it is possible to differentiate the objects. A balance has to struck between the number of bands (the more the better) and their width (the less the better): for forest cover studies, the monitoring bands 5 and 7 of the MSS (multispectral sensor) and composite of 4,5 and 7 in MSS and 1, 2 and 3 of the TM (thematic mapper) sensor are used. The principle underlying **digital** analysis or digital image processing is to assign each pixel based on its radiance vector to one of many spectral signature classes, which have been pre-defined based on the range of parameters measured. This assignment can be done by **supervised** computer classification, under which the interpreter decides which classes are to be formed by the aggregate of data and uses the available ground truth information to locate samples of these classes in the pixel matrix; appropriate software then computes the range of statistics for the sample of each class, the spectral signatures for the purpose of the classification often referred to as **training areas and sets**. The other type is **unsupervised** classification, in which clustering is carried out by the computer itself in a sequence of pixels from the data set to establish the series of initiating cluster centers.

GPS receivers became usable in the Indian context only from the late 1990s and particularly after 2000 when the US Government removed selective availability (a euphemism for the noise deliberately introduced in the signal to reduce accuracy available to civilian users.) Now, with typical hand-held GPS receivers costing around Rs.25,000 or less, it is possible for an average organization to get positional information with an accuracy of 5m in flat terrain and perhaps 8-10m in hilly terrain. With a **differential** GPS, which includes a base station and handheld receiver operating in synchronization, it is possible to get position accuracy of less than 1m.

Although the three technologies emerged independently, they are increasingly being interlinked. Thus, RS software such as ERDAS Imagine now have vector modules in which GIS layers can be imported and even created. Conversely, ArcView has an Image Analysis extension for satellite image processing. As mentioned earlier, IDRISI was always a hybrid GIS-RS package. GPS data can now be easily downloaded into GIS software, and uploading of maps into GPS receivers so as to view them in the field has also become possible.

With the availability of spatially and spectrally detailed satellite imagery in digital format and increasingly accurate positional data from GPS devices, which can both be loaded into highly sophisticated but menu-driven GIS software on powerful but cheap computers, the capacity to carry out sophisticated spatial analysis has increased enormously. But the costs of using these technologies are still significant, not just in terms of financial or computer resources but most of all in terms of the level of training required to use them properly and to understand their limits.

Various agencies are involved in collection of data on natural resources throughout the country at both Central Government and State Government levels. For forest and vegetation surveys, there are the Forest Survey of India (FSI) with headquarters at Dehra Dun and many regional centers including one at Bangalore; National Remote Sensing

Agency (NRSA); State Remote Sensing Centers; and the State Forest Departments. Karnataka State Remote Sensing Technology Utilisation Centre started functioning in 1989, and has developed visual and digital image analysis system with GIS package. Several wide ranging products from the Ring Road alignment to ground water mapping, land use/ land cover mapping, combating drought, etc. were taken up. NRSA has satellite data processing and analysis facilities as well as 8 applications on various themes including forestry and ecology, agriculture and soils, land use, water sources, etc. RRSSCs (Regional Remote Sensing Service Centres) were established in 5 centres (including one in Bangalore) basically to cater to the needs of digital image processing of RS. Recently, State Remote Sensing Application Centres have been set up in each state, e.g. Karnataka State Remote Sensing Applications Centre (KSRSAC), Bangalore, to serve as nodal and turnkey agency for all RS requirements of the state.

Forest Survey of India, formed in 1981 as a successor to the Pre-Investment Survey, has a photo laboratory, digital cartography system and image processing facilities including GIS. FSI was mandated at its inception to monitor periodically the changing situation of land and forest resources and also provide for national planning of forest resources utilization. Again in 1986, the objectives and activities were revised and FSI was entrusted with forest cover mapping for the whole country, preparation of thematic maps showing categories of dense, open and scrub forests, and publishing it in the form of the biennial State of Forest Report (SFR), conducting forest inventories including trees outside forests, designing methodologies and organizing training. Forest cover assessment using satellite data started in 1987, when Landsat MSS data was used with a resolution of 80m x 80m on 1:million scale. Subsequently, in the next assessment, it was improved using IRS-1B and 1C data, which had a resolution of 36m x 36m and 23m x 23m respectively. The methodology used for a long time, up to the assessment of 1999, was visual interpretation, and only in SFR 2001 and onwards was it digital processing using data from IRS 1C/1D with a resolution of 23m x 23m on a scale of 1:50,000. The use of RS data for assessment of tree resources outside the forest area is being taken up, wherein the RS data is used for stratification within each district for locating sample points. This is done using IRS PAN data with a resolution of 5.8m and LISS-III data with resolution of 23.5m, and merging them to obtain spectral information with high resolution. FSI is also making efforts to constantly improve the methodology and extend applications, e.g. creating additional density classes, assessment of bamboo crop, identifying forest types, estimating biomass, using RS application of microwave/radar data for vegetation mapping, monitoring health and extent of coral reef and mangroves.

Some of the limitations met with include cartographic and resolution related problems, poor reflectance pattern of young plantations, cloud cover and shadow, variations in tone, species identification being not achievable, plantation not differentiable from contiguous natural forest, and delineation of recorded forest areas being difficult in the absence of notified forest boundaries. For more detailed work, aerial photographs may be more effective. Medium scale photography of 1:20,000-40,000 scale is useful for most survey and inventory applications. Detailed land use classification and forest stratification by type, density, volume, site and size class are stated to be possible. A broad height classification into low, medium and good height is said to be feasible. A few species forming gregarious stands or showing typical phonological characters at the time of photography such as sal, teak, *Dipterocarpus, Boswellia, Sterculia*, and *Pterocarpus* may be identified at 20,000 scale. With large scale photography at 5000-20,000 scale, detailed information on management, inventory, and allied aspects, species identification, and

height and crown density classification may also be feasible at this scale, though cost may be a factor.

At present, FSI products are not geo-referenced for national security reasons, nor are they given out in digitized (vector) form, which severely restricts or reduces the feasibility of integrating them into the GIS frame of the user state. Consequently, there has been a tendency for the user department to develop products of RS interpretation (like vegetation maps, forest types/density maps) de-novo, through other government agencies like NRSA or the state RSAC, or through private RS/GIS companies.

In summary, it is apparent that

a) GIS/RS/GPS technologies have evolved rapidly over the past two decades in terms of spatial and spectral detail, positional accuracy and declining costs of data acquisition and computation.
b) Many agencies, specialised and otherwise, have been engaged in forest/land cover mapping in India, but the Indian forest landscape continues to pose special challenges in terms of fine-scale changes, spectrally similar land covers, and diversity of ecosystem types and land-uses.
c) For GIS to add significant value to RS, it needs many other layers of data, which are not easily or cheaply available in Indian conditions and even when they are, they are not at the desired (higher) scale.

2.2 GIS/RS development in KFD

2.2.1 Initial developments

GIS/RS induction into KFD began almost 20 years ago but has had a chequered path. KFD set up a Remote Sensing unit in 1986 at Bangalore, equipment was acquired and hard copies of aerial photographs and satellite imagery were acquired.

One of the initial works taken up by departmental personnel was the visual interpretation of satellite (LANDSAT MSS) False Colour Composites (FCCs), and a set of coarse category forest cover maps was prepared in-house for 19 districts of the state on 1:250,000 scale (this would correspond to a district map sheet), depicting Closed, Open and Degraded forest. Equipment procured and used consisted of light tables, large format Optical Enlarger, Optical Reflecting Projector, Digital Planimeter; the work was done manually. Districts covered are: Bangalore, Kolar, Tumkur, Mandya, Myore, Hassan, Mercara, Dakshina Kannada, Chikmagalur, Shimoga, Chitradurga, Dharwad, Bellary, Raichur, Belgaum, Bijapur, Gulbarga, and Bidar. Only hard copy maps were prepared in this phase..

During 1987, wasteland mapping of Kolar, Tumkur, Hassan, Chitradurga, Raichur and Bellary districts was done by visual interpretation of Thematic Mapper (TM) False Colour Composites on 1:50,000 scale using Procom-II enlarger for satellite dia-positive film, again by KFD staff. During 1998-99, a second series of vegetation maps on 1:50,000 scale was initiated using IRS 1A LISS II satellite data for Tumkur division and entire Kanara Circle, and the work was finished by 1993 using visual interpretation. These maps were also produced only in hard copy format.

An Indo-FRG (Phase III) project was funded and implemented by NRSA during 1987-89, in collaboration with Freiburg University, Germany and KFD. Its main objective was to develop a technique for estimating standing forest volume (growing stock) using multi-phase forest inventory sampling. An area of 100km x 100km in Virajpet forest division in Kodagu district was selected. Satellite imagery from IRS 1A (LISS-II) was processed. Additionally, black-and-white aerial photography (1:25,000 scale) was done on 10 to 12 lines of aerial photo coverage covering nearly 10% of the area, and infrared photography (on 1:10,000 scale) was done on a small portion. These photos were interpreted selectively, and ground inventory was conducted for around 40-60 field plots, each of 20m x 20m. The output was a computed forest volume for the study area and a brief quantitative report. (We are indebted to Dr.C.B.S.Dutt of NRSA for the above information).

The experience gained in this exercise was useful in implementing a larger growing stock estimation project for North Kanara district under the Western Ghats Forestry Project (see below).

2.2.2 GIS/RS Developments during the WGFP

Under the **Western Ghats Forestry (and Environment) Project** (WGFP), which was implemented with aid from Department for International Development (DfID) of the United Kingdom starting 1992-93, three different (but over-lapping) initiatives were taken up:

- forest cover (thematic) mapping and zonation for Kanara Circle based on aerial photographs and satellite imagery;
- integrated GIS/RS database development for several divisions;
- standardizing planning procedures and integrating them within a GIS/MIS framework.

a) Thematic mapping and zonation using RS (aerial photographs and satellite imagery)

The first GIS/RS activity under the WGFP was a major task of thematic mapping of forest types, density, etc., accompanied by development of "an efficient forest inventory design to estimate block-level standing timber", i.e. growing stock, for entire Kanara Circle (viz., Honnavar, Sirsi, Haliyal, Karwar and Yellapur divisons). This was carried out by NRSA and completed in 1996. Their method involved starting with digital analysis of IRS 1B LISS II /LANDSAT TM satellite data of December 1992 for stratifying forest types. They then carried out visual interpretation of aerial photographs of 1:25,000 scale for deriving detailed stock maps of the entire circle. The third phase involved ground inventory, for which sample plots of 0.1 ha size were laid out randomly in the field in proportion to the predominance of each stratum, and inventory data compiled in six different field inventory forms. (For instance, in Karwar division, there were 156 main inventory plots over a total forested area of 2096 sq km, which works out to around 0.0075% sampling.)

These data have been used to derive growing stock of different forest types and of plantations (using volume equations based on girth alone for some species groups, and girth and height for others). From the sample plot enumerations, estimates have been built up of plot volumes, stratum volumes, Block volumes, and finally the Division volumes. NRSA records that the computed standard error of estimates at Block level is well within design accuracy limits of 10%, and overall reliability of volume estimates of the Division

is claimed to be around 98%. Hard copy on 1:25,000 scale only is available in HQ, showing respectively forest types (evergreen, semi-evergreen, moist deciduous, littoral, swamp), growing stock (density and height, main species like teak, bamboo, acacia, areca/coconut, mixed plantation, scrub, grassland, mangrove, rocky outcrop, sandy area, forest blanks), slope, and aspect. NRSA did give some digital data in a GIS framework, only for Sirsi division (excluding growing stock), as part of a pilot effort to develop a GIS-based system. Subsequently, all these maps were digitized by private agency , but the digital datasets seem to have had problems in terms of spatial registration and edge-matching (which were apparently mitigated subsequently by digitizing from the original mylar sheets rather than from the printed hardcopy).

The data generated by this project were used in the preparation of working plans of Kanara Circle, especially in producing various maps and replacing the time-consuming traditional growing stock (volume) inventory methods with the NRSA estimates.

b) Developing an integrated GIS/RS database under Working Plans Support Programme (WPSP) under WGFP

A second and much more significant component of RS/GIS activities under WGFP began in 1998-99, under the DfID-supported Working Plans Support Programme (WPSP). Led by a DfID Associate Professional Officer (and later Consultant) working through the Working Plan office in Bangalore, a major effort was made to prepare a "fully-integrated" digital geo-spatial database, containing detailed forest-cover, physiographic and administrative boundary data layers.

During 1998-99, the RS unit at HQ was converted into an **RS/GIS unit** in the Working Plan wing. A GIS engineer was engaged on contract basis from July 1999 to March 2004. A private firm (IN-RIMIT) was sub-contracted for the GIS work for Sirsi, Karwar, Honnavar, Sagar, Mercara, Chikmagalur, and Bhadravati divisions, and Khanapur part of Belgaum division. The March/April 1998/99 images from the IRS 1C/1D LISS-III sensor (23.5m resolution) and PAN sensor (5.7m) were geo-rectified, merged to generate hybrid photographic product on 1:25,000 scale, and visual interpretation done. The layers generated were: administrative boundaries (State, District, Taluk, Forest), contours (100m, bench marks, spot and triangular heights), drainage, forest administrative boundaries (Circle, Division, Range, Section, Beat, Block, Compartment), forest type (evergreen, semi-evergreen, moist deciduous, dry deciduous, scrub), density (0-10%, 10-40%, above 40%). The work was completed by March 2002.

Subsequently, during 1999-2000, a similar exercise was taken up for Kolar division in collaboration with ORG GIS, Secunderabad and for Shimoga division and Hassan district in collaboration with ESRI India and NIIT. In addition, change analysis of forest type and density was done for Hassan district, comparing data from 1987 and 1999 satellite images. Layers in the GIS are as above, with the addition of a layer giving village boundaries.

During this work, the following equipment was purchased in the HQ unit: Bull-Estrella series 300 computer system, HP 50 A0 size colour printer, HP 6100C flat bed scanner, TNT Mips GIS software, and ArcView 3.2, ArcInfo 8.02, and ERDAS Imagine 8.4.1. During March 2000, a HP Net Server E60, PIII computer. The Working Plans offices in the Western Ghats Circles also received several pieces of equipment: several hand-held

GPS units, 1 DGPS and several Total Stations for surveying, in addition to some PCs and printers.

Our assessment of the quality of these series of integrated GIS/RS databases reveals that the quality of the databases is rather mixed. The forest boundaries in the databases for Kanara Circle are more detailed, because they are based on Bombay Forest Survey maps, whereas those in other Circles are of limited value as they are based on SOI maps alone.

The usefulness of this integrated GIS/RS database for KFD activities is discussed at the end of the next section.

c) Integrating GIS and MIS for planning and monitoring

Under the WGFP, GIS was not seen as an end in itself, but more as one element in the complex planning, monitoring and implementation management framework, a concept developed over time through a number of consultancies and consultant support programmes. This was the third of the initiatives under the WGFP, the integration of GIS with MIS for planning and monitoring.

One of the first consultant reports, **Bird & Unni** (April 1992) did essentially what this report sets out to do, that is to describe the current RS/GIS activities in KFD, review the existing RS and GIS experience in India, assess and express the spatial information needs of KFD, and make recommendations on strengthening and developing the RS/GIS facility and implementation of the system. Noting that currently, working plan inventory is based on field work, they suggest that there is much scope for applying GIS:

> *"The selection of areas* [for production, protection, etc.] *is based on a number of factors including the slope of the ground which is derived from 1:50000 topographic maps, the soil type and depth derived from field mapping, the forest type and cover density derived from satellite images and aerial photographs, the altitude derived from the topographic maps… These map data are overlayed manually and areas defined which match a set of criteria. For example production should not be considered for slopes of more than 45 degrees, for areas of fragile soils or for areas of climatic extremes. The majority of the initial decisions are therefore based on the classic GIS operations of multiple criteria map overlays."*

With this focus on forestry planning in a GIS framework, Bird & Unni saw 1:50,000 scale maps as the main output of a GIS. They envisaged further linkages with a Management Information System (MIS) that would deal with "reporting, planning and monitoring" in the WGFP, with the underlying vision that the whole gamut of planning, implementation, monitoring etc. in KFD would be transformed by the combination of processes and institutions created under the WGFP.

A second consultancy under the WGFP, **Furley & Harrison** (December 1994), did another review of "A strategy for introducing a GIS as a management tool in KFD". They also took as a starting point the institutional change sought to be brought about by the WGFP interventions:

> *"It is now widely recognised in KFD that the bottom-up demand-oriented planning process described under JFPM will require changes to the present planning practices and management procedures… a review of existing planning and the development of new planning procedures… generating more effective and relevant management information… it will be essential that KFD moves towards some form of information management system… Since much of the data are collected on a geographical basis,… it is logical to move towards a spatial information system or GIS"*

The GIS is envisaged not just as a tool to do something more efficiently, but as one of the elements that will push reform in the system; for

> *"It can help beak down orqanisational barriers and encourage a coordinated approach to planning and management; … it can reveal trends over time, produce forecasts and monitor changes, … and thereby indicate fresh management opportunities."*

And,

> *"The purpose of the present report is to address the immediate and practical issues… -in particular with the introduction of JFPM and forest management zones – and how a GIS can be introduced into KFD as a management tool to assist in more effective planning and monitoring. A framework for focussing on management information needs… defining local management activities in management zones I, II & III, IV, and from these, determining planning information needs (supply and demand within different geographical locations), and monitoring and evaluation needs (changes in supply and demand over time), for effective management…need for the development of a Management Information System (MIS), to encourage improved reporting and budget preparation, and more effective planning and monitoring systems… Development of a MIS is currently underway, and close coordination between the two development strategies will be essential.., to ensure efficient integration of all components of the WGFP."*

The WGFP was thought of as a change-inducing intervention, implemented in one circle (Kanara) on a pilot basis (to be followed in a second circle during the project period). Introduction of new systems was planned to be piloted in one division – Sirsi– for GIS/MIS, so that "confidence in the use and value of GIS is built". It would start with a PC-based system in the PMU at WGFP headquarters at Bangalore, then initiate use of the GIS in North Kanara (the pilot Circle in the WGFP), "focussing on one or two villages or ranges, for basic data storage and simple geographical presentation of information". Soon after, a PC-based unit for data entry would be located in the pilot Division (Sirsi Division as it turned out); later to be set up also in other divisions (of the pilot Circle). A GIS expert would work alongside the PMU, and there would be a "broad programme of training in the use of GIS at different technical levels, and for different KFD management levels, as appropriate to needs": brief introductory overviews or workshops for senior KFD, short courses of several weeks for digitising technicians, data managers, general users at RFO-DCF management levels, and longer courses of several months up to a year, for GIS specialists, in a *continuing* training programme.

There was a desire on the part of the WGFP consultants to link up GIS with some sort of MIS and with a transformed Planning System that would be computerised and enable planning to be done at the front-line staff (FLS) level ("bottom-up" planning). MIS systems were developed by computer consultants working with the Project, named CoRMIS (Computerised Range Management System) and RAMIS (Range Management Information System) or RAMPS (Range Management Planning System). An elaborate Planning Manual was prepared to guide the process of Site-Specific Planning (SSP) with elaborate formats for each "type" of planning situation (e.g. Plantation, Bio-diversity, Non-Timber Forest Products). All these essentially presented a more or less elaborate framework to enter all sorts of data, at various levels—the Compartment, the Range, the Division, the Village, etc.—to enable FLS and Village Forest Committee (VFC) members to query and use for decision-making. Much was also made of the need (from management theory point of view) to change the sequence of events from budget-plan-implement to plan-budget-implement, which the new MIS was supposed to enable.

The progress made in implementing the above larger vision of integrating GIS/RS with MIS was, however, rather limited and short-lived. A Computerised Range Management

Information System (CoRMIS), that included both static data and changing current administrative and planning and management data modules, was already being developed in Sirsi Circle. A Range Management Information System (RAMIS), meant to address data needs for integrated planning at the Range level, was attempted later. It was to be linked with a GIS database. However, the elaborate CoRMIS framework was not used except in a rudimentary way for preparation of estimates (for which a simple word-processor approach would have sufficed) because the data could just not be filled in (and would be of little use for the regular operations of FLS, even if filled in). Even estimates and Fund Indent preparation was not feasible because the maser unit rates schedule could not be updated without the intervention of the computer firm, and hence was abandoned after the expiry of the project contract period. The linkage of RAMIS with a rudimentary GIS at Range level was attempted on an experimental basis by a DfID sponsored research scholar for Banavasi range of Honnavar Division, but again did not go further than that.

The Working Plans Support Programme (WPSP), led by the DfID consultant mentioned earlier, had as a major objective the development of a new type of working plan and planning process, one which would merit being called "strategic", incorporating the bottom-up participatory, site-specific planning processes being developed in the implementing Circle. These were thought to require a range of "policy instruments" (Working Plans Support Document No.1): institutional arrangement like Village Forest Committees (VFC); economic levers like subsidies, costs, etc.; setting geographic priorities; as well as the usual technical forestry operations. These new instruments were said to require: new understanding (especially, analytical skills to address policy, institutional and economic issues); techniques (use of GIS for geographic processing of data and of spreadsheets for economic analysis); and skills (technical as well as non-technical like negotiation and facilitation):

> *"To allow strategic analysis, the main component of the Working Plan preparation process, it is important to define the principles and values that will apply to the management of the forest, and these in turn will determine the information needs in order to undertake strategic planning…"* (WPS Document No.7, May 2000, Review & Exit Support Programme, p.5)

It is here that GIS was supposed to be positioned, and accordingly the support programme emphasized the use of GIS in implementing socio-economic and resource integration, rather than as a mere tool to handle spatial data (maps). A pilot project to implement all these ideas (integrating GIS with Range-level planning) and developing training modules was taken up in one Range – Manchikeri in Yellapur Division – under the guidance of Alistair Anton, the DfID Associate Professional Officer, with INRIMIT, Bangalore, "to acquire, process and interpret satellite imagery, and in conjunction with territorial staff, derive information on forest type and construct a database of range information to allow informed analysis for planning purposes" (WPS Document No.3, Dec 1998, p.20) .

Under this exercise, SoI toposheets (1:50,000 scale) were used to prepare base maps, village boundaries were identified from 1":mile toposheets (Bombay Forest Survey maps); Block, Beat and Compartment boundaries were also included. Digital data from IS-1C LISS III and PAN sensors for the period 31 March 1998 pertaining to Manchikeri was acquired, geo-rectified, enhanced to increase the interpretational accuracy, then merged to produce a hybrid false colour composite (FCC), which was interpreted visually for land use/land cover and forest type classes. During ground verification exercises, other parameters such as canopy cover and regeneration status were also recorded at the sample points. All the data were put on ArcInfo software at 1:50,000 scale. Associated

socio-economic data of each village like demography, occupational structure, etc. from 1991 Census, and development activity like number of smokeless stoves provided, etc. were linked in to increase the utility of GIS as an analytical tool to facilitate management planning at different levels. The aim of the pilot project was:

> *"…to ensure that the training is relevant to the forestry situation, to improve the efficiency of the training… to assist the Working Plan staff in the appropriate techniques for the analysis of their own Divisional data… In addition, customised courses on forestry applications using MS Excel and MS Access were conducted to assist with the analysis of inventory data and in the preparation of Range profiles…Training was also conducted on topics such as: remote sensing using satellite imagery; forest resources assessment methodology; data analysis and database design." (WPS: No.7, May 2000, p.9)*

The WGFP proper closed its field operations by March 2000, and accounting by March 2001, although there was a considerable financial commitment to Working Plans support in the Exit Phase of 2000-01. During the Exit Phase also, the main objectives were spelt out as: standardization of systems and procedures (consolidated in a March 1999 document *"Guidelines on policies and procedures to be applied to all Working Plans",* intended to serve as a Working Plans Code which incorporated all the new elements like bottom-up planning, SSPs, etc.); ensuring sustainability of GIS within the KFD, by extending use of GIS beyond the Working Plans by providing training to territorial divisions; completing the digital database of the two WGFP Circles; ensuring that the data products have a wide distribution within the KFD; and sharing the experience and lessons (WPS; No.8, July 2000).

As far as can be gathered, wherever the integrated GIS/RS database was available in time, Working Plans officers used the GIS mainly in preparing the maps appended to the Working Plans. In Kanara Circle, because NRSA's project (see above) had generated growing stock estimates, it can be stated that RS/GIS tools were used at a higher level than just for map generation. In other cases, the new maps seem to have played a limited role in shaping the content of the Plans themselves—most of the silvicultural prescriptions emerge from field understanding and inventory, not derived from the GIS/RS database.

2.2.3 Post-WGFP period

As mentioned earlier, a GIS engineer had been appointed in July 1999 in the WPSP phase (and continued up to March 2004). A post of Conservator of Forests, GIS, Monitoring, and Evaluation was created from April 2000 (although it was wound up by March 2003). During 2002, GIS databases was completed within the RS/GIS cell for Tumkur, Davangere, Bangalore Rural, Bangalore Urban, Mandya, and Hunsur divisions, for which only basic layers viz., administrative boundaries and forest boundaries have been created. Much of the work reported for 2002-03 pertains to distribution of digital draft GIS data to 19 forest divisions (Karwar, Sirsi, Honnavar, Haliyal and Yellapur in Kanara Circle; Shimoga, Sagar and Bhadravati in Shimoga Circle; Chikmagalur Circle in Chikmagalur Circle; Belgaum (Khanapur taluk) in Belgaum Circle; Davangere in Bellary Circle; Hassan and Tumkur in Hassan Circle; Bangalore Rural and Urban, and Kolar in Bangalore Circle; Mandya and Hunsur in Mysore Circle; Madikere in Kodagu Circle), i.e. the work done by agencies such as IN-RIMIT under the Exit Phase of the WGFP.

The post-WGFP phase starts, in reality, with the work entrusted to KSRSAC during 2002-03, with budget from the Eastern Plains Forestry Project (funded by Japan's JBIC), to develop a geo-spatial database for 19 forest divisions covering 15 districts (Bidar,

Bijapur, Bagalkot, Haveri, Dharwar, Raichur, Chitradurga, Bellary, Koppal, Kollegal, Mysore, Gulbarga, Belgaum, Ghataprabha, Gadag). In addition 4 divisions have been taken up free as goodwill (Mangalore, Kundapur, Virajpet, Koppa), which are those Western Ghats divisions not covered under the WGFP efforts. The KSRSAC vegetation maps depict forest types and density (at 1:25,000 scale). The administrative map depicts District, Taluk, and Village boundaries, Forest administrative Block and Compartment boundaries. The transport layer covers railway lines, National and State Highways, and metalled and non-metalled roads. Other layers include drainage, soil type (based on 1:250,000 maps from National Bureau of Soil Surveys & Land Use Planning, ICAR), slope, and Protected Areas. Hard copies on 1:50,000 scale (Range-wise sheet printouts) have been given to the respective divisions along with CDs by the end of 2003-04, and a master set of CDs is also lodged at the Working Plan HQs.

During 2004-05, a separate MoU and contract has been signed with KSRSAC for "standardization of geo-spatial database" in respect of the remaining 18 divisions (Bangalore Rural, Bangalore Urban, Kolar, Mandya, Hunsur, Madikeri, Sirsi, Yellapur, Honnavar, Karwar, Haliyal, Shimoga, Bhadravati, Sagar, Chikmagalur, Davangere, Hassan, Tumkur), and creation of GIS for the Protected Areas covering 5 National Parks and 21 Sanctuaries. These 18 divisions are the areas covered by IN-RIMIT and others in the last phase of the WGFP. The original idea was that the work carried out by different private contractors (INRIMIT, ORG-GIS, ESRI, etc.) would be standardised and a few layers added where missing. However, it was discovered that there were several inconsistencies and omissions in the earlier work. For 3 divisions scale of mapping was 1:2,50,000. For 2 divisions digital classification scheme had been used, whereas visual interpretation had been used in other cases. And for 8 divisions, image interpretation itself was incomplete. For 5 divisions, the classification scheme employed was different and scale of mapping was also not same. Projection parameters used by different agencies were also not identical. In light of this, KSRSAC decided to essentially redo the work in all the 18 divisions, i.e., re-interpret the imagery using their standard methodology, and generate all data layers on a standard projection. (This summary is based on a presentation made by KSRSAC to the evaluation team.)

KSRSAC have also designed a more user-friendly front-end called "Vasantha" to go along with their GIS database, which provides for: basic GIS viewing, querying, and analysis; inbuilt external database (MS-Access/MySQL) permitting generation and linking in of new databases; and GPS Module, which enables co-ordinates of points captured with a GPS hand-set to be downloaded directly to the computer and converted automatically into a Shape file to be then overlayed as required, which is not provided in ArcView.

KRSAC's work for the KFD has been based on information from a number of sources:

- Survey of India topo-sheets (1:50,000)
- IRS 5.8m PAN and 23.5m LISS III images of different seasons (year 2000)
- Forest Survey of India vegetation maps 1976-79 based on aerial photography
- French Institute, Pondicherry vegetation maps of 1982
- Forest Department administrative maps
- Taluka-wise village boundary maps from DSSLR

KRSAC is also committed to carrying out training for field officers through division-level workshops, also a 3-week module for officers in the working plans, all scheduled during 2005.

The outputs of the first stage of KSRSAC's work are of a generally high quality. KSRSAC has distinguished many more categories of land-cover than (say) available in corresponding maps prepared by FSI under its State of Forest exercise. Although KSRSAC's initial set of ground-truth points seems small, they are trying to get the maps verified by the field staff, which will improve the interpretational accuracy. KSRSAC reports that the initial response of the officers who participated in the trials with these outputs has been positive.

However, the source data on which the GIS layers are based impose certain limitations. For instance, the soil layer provided by KSRSAC is from the soil map prepared by the National Bureau of Soil Survey, which is a coarse-scale (1:500,000) mapping exercise. The village boundary layer is based upon the taluka-level village boundary map prepared by DSSLR, which is not (by their own admission) of high positional accuracy—rms errors in geo-rectifying these maps are typically 300-500m. Similarly, the RF boundary layers are drawn from SOI toposheets, which are both out of date and depicting only the larger RF parcels. And the forest cover map itself is limited by the spatial and spectral resolution of the satellite imagery used, hence is best viewed at a 1:25,000 scale. This scale and level of accuracy in the different layers makes the database suitable for ACF/DCF-level officers who need to get a general idea of the forest vegetation in their division quickly. Of course, even to do this, the officers will need some basic training in GIS. One can then hope that at least some of these officers will put this larger geo-spatial database to innovative use in their planning and implementation activities.

A summary table of the outputs produced since the inception of RS/GIS in KFD is given in Appendix II. As it shows, the emphasis has consistently been on forest cover mapping, with increasing addition of some physiographic and administrative information.

2.3 Present status of GIS in KFD

After reviewing the history of GIS/RS in KFD, an attempt was made to get some idea of the actual present status of GIS in the Department by visiting the Working Plan offices in the State and having formal discussion sessions with the officers and staff (the RFOs, Surveyors, Foresters, Draftsmen, computer operators, etc.). A list of issues was provided to the Working Plan Officer by post, and copies made and distributed to the participants on the spot. An inherent limitation in this approach is that field staff find it quite difficult to open up to senior officers, however well meaning or conciliatory the approach. In principle, one would expect that FLS would emphasise the achievements and downplay the shortcomings, so it is likely that the impressions gathered in these meetings would if anything be on the positive side rather than overly critical. To test the impressions coming from the formal discussions, independent interviews were conducted separately by a Visiting Student of CISED at a few locations and her impressions are also summarised later.

What follow in this section, are accounts of the impressions gained and opinions expresses by staff of the respective field units of KFD (mainly Working Plans offices).

2.3.1 Mysore Working Plans office

In **Mysore Working Plans** office, visited on 21 April 2005, out of the nine RFOs hardly a couple seemed to have any familiarity with use of computers, let alone GIS. Much more

awareness and enthusiasm is attached to use of GPS (hand-held), which the RFOs say they are using for the last two years.

The unit has a stock of 1:50,000 topo-sheets and village maps, a Celeron (PII) 500mHz computer, A3 size inkjet printer (slightly larger than the normal A4 size paper used for photo-copying etc.), as well as a full map-size (A0) inkjet plotter, and a scanner (A4 size).

There seems to be no institutional memory of the Indo-FRG Project at all, even though it was housed in this office. However, there is awareness of the NRSA maps of North Kanara, which are believed to have been used in the preparation of working plans in that region; and also of the DFID-supported work (led mainly by Alistair Anton) in Mercara and Virajpet Divisions: apparently IN-RIMIT has supplied the maps, and GIS data with layers (themes) that were useful in working plan preparation. They believe that such data were also given to other divisions like Kolar, but it seems that they were not actually used in preparing the working plans. The datasets provided by INRIMIT are viewed using ArcView 3.2, which enables viewing and digitising fresh data. But apparently ArcView is very slow on their computer which has only 64MB RAM, 128 would be better; on the plus side, ArcView can run on computers with older operating systems like Windows 98 (Windows XP is not obligatory). ArcExplorer (a free programme from the same firm, ESRI, used for basic viewing and printing operations but without facility for inputting fresh data) is stated to require a minimum of 256MB RAM, which apparently is not available in most of the older machines. Incidentally, all these technical points could be elicited only because the Mysore Working Plans office has a computer operator (on contract basis).

Recently, KSRSAC have provided data (on CDs) of Mysore and Kollegal divisions in the first batch of 19 divisions taken up by them with funds from the JBIC supported Eastern Plains Forestry Project in 2003 (subsequently funds were given to cover remaining divisions in the rest of the state). These data are also stated to have vegetation distribution, Division boundaries, Range boundaries, etc. The KSRSAC data come with their own viewing programme, called “Vasantha”, which requires again minimum of 256MB RAM.

From the discussion, a better understanding came out that the main use of maps is as follows:

i) In preparation of working plans, wherein a set of maps is usually provided along with the document showing such themes as administrative delineations, forest types distribution, forests by legal status, working circles, etc.

ii) Within the forest proper, compartment boundaries are marked on 1:50,000 topo-sheets (following natural features wherever available, in order to aid recognition of the boundary on the ground without having to continually maintain boundary markers like pillars etc.).

iii) For drawing up of proposals under Sec.4 of the Forest Act (notification of intent to constitute areas as reserved forest), maps are collected from the territorial division, the revenue offices, etc. and the boundary surveyed in the field and marked on the map; village maps are essential to draw up the proposed boundary survey number-wise.

iv) When special surveys are made of specific cases, e.g. C&D class lands, mapping of encroachments, outside felling, boundary fixation of any nature, again village map and survey-number wise details are required.

On discussion, it was apparent that village maps (or forest maps of large scale like 4" to a mile or village map on 8" to a mile) are universally used for any work involving boundary demarcation or anything to do with revenue lands (survey numbers being the essential identifying character). Even though SOI topo-sheets do show State Forest boundaries, the village boundaries are not clearly discernable on 1:50,000, and even apparently on 1:25,000 topo-sheets. Old Forest Surveyor maps of 1:16,000 scale, and old SOI Forest Maps of 1:15,000 scale, are perceived as much more useful (although the SOI forest maps seem to be drawn by blowing up from 1:25,000 topo-sheet!). Village boundaries were seen to be clearly marked in examples shown of 1:15,000 SOI Forest Maps (e.g. sheet no.57H/12/6 Mysore/Salem Forest Circles, 1st ed. 1976). A map of 1905 on 4"-mile scale was also shown, as well as a village map on 8"-mile scale.

Where management maps of forest proper are prepared for working plan purposes, however, it is apparent that 1:50,000 topo-sheets are usually the base. Forest inventory (growing stock estimation) is such an application; it was explained that the sampling methodology used is to mark every kilometre square, locate a sample plot at 0.1% sampling intensity, and record the type of vegetation, height class, girth, and species of trees in the sample plot; and also the slope, and soil type, in the plot. These detailed data are generated by field staff in booklet form for each compartment (wherever such have been delineated), and brought up to the compartment-wise (summary) tables at the back of the working plan. It was stated that such data are not being actually presented in map form. (The maps seen in some of the working plans, e.g. in Kanara Circle, are small-scale maps of a whole division, as obviously folding and keeping 1:50,000 topo-sheets for each theme will soon become unwieldy for practical purposes; if such maps were to be prepared, they would be on smaller scale, probably 1:250,000). Teak plantations are also inspected and inventoried, and prescriptions made for each plantation, but apparently individual plantations are not presently shown on a map (1:50,000 would probably be too small a scale for this in any case). The Draftsman also explained that they have tracings of 1:50,000 topo-sheets with the Range, Section, Beat and Compartment boundaries marked, as also village boundaries. Although they have a full-size A0 map plotter, it appears that it has not been used at all recently (the unit was kept under a covering in a corner, apparently not connected to the computer).

2.3.2 Belgaum Working Plans office

Belgaum Working Plans office was visited on 3 May 2005. With 5 RFOs and 2 Surveyors, the unit is hamstrung because the 2 posts of Draftsman continue to remain vacant. The office has a computer operator, hence the system is in use, but there is a problem with installing/running ArcView, which is therefore not in use; instead, ACDSee programme is being used to view GIS files. The office has an A3 inkjet printer.

As described earlier, under the DfID-funded Western Ghats Forestry Project (WGFP), a "Fully Integrated GIS using Remote Sensing and Collateral Data" was developed and delivered by March 2000 for Khanapur Taluk (4 Ranges). Recently, the KSRSAC maps have been received by all divisions (Belgaum, Bijapur, Bagalkot, Gokak); softcopy (CDs) are expected to follow soon. Working Plans offices have not been given a copy of these maps, which have been sent straight to the territorial divisions. The maps are of 1:50,000

scale, are laminated, and show vegetation and administrative features. However, the KSRSAC package "Vasantha" is thought to require a PIII system, whereas the Working Plan office has only a PII, hence they anticipate problems in working with the KRSAC data. (Subsequently, KSRSAC scientists have clarified that Vasantha requires 256MB RAM on machines having CPU chip PII or lower; with chip better than PII, Vasantha will run with 128MB also).

As per the Surveyor, the main survey activities fall under the following types:

(i) Survey (chain and compass mainly), e.g. for fixing boundary of forest, for which the 1:50,000 topo-sheet may be used as a broad reference, but which ideally requires 4-inch (4 inch = 1mile, i.e., 1:15,840) maps, an example shown of which was the 1901-02 season map of 4":mile (Sheet No.244 SE/1); or even 8":mile maps available in old Bombay Presidency maps.

(ii) Block and Compartment boundaries: are again taken from 4":mile maps or village maps to make the separation of village land and forest clear.

The experience of the field staff was generally that 1:50,000 topo-sheets were useful for a broad overview, e.g. at the Divisional level; now that Blocks and Compartments have been marked out on the ground, naturally a need arises to draw them on the maps. The Draftsman showed how he had done it: by drawing them on (photocopies of) the old 4–inch maps, and pasting a number of them together and issuing these physical mosaics to all the RFOs. A "guide" map on 1:50,000 has also been prepared showing Block and Compartment boundaries. A computerised GIS would presumably be advantageous in doing such updating and map preparation and printing more rapidly than doing it by hand. It was also felt that the older larger scale maps also need to be digitised and brought into a GIS urgently.

It was also felt that to work on any question where boundary of forest and private land (malki) would be involved, especially where compass bearings would be used, it was essential to work with the larger maps, e.g. 8–inch maps. Measurement of the periphery (length of boundary, for instance), was done on 8" or 4" maps, with the 1:50,000 topo-sheet providing a cross-check.

On use and utility of GIS, the CF Working Plans brought to bear his own familiarity with the Indo-FRG project when he himself was DCF, Mysore. He remembers that the GIS then developed was extensively used in working plans work, especially for siting the sample plots. Other maps were also prepared using the GIS data, like working circles, forest types, Range and Beat boundary maps, settlements, soils, drainage, villages, land use etc. The land parcels data have not been updated in the village maps (issued by Department of Survey and Land Records) since 1978, so more recent changes in legal status (fresh forest notifications, de-notifications, etc.) have not been incorporated in Village Forest Register (VF). A continuing unit of say 2 Surveyors and 2 Draftsmen, trained professionally in GIS, would be able to keep the land database up to date. Equipment-wise, Belgaum Working Plans unit is in need of better computers, A3 size scanner, laptops, and A0 plotter.

2.3.3 Dharwar Working Plan office

Discussion in **Dharwar Working Plan** unit was held on 6 May 2005. The unit has 1 ACF, 5 RFOs, 2 Foresters, and 3 Surveyors (of which one post is vacant), and a computer operator (as usual, on temporary basis). The unit uses ArcView 3.2, although the

"Projections conversion" function is not working. The unit has a stock of topo-sheets, as well as the 1994-95 printed maps from the NRSA project on 25,000 scale and 50,000 scale for potential JFPM area delineation (forest areas with less than 0.25 density). The NRSA also produced "inventory" data, i.e. estimates of growing stock (volume per hectare) in each compartment (these estimates were generally on the high side according to some). The NRSA database was extensively used in preparing the working plans of Kanara circle, after due ground verification.

Apart from these, the unit has got digitised 4" maps of Sirsi, Yellapur, Haliyal divisions under ArcView, with State Forest boundaries marked. These are used for plantation mapping and printouts are given to the concerned territorial RFO. In the preparation of working plans, maps made from 4" GIS scaled down to 1:210,000 were printed out. Recently the KSRSAC data have also been received by the territorial divisions (not by Working Plans unit, though).

Once again, it came out in discussion that much of the actual work of the staff is at the village level, hence the prime need is for data at village map level, e.g. mapping of encroachments. This also requires forest Block/Compartment boundaries to be transferred on to the village survey numbers concerned. Plantation maps are another application using a 4" forest map or a village map. Problems are being experienced (in this unit) in transferring details on to the GIS due to the malfunctioning of the "Projections Conversion" function (pointing to need for more software support). For fixing the forest boundary pillars, the positions of the boundary features, pillars, etc. are marked on the village map or forest map with village boundary, and given in 5 sets to the territorial division.

The GIS has been used during preparation of the working plans, the main output being the set of maps at 1:250,000 scale at the back of each Plan. For fixing boundaries, usually the photocopies of village maps are used as described in the previous paragraph. For mapping of plantations, staff are readily using the GPS receivers, but they do not download the data into any GIS; they simply use the bearing and distances generated from one point to another to draw the polygon instead of obtaining the bearings and distance from the traditional (and more laborious) chain-and-compass method.

Regarding general exposure to GIS and training, it appears that the RFO who had one week's training has recently been transferred out, the Surveyor has had a 4-day training, and the rest of the RFOs have not had any exposure. Training is required for the Surveyors and Draftsmen, as they are the persons in the system who will be primarily working with maps and generating geographical (spatial) data.

2.3.4 Chikmagalur working plans office

Discussion in the **Chikmagalur working plans** office was held on 24 May 2005, with the DCF, Working Plans (actually, Survey & Demarcation), and RFOs and others. The unit has 9 RFOs, and 9 Foresters' positions (4 of which are vacant), all 3 Draftsman posts are also vacant, and one of two Surveyors' posts is vacant. The heavy work load is carried by one draftsman and 2 computer operators on "daily wages". The main work of the division involves survey and demarcation of lands identified for transfer, or for notification as forests (i.e. under Sec.4 of the Forest Act), MF boundary demarcation, etc.

Here again it was confirmed that without village maps, it is not possible to trace out boundaries of forests or Sec.4 notified areas, encroachments, etc. The village maps must be used as the main basis. The RFOs confirmed that they do not use GIS, but they are generally happy with the GPS facility, which enables them to mark points on larger scale maps such as the Forest Survey maps (4":mile or around 1:16,000 scale). Some of the difficulties and errors of compass survey (like local magnetic attractions in these hilly iron-bearing tracts) are avoided by using GPS. The main important feature required in most of their activities is the boundary, and it will be most useful to have these on large-scale maps like village maps (8":mile or around 1:8000 scale), and with survey numbers also marked. The ADLR is also supposed to incorporate forest boundaries during the process of rectification ("durusti") of village maps. Without a GIS as such, even now for drawing maps of new forest blocks, adjoining village maps are put together physically, and a tracing made of the composite map, and forest boundaries marked from point to point on the tracing. If GIS is to be used regularly, it is essential to have GIS and computer system professionals (perhaps on contract) to set up, maintain and expand the GIS, and to impart regular training to others in the department. None of the RFOS use computers, so the impediments to FLS actually using GIS can be imagined.

During the discussion in Chikmagalur working plans office, light was thrown on two other issues that have been much talked about of late: the utility of Differential GPS, and the use of Total Station for survey. As far as D-GPS is concerned, there is one base station instrument in the Forest Department, and that is at this office; it is not in use at present because of some problem with batteries. However, it was also the general opinion that such a high level of accuracy (within a few metres) will rarely if ever be required for forest surveys, hence even ordinary GPS will be good enough, especially as the inbuilt error, imposed initially for defence purposes by the US government, was removed and the error reduced to tolerable levels.

As regards Total Station, 6 such survey instruments were purchased under JBIC Phase 1 project, one of which is in the Chikmagalur working plans office. It has never been used; staff are of the opinion that without training it will not be of much utility, especially for the type of surveys generally carried out in the forest department.

2.3.5 Local initiatives: Haliyal Division

An interesting initiative has been done in Haliyal Division of North Kanara in getting village maps digitised. It appears however that they have not been geo-referenced, and are being utilized as stand-alone maps for various purposes, analogous to the existing physical village maps. For special jobs like plotting the boundary of a named forest, two or three adjacent village maps may be put together to make a composite map. These works of digitization are reported to have been done through a local technician using funds from different sources (i.e., not as part of KSRSAC's official contracts). Their utility is termed as high by the Divisional Forest Officer.

2.3.6 Assessment through independent interviews

Ms.Muthatha Ramanathan, a Visiting Student at CISED and a doctoral student of Geography at the University of Washington, Seattle, took up a special exercise to get an independent assessment of the use of GIS/RS in the field, and experiences with the technology in the recent past. She had two days' discussion with officers and field staff (mainly RFOs) in Dharwar Working Plans unit, and also interacted with the officers and

field staff of Haliyal Division in Kanara Circle. Her impressions and findings are very similar to what has been summarized above; in brief:

- there was a keen interest in the technology; but
- in the absence of any institutionalization for the employment of these technologies, what remain are some software resources and some digital data, and some memories of data generation;
- there is a general lack of even basic computer skills;
- there is lack of specific knowledge of the use and role of the GIS/RS technologies;
- there is a general recognition of the nodal position of the Working Plan offices with respect to forest management planning and land matters;
- the strongest need for spatial information is in positioning on the ground relative to administrative boundaries;
- there is a consensus on the absolute indispensability of cadastral maps showing survey numbers in this type of work, with large scale Forest Survey maps coming next in terms of utility, with the consequent importance of using technology to preserve these maps;
- contrastingly, there was clearly limited utility of 50,000 scale topo-sheets or vegetation distribution maps (and GIS) at field staff level, these being of some relevance mainly at DCF or higher levels, where detailed knowledge of a tract is not called for and cannot be acquired;
- there was a suggestion that a separate GIS wing be instituted within KFD, with its own well-trained professional, specialist staff.

2.3.7 Working Plan HQ, Bangalore

On 12 May 2005, a discussion meeting was held at HQ of the APCCF, Working Plans, Bangalore. Apart from reviewing the history of GIS/RS deployment in the department, the team reviewing the data layers and equipment available and the use they are being put to. The data layers in soft copy format supplied by different agencies (INRIMIT, ORG-GIS, ESRI and KSRSAC) were available in the RS/GIS unit, as also earlier hard copy maps. However, none of these had been properly catalogued in a manner that would readily show their contents, etc. (i.e. metadata is not maintained). Further, a look into the GIS cell at HQ revealed the uninspiring position that the UNIX-based system has not been operated ever since the GIS specialist left after the close of the WGFP, and no mapping or GIS work is going on, and it was felt strongly that qualified technical personnel are absolutely necessary to get the unit running and enable it to perform its role.

2.3.8 Feedback obtained by KSRSAC

On request, KSRSAC have been kind enough to share with us the feedback they have been getting from field officers and staff during their installation visits and training programmes (KSRSAC letter dated 19 July, 2005). The salient points are as follows.

Firstly, the field staff show keen interest in the database, as it gives them the hope of getting details of the entire natural resource that they are managing parcel by parcel, which they do not usually have for all their land holdings (correct location, area, present status, vegetation class, type and density, nature of land, other statistical data).The initial response of front line staff (FLS) is to cross-check the details as presented by the database (**authenticity**), and once they are satisfied that the database has taken care of the finer

details, they want to know whether they can append to the database as per field requirements (**expandibility**).

One of the major interest areas is the **generation of maps** for routine office works (e.g. map of all acacia plantations along with statistical data). Other major field requirements include: identification of encroachments, quick survey of Reserved Forest, Section 4 notified areas, C&D class lands, plantations, etc. using GPS. In this respect, since the user interface Vasantha developed by KSRSAC has a module for GPS integration and area calculation, it is in this module that the staff show most interest. This is the only interface available to them for appending data. However, they want the database to go to the level of **survey number-wise details** (which are obviously not available). They are keen to know whether the GIS can be used for **legal purposes** as well (which is not supported).

It was observed that **training** makes a major change in the way they look at the GIS. Appreciation of GIS as a tool which has lots of utility comes only after the training. Since the hardcopy maps of forest type/density are given as part of the documentation, it was observed hat after training the RFOs, ACFs and DCFs were able to appreciate fully the utility of the database as a management tool, e.g. for identification of locations suitable for different plantation models.

However, the general inhibition to using computers makes the entire process of capacity building very difficult. Even in the hands-on sessions, the general tendency of staff is to ask the computer operator to handle the computer. Moreover, since this is usually the first exposure to the GIS, GPS, etc., the learning pace is slow, although those who have earlier attended some or other GIS training pick it up much faster.

In such a situation, it is felt that absence of permanent computer operators is the major challenge to the continuity of the entire process of capacity building as well as the use of GIS. In this context, KSRSAC recommends sensitization of staff regarding the capabilities of GIS and equipping the division with at least one computer operator who can handle the database, which would go a long way in ensuring continuity of the entire process.

2.3.9 Development of GIS/RS in AP Forest Department

Andhra Pradesh Forest Department is generally perceived as having made substantial progress in developing and institutionalizing GIS/RS technology. A note has been provided by Dr.Shashidhar based on a visit to their Geomatics Centre at Hyderabad. Database creation is seen as a major activity, using 250,000 and 50,000 (and sometimes 25,000) scale SOI topo-sheets for preparing layers on administrative boundaries, drainage, roads, railway lines, community forest management boundaries, village locations, etc. These are supplied to the Divisional offices (at 1:50,000 scale).

Vegetation maps are prepared using LISS-III data from 1996 onwards, following density classifications of Forest Survey of India (FSI). State of Forest reports are published, Change Detection analysis is done, and vegetation type mapping has been done for a few districts. Maps on fire hazard and a fire risk model have been prepared by using themes (layers) such as vegetation, slope, aspect, road and village locations. Other maps such as micro-watershed management plans, wildlife habitat maps, etc. are also generated with various themes.

The Centre also has a full-fledged training and extension wing, and they are conducting periodic training programmes for FD staff. There are also three Regional Geomatics Centres at Warangal, Kurnool and Rajamundhary. A notable feature is the effort made in developing or building the infrastructure both in terms of equipment, classrooms and hardware, as well as in terms of personnel. The Centre has on its faculty ACF and RFO level officers trained in GIS and RS both within the country and abroad; the department also employs Project Managers for various other works related to GIS and RS with specialized knowledge of computers/GIS.

Some of the applications in which these GIS/RS technologies are used include: generation of different types of thematic maps (existing land use, proposed land use); growing stock assessment using GIS (stratifying the forest and low intensity sampling); Working Plan preparation, management maps, working circle identification based on overlaying different layers and applying relevant criteria; attaching attributes database to spatial features for analysis and decision-making; stratification for laying sample plots using GIS; forest type mapping; forest fire danger rating; tiger habitat mapping, etc.

2.4 Summarising the experience

The above review of experience throws up a sharp paradox. The idea of using aerial photographs and satellite imagery (i.e., RS) for forest cover mapping was accepted and implemented quite early on by KFD. Staff were sent abroad and within India for training. The WGFP phase saw further development in several directions—more detailed mapping, integrated RS/GIS development, and attempts to integrate this geo-spatial database with MIS efforts. Very substantial financial and human resources were poured into these activities during this phase. Subsequently also, substantial resources have been invested in getting geo-spatial databases and maps prepared through KSRSAC. Indeed, KFD today can be said to possess a reasonably complete GIS database for the entire state comprising a basic system of geo-referenced maps based on interpreted RS images distributed individually to the field divisions.

In spite of all this, there is a distinct impression of a lack of impact or institutionalistion. In the Head Quarters itself, the GIS/RS unit is lying dormant—the GIS system (Unix-based ARC-INFO) has not been operated for a considerable length of time. In some of the field Working Plan offices, while the GIS systems are operational (based on ARC-View), there is a distinct impression (gleaned from discussions with the office and field staff) that its use is limited at best, and has not certainly percolated to the field staff. There seems to be a major barrier to the use and propagation of GIS/RS applications within the Working Plans wing itself, not to speak of territorial units. Officers who showed interest in these technologies have been transferred (in the normal course), the CF (GIS) and GIS specialist posts at Headquarters have been eliminated, and even the computer technicians in the divisional Working Plan offices are feeling the absence of institutionalised technical support.

Thus, the experience of GIS/RS induction in KFD so far may be summarised as follows:

1. The focus of most efforts has been on generating RS-based **forest cover maps**, usually without authenticated forest boundaries, and often at coarse scales (usually 1:50,000 or smaller). Such maps are useful for providing a broad overview of the forest cover to officers in the Headquarters, and for appending to the working plans,

but of limited use to FLS daily operations or even in actual development of silvicultural prescriptions for the once-in-ten year exercise of writing Working Plans.
2. The main map-related activities of the FLS in both territorial and Working Plans are related to investigations into drawing up proposals for notifying new reserved forests, monitoring encroachments, issuing felling permissions, doing boundary consolidation, etc, all of which requires **large-scale cadastral and forest boundary maps** and also the associated information on **legal status of the land**. These needs were never really addressed in the GIS/RS efforts thus far, and whatever administrative maps have been prepared are of poor resolution and missing many details.
3. Complex databases that try to link physiographic features and administrative boundaries to other operational and socio-economic data turned out to be mismatched with the needs and capabilities of frontline staff.
4. While the internal capacity for GIS/RS work has developed inadequately, the policy of wholesale outsourcing, coupled with the regular transfers, has further undermined this capacity and increased the distance between the data producer and the user.
5. Lack of institutionalization and long-term planning has resulted in haphazard acquisition of sophisticated equipment such as Total Station and Differential GPS, which are not being used, while basic computer equipment that is in use suffers from lack of maintenance and threat of obsolescence.

Overall, the adoption of these technologies and tools seems to have been **supply-driven**, i.e., 'because the technology is there' and based upon many assumptions borrowed from the deployment of these technologies in the West, rather than being **demand-driven** or **need-driven** and cognisant of the organisational context in which they are being deployed.

3 Understanding the needs

It is quite clear that the past efforts to induct GIS/RS technologies into KFD planning and other operations have encountered a block somewhere. The most plausible explanation for this, as discerned from on-the-site discussions with WP officers and staff, appears to be **the weaknesses in the basic assumptions on the role and utility of GIS/RS**.

The WGFP consultants, influenced perhaps by accounts of GIS/RS in the western context of large pulpwood and lumber growing corporations,

- saw GIS as *the* tool for integrated forest and social management planning,
- visualised RS as *the* technique for providing information on one crucial component of the GIS database, viz., forest cover information, and
- assumed that other data layers can be easily acquired or built up.

They thereby arrived at a grand vision of forest staff on the ground (say, Foresters and RFOs) sitting on the computer systems and querying the GIS/RS database for information on biophysical characteristics of the forest well as on demographic, livestock, and other socio-economic data, and then taking strategic decisions based on (as yet unspecified) decision support frameworks. They further visualised this being integrated into a complex MIS-based way of functioning in KFD as a whole. This vision essentially underpins the work done during the WGFP and even the post-WGFP phases.

Unfortunately, this vision is incompatible with the needs of the frontline territorial staff and even those of the Working Plan offices.

3.1 Limited usefulness of "forest cover" maps

It is clear that forest cover maps at 1:250,000 or coarser scale have very little operational value. They only serve to give a general overview of the location and type of forests. Once they have been prepared, they need not be updated very frequently – maybe once in 10 or 15 years – since at that coarse scale, change will not be readily discernable.

What is coming through in this survey, is that even finer scale maps (1:50,000 or even 1:25,000) of forest cover have rather limited operational value. There are several reasons for this:

- forest cover is generally highly fragmented and human activities are taking place at the scale of a few hectares, which cannot be depicted adequately even on 1:25,000 scale;
- forest cover (and land cover in general) is very diverse, and accurate separation of different types of cover (such as Acacia from dense evergreen forest) is difficult unless one is intimately familiar with a particular region – which is a time-consuming task;
- forest management activities and decisions take place at the Division level based on information from the Range and lower levels, where individual officers know as much about the quality of the forest and the land cover as the maps can generate; field officers can better integrate their knowledge of the micro-site conditions of soil, terrain, human pressure, rainfall, etc. at the required scale of a few tens of hectares (and variations from point to point within that) than can be provided by a RS/GIS system which does not have access to data variation at that scale (e.g., soil is taken from 1:250,000 soil maps)

In the case of territorial divisions, it is clear that vegetation ("cover") maps at 1:50,000 scale cannot be used for day-to-day operations, like plotting the boundaries of plantations, mapping enclosures or forest boundaries, and so on. It is clear that almost all the field activities of FLS and RFOs demand the use of village maps, old Forest Survey maps, and large scale (8":mile or 4":mile) topo-sheets. The 1:50,000 "cover" maps produced through RS/GIS can only be a very broad "thematic" representation of the forest. Paradoxical though it may seem, this is the information *least* likely to be demanded by FLS: to tell them that their hillock is covered with, say, scrub forest, is telling them nothing that is new to them, and is something that will not enable them to decide on site treatment (whether it be plantation or soil conservation or fire protection), without physically visiting the area and looking at micro-site conditions and the actual present situation on the ground.

3.2 Need for detailed cadastral and boundary information

On the other hand, most of the actual day-to-day work of FLS requires the boundaries to be delineated or marked on the map in great detail, as used to be done on the Forest Survey maps or the SOI large-scale Forest maps (even marking the position of boundary pillars). Equally crucial is the correlation of village boundaries and survey number (cadastral land parcel identifier) boundaries with the forest notification. The existing GIS products are **weakest in the boundary zones**, as they gave priority (by design) to characterising and depicting the vegetation **inside the forest polygons** (e.g., by forest type and crop density). In effect, the GIS produced was targeted at the needs of higher policy levels, as perceived by specialists with set ideas on how our forests ought to be

managed and administered, ignoring the complex situation in the field and the actual day-to-day activities filling the time of the forest staff.

What is surprising is that even in the working plan units, GIS has come up against such blocks, so that as discussed above, very few of their RFOs or survey staff are familiar with the GIS or comfortable using it. In the case of working plan offices, the GIS has been more or less put in storage once it had served its single purpose in preparation of working plans, which was the preparation of a set of maps in each working plan showing, for instance, the main administrative boundaries and locations, the vegetation types (maybe even density), and the working circles. None of these maps are actually useful for operational purposes: larger scale compartment maps are required to site plantations etc., the **boundaries are again the weakest** element, variations within the micro-site will have to be seen in the field for any operations, and so on. Quite possibly they will be used again only when the working plan comes up for revision. Thus there is **no incentive to actually use the GIS** presently available.

This divergence is due to high expectations on the use of maps and spatial information: consultants in WGFP thought that it was virtuous to use GIS for an idealised holistic planning, therefore requiring the integration of demographic, socio-economic, and ecological data. This thinking has influenced our subsequent approach, and **given priority to the planner at a higher level** in the system, not responded to the **operational needs of FLS**, who use maps most of the time to check boundaries. Their operational plans follow the working plans where possible, and more often are dictated and determined by the budget available under different schemes. Even for Working Plan preparation, as forest management objectives are shifting away from timber working to broader management regimes like non-timber products, biodiversity conservation, watershed values, etc., the broad mapping of canopy cover or crown density may not require frequent use; on the other hand, any work related to ecological monitoring or biodiversity would require more detailed, compartment-level sampling and enumeration at a larger scale not available in the present GIS. The requirements of participatory village-level micro-planning under the JFPM regime will also demand more detailed information than available from RS.

Once the working plan has been written, it is not revised for a decade or so. In the interim period between writing of working plans, however, the activities of the working plan staff revolve around the following:

- mapping boundaries,
- drawing up proposals for notification of parcels of revenue land as forest (or sometimes the reverse),
- conducting investigations on illicit fellings, encroachment, and so on.

These all require village maps and large scale forest maps as described above.

Some of these issues were already apparent at the time of the WGFP Support Programme; Mr.Sai Baba, then the DCF Working Plans Sirsi, said at the Review Workshop on 24 July 2000:

> *"… GIS was absolutely required to assist analysis and planning in all Divisions. However, care should be taken in the scale and quality of the base maps used. Lessons from Kanara was that it was better to digitise from the 4" to 1 mile maps than the SOI 1:50,000 sheets as village boundaries were available on the 4" maps. Although a greater number*

> *of maps would be digitised, this saved time in the long run…"* (Working Plans Support: No.8, Review of Experiences, July 2000, p.4)

And as stated by the then Project Director, WGFP:

> *"…any planning system, however efficient and sophisticated will not be maintained unless it meets the needs of those who (are required) to both operate (it) and keep it up-to-date. These needs must be considered and take account of the realities, such as the staff capacity, transfers and postings…Working Plans must also take account of realities. If they are too complicated… they will not be implemented in the field… lengthy financial proposals in the plans will not be followed…"* (ibid., p.4)

The views expressed by Venkatasubbaiah (the first Conservator of Forests in the GIS cell at HQ) in his note of July 2002 are also of interest in this context. He stresses the importance of procuring village boundaries data: of 29,390 villages in Karnataka (1991 census), some 7130 villages are said to have forest as a land use, and his assessment is that only some 3000 villages have notified forest area. He proposes that priority should be given (now that vegetation and basic administrative features have been covered) to digitizing the village (cadastral) maps, and large scale topo-maps (e.g. Forest Survey maps), and putting them together on a geo-referenced grid in the GIS, basically to show the forest lands in relation to village boundaries and village survey numbers. Use of GPS to geo-reference the village map or forest boundary features is suggested. The existing software like ArcExplorer (free to user) is, in his view, sufficient for data creation and correction. The data and software will be distributed to all the computers in the department, and they will be used to prepare maps showing forest and village boundaries, plantations, etc. for the benefit of front-line staff concerned: "GIS should help the forest beat-guard the most and also all other forest officers in performing their statutory duties".

4 Presenting an alternate strategy

4.1 Basis of the proposed strategy

Based on the understanding of needs and conditions in the field as gained in the course of the above review, the following premises are suggested as a basis to form a more realistic and effective strategy to induct and develop a durable, living Geographical Information System for the KFD. These premises are as follows:

- A GIS will flourish if it actually serves the needs of the users. The focus of most past GIS/RS efforts has been on generating RS-based **forest cover maps,** but these maps were too coarse-scale and even otherwise the demand for such maps within the department has been limited so far. Executive staff in the field operate **with large scale administrative/legal maps**, e.g. village cadastral maps, forest survey maps, etc., as their major GIS-related pre-occupation is land management, rather than forest management. Hence they will gladly support a GIS if it helps them by expeditiously providing authentic records (archives) and maps at this larger scale.
- Vegetation maps provided so far cover all the forest divisions of the state, and Forest Survey of India is periodically giving updates; hence further development in this direction may be deferred at this time, and may be taken up at the time of revision of working plans if felt necessary.
- KFD staff and officers will rarely be able to actually sit at the computer and maintain the GIS or update it, as it is a highly time-consuming and technical undertaking, hence it demands the appointment of separate technical staff.

- As the highest standards of cartography and data integrity must be maintained, it is appropriate to develop the GIS at the offices dealing with cartography and surveys, which are the Working Plan units.
- It is essential to maintain a database of GIS information available, to avoid duplication, enhance value, and register constant improvements in quality and reliability.

4.2 Features of the proposed strategy

With these premises spelt out, the direction that the Forest Department should take (in GIS-related matters) for the next few years emerges naturally: the priority is to

- provide **large scale** maps (larger than 1:25,000, e.g. forest survey and village maps) in a digital framework, at the same time
- provide suitable **equipment** (especially better computers, connectivity, mass storage, etc.) and
- **provide technical staff** (on contract or deputation from outside KFD) to manage the system;
- develop a limited MIS to list out forest lands survey number-wise and Forest-wise (concordant with Bhoomi land database of the Revenue Department) along with scanned images of forest notifications and other old documents; and
- at a later stage, link the digital maps to the land database, to make searching, querying, reporting and building management records more efficient.

4.2.1 A hybrid strategy

What emerges from our discussions is some sort of a *hybrid strategy*, where on the one hand we are equipped with geo-referenced and rectified digital maps based on SOI gridded topo-sheets (which has already been developed by KSRSAC now for all the divisions), and on the other hand, we provide digital versions of all the available larger scale **cadastral/village maps and forest survey maps** that have references to village and forest land record details. The village maps and forest survey maps could be updated to some extent if possible, forest and revenue land details incorporated, and scanned, and digitised.

4.2.2 Cadastral maps

Village cadastral maps (or village revenue maps) along with the village RTC (record of rights) are constantly in use by KFD staff, but they suffer from many limitations:

- They are not geo-referenced (no latitude-longitude information in them).
- They have not been updated since at least 30 years, thus interim changes are not incorporated.
- They do not contain legal status of each parcel of the land, which is obtainable only from the RTC or similar records.
- There are a few tracts where the forest land is in unsurveyed villages, which do not figure on the cadastral maps available.
- There are several land tenures such as *kumki* and *bane* where the boundaries have never been surveyed and settled.
- There are geometrical (spatial) distortions, especially in hilly terrain.

Nevertheless, there is no option but to use the available cadastral maps as the starting point. According to KSRSAC, it is possible to geo-reference each of these larger scale

village maps or Forest Survey maps, but some problems will have to anticipated if it is attempted to put together a number of them to build up maps of large tracts (taluk, district, etc.). Among other problems, there is the problem that village maps generally follow the ground undulations as though the land surface were ironed out and stretched flat (they are apparently not horizontal projections). Hence they cannot be fitted into the SOI topo-sheets directly without some "rubber-sheeting", which may introduce discrepancies at the level of individual parcels or survey numbers. Another, related, problem would be fit the village maps into a standard projection. These problems would have to be addressed by qualified technical people, case by case. In the meantime, we suggest that at the beginning, these large scale maps can be used in the GIS much as they are at present used in the physical system, that is as **stand-alone** maps covering a small, defined area, with no intention to put them together ("mosaic" or "tile" them) to form cartographic maps for large tracts, or to change the scale to a smaller value to put together taluk or district maps.

In other words, one accepts the inherent limitations in cartography, and works with two alternate systems: with large-scale maps (Village and Forest Survey maps) and their digital counterparts where required for boundary-critical work at FLS level, and with small-scale maps (topo-sheets) and their digital versions where thematic maps are needed by higher management. There is thus no compulsion that the entire GIS be one self-consistent and continuously transformable system from one end of the range of parameters (like scale) to the other. If the cartographic problems can be sorted out, it may be possible to put together village maps of adjoining villages, say, to make one forest map, but even here one should expect gaps ("no-man's land") between boundaries and slight differences in shape, registration, etc., that is the mosaicing may not be "seamless", especially in hilly tracts. These problems can hopefully be sorted out at the technical level, and suitable quality checks and certification procedures would have to be put in place to ensure that the limits of accuracy are specified at each stage of integration of the different systems.

The advantage of having individual maps is that changes like plantations etc. can be brought on to them by following the existing procedures of survey, and can be made available to be used by the FLS. It is not at all necessary to first map the entire forest in all its detail (which will be a never-ending task), before making a useful product available. In fact, one of the lessons is that a system that demands a huge effort at computerising (digitising) **"dead"** information will founder from the start and perhaps never come up to operational status (the various MIS initiatives in the WGFP are a good example). A busy and hard-pressed department does not take kindly to dealing with massive amounts of historic data as a pre-condition to inducting new technology or new methods of doing work.

4.2.3 Forest Lands Information System (FLIS)

The utility of the village map-based GIS can be increased by **linking it up with an MIS** that can be termed the **Forest Lands Information System ,** i.e. a database of **forest survey numbers or parcels, along with the related notifications, boundary descriptions, etc. (maybe as digitised images of the respective documents rather than text)**. In fact this is an essential project for the department to take up, regardless of GIS, to increase the efficiency of its land records maintenance, and as a means of preserving these old materials. The forest department needs to make their land management practices more efficient, to reduce ambiguity about the legal position of parcels of land etc. It may

be entirely feasible at some future point in time to integrate the forest lands MIS with the state government's MIS on revenue lands **(Bhoomi)**, so it will be advisable to develop the forest land MIS in such a way as to maintain concordance with Bhoomi.

Additional fields in the database will be required for the special purposes of the forest department, e.g. entries to track the various stages of notification and settlement as reserved forest. KFD will need to work with the specialists in the Revenue Department (Bhoomi division) and their computer consultants (NIC) in developing the forest end of the database programme. Mechanisms will also have to be developed to give access of forest officers to the forest land database, and to periodically incorporate changes so that the database is up-to-date and useful to the field officers.

4.2.4 Forest Management Information System (FMIS)

In the immediate future, there need not be any massive exercise in building up management history or ecological data of each land parcel; development of such a larger, more elaborate and detailed **Forest Management Information System** (for forest management purposes) can be thought of at a later stage, once the land database is stabilized.

The intention is that GIS/MIS should be developed as a tool to improve the efficiency of FLS in what they are doing, rather than inducing new methods of planning and budgeting (which was the ambitious agenda of GIS in the WGFP).

4.2.5 Setting standards and Quality Assurance

There should be a simultaneous mechanism to ensure adequate quality standards, perhaps an Overseeing Committee with representatives from the administrative bodies which deal with geo-spatial data, such as the ADLR, the KRSAC, and a consultant institute or centre of expertise like CISED.

4.3 Institutional setup, staff and training

4.3.1 Institutional setup

We now turn to institutional aspects, e.g. the question of where in KFD the relevant expertise and facility will be located and built up.

The assumption of the WGFP was that every forest official would personally use, and maintain, the GIS. Accordingly an attempt was made to induct it in all Ranges of the pilot division, and various types of training events were organized throughout the circle and at headquarters. Elaborate manuals were prepared for various components of the planning system, including a working plans manual to take up many of the so-called innovations in planning and monitoring, such as Site-Specific Planning, local GIS/MIS, and so on. Little institutional memory of all this work remains today, even in the headquarters and in the Working Plans wing, for institutional reasons that will be discussed below.

Firstly, there is a constant turnover in the personnel due to the regular progression of transfers, recruitments and retirements. However much one may demand that persons trained in GIS should be retained in a particular position, in practice this will be so

difficult to ensure that any strategy based on this institutional model will start with a crippling handicap.

Secondly, the WGFP consultants seem to have generally underestimated the time and persistence required for an individual to maintain, use, and update a functional GIS. Obviously this requires a full time GIS specialist and a computer operator. Setting up the system and supervising its implementation and use presupposes the availability of a systems manager or programmer. Without these types of specialists, it would be a vain ambition to think of transforming a tradition-bound department like the KFD in the manner envisaged in the WGFP.

The location of the GIS would therefore have to be thought through afresh. Whereas the WGFP strategy was to make every forester a hands-on user of the GIS, and hence saw GIS as very much to do with the territorial units, an alternative would be to develop certain offices or units as **nodal points** to service the GIS needs of the respective jurisdictions under the guidance of a **central GIS unit** at HQ. Provided they were staffed adequately, they could take up both development and maintenance of the database, as well as training of the users, who are identified below. At some later stage, it may be feasible to think of extending the GIS installations to the rest of the department, provided the requisite complement of technical staff could be provided; all this could be done in phases. At the present, however, it will be a big enough task just to stabilize the system in the nodal offices (and HQ) itself.

Fortunately there is a ready candidate in the KFD for this nodal function, the **Working Plans wing** which has its HQ at Bangalore, and regional offices at Mysore, Chikmagalur, Shimoga, Dharwar, Belgaum, and Bellary. Since they deal primarily with the land base, the working plan offices will be the logical and natural choice wherein to station a functional GIS and to strengthen by providing specialist technical staff. A senior systems specialist could be stationed at the Working Plans HQ at Bangalore, where a master copy of all data can be maintained, and support given to the nodal units. Necessary complement of staff – computer operators, GIS professionals, surveyors, draftsmen – will have to be provided at HQ as well as the nodal offices.

The post of **Conservator of Forests (GIS & Evaluation)** at HQ may be revived in order to give leadership to the technical staff, give proper orientation and momentum to the process of further developing the GIS programme, and above all providing a medium of communication and interface between the rank and file of KFD on the one hand, and technical wing of the GIS in KFD, KSRSAC, and Bhoomi in the Revenue Department of Government.

In setting up this system, one choice available is to start with all the nodal points simultaneously, or alternatively one could start with a pilot division. We recommend starting with all the nodal units at once. Within each nodal working plan office, again there is a choice between starting with one pilot user division (territorial or wildlife etc.), but again since each nodal unit already has the basic data of all the divisions in its jurisdiction as a working plans office, it will also be entirely possible to proceed on a need-based approach in more than one division, so that the entire jurisdiction is covered like a jig-saw puzzle from different points, rather than following a strictly linear progression from one end to another like rolling out a drawing. In fact one would even recommend the multi-centre, opportunistic, approach, so that wherever data is available,

it can be taken advantage of, and a composite GIS built up over time covering all the territorial (and wildlife) divisions.

4.3.2 Need for technical staff to operate and maintain the GIS

A very important issue here is: who is to actually operate and maintain the system. A strongly held and proclaimed presumption in the WGFP was that FLS would actually maintain, use and update the GIS "hands-on", filling in data, running analyses, getting various outputs, and so on. While well-intentioned, the weak link in this approach is the assumption that FLS have the technical proficiency to do this by themselves. Obviously most RFOs, let alone Foresters and Forest Guards, do not possess the technical proficiency, despite all the efforts at broad-based skills up-gradation through trainings and workshops under the WGFP and subsequently. The second problem is that even if they have the skills, they do not really have the time to sit at the computers for the extended lengths of time demanded by the nature of this work. This is a major reason for the almost complete lack of engagement of KFD staff with this technology.

Bird & Unni (April 1992), in their consultancy report, emphasised that it would be necessary to appoint qualified staff and train and retain them for a certain period to implement and run the system, as well as having an IFS officer of suitable seniority (they suggest the Conservator of Forests, Planning & Monitoring Unit of the WGFP) to supervise and oversee, and a System Manager to run the system; apart from 3 System Operators, 3 Digitising and Cartography Draftsmen, and 6 Data Entry Operators. In reality very little of all this was actually provided, and after the closure of the WGFP, whatever was provided was withdrawn, so that presently there is really no GIS/RS unit to speak of (at HQ).

The Working Plan units, which otherwise would have been expected to be much more dynamic in adopting and owning this technology, also suffer from lack of technical hands, with even many of the existing draftsman and surveyor positions being vacant. The task of maintenance of the GIS falls then on contract staff like computer operators, who are retained on a very shaky basis as daily-wagers or temporary workers. The computers are also fairly old, with very little RAM, comparatively small hard disks, and slow speeds, so that recent upgrades and packages (like Vasantha developed by KSRSAC) fail to run. All these problems need a systems person to sort them out on a sustained basis (apart from investing in new hardware, which of course is necessary).

A different strategy would therefore be indicated for the future development of GIS capacity in KFD. This would require the appointment (perhaps on deputation or contract, but definitely on a long-term basis) of the required specialist staff in each office where the GIS needs to be established. It is suggested that each Working Plans or other Nodal centre be provided one GIS professional, and at least one (preferably two) computer technicians, apart from the full complement of surveyors and draftsmen. The HQ unit must have a senior GIS/Sytems professional (at a higher level than those in the nodal units), as well as at least two technicians (one for GIS, one for computer operation). This is the minimum complement, and if larger works are taken up may be increased by taking people on contract.

This strategy or model also leads naturally to identifying the **surveyors and draftsmen** as the primary users of the GIS, since it is they who deal primarily with maps, which they now do manually with photocopies, tracing paper and pen and ink. They will then form

the **core stakeholder group** to ensure continuity and integrity of the GIS set-up; but the necessity for computer and GIS specialists may never really disappear, as using a system occasionally is a far cry from maintaining and running it from day to day. In other words, if KFD is really serious about establishing a functioning GIS (as against a pilot here or an experiment there, driven by extra-ordinary efforts and inputs from external agents that cannot be replicated), then KFD would have to seriously consider providing permanent positions for computer and GIS professionals as described earlier. It is very unlikely that the WGFP strategy of forest officers doubling up as GIS experts, will ever work in the larger departmental set-up, nor is it likely that surveyors and draftsmen will be able to step into that role (except as stray instances), although it is very much intended that they move over to the GIS for their office work.

Training opportunities should also be provided to the professional and technical personnel maintaining the GIS and computers, apart from providing adequate promotional opportunities in case they are provided permanent positions.

4.3.3 Equipment and software needs

There is already some equipment in the Working Plans units which will be useful, like large-size plotters, but most of the computers need replacement urgently. The following is suggested as an adequate complement of equipment to start with:

1. High-end desktop computers with dedicated graphics card and higher memory and hard disk
2. Scanners (typically A3 size at working plan offices, A0 size at HQ) for converting hard copy maps into soft copy
3. GIS software (typically ArcView or ArcInfo with Spatial Analyst and Image Analysis extensions and DNR-Gamin extension) for on-screen digitization of scanned maps, reprojection, layering and analysis, additionally ERDAS Imagine 8.4 at HQ
4. Printers (typically colour, A3 size), plotters (A0) for map output
5. Handheld GPS with additional external antenna and DGPS
6. Total Station surveying tool to give very accurate and rapid maps of small land parcels, in theory can be interfaced with differential GPS to give geo-referenced output

Upgradation of software may be taken up at HQ once the suggested GIS specialists are in place, and as the GIS installation and skills upgradation at the nodal units picks up, the software upgradation needs of the nodal units can also be considered according to the developing capabilities and applications. We do not, however, see software availability as a major bottleneck at present, as ArcView 3.2 presently available would suffice for most purposes, complemented by Vasantha user interface developed by KSRSAC.

4.3.4 Training needs

Having identified the **surveyors and draftsmen** as the core stakeholder group that will actually use the GIS on a daily bais, it is apparent that a special training programme should be instituted to give periodic, and graded, training in GIS to them, so that each of them develops technical expertise in GIS and computer-aided cartography to the maximum level he or she is able to by aptitude and background.

Apart from professional training for the core group who will be using and running the GIS and the accompanying MIS and hardware systems, there is of course no difference of

opinion in that the general KFD staff (from officers to FLS) should be exposed to the GIS facility, but as the client group (rather than as direct users).

Additionally, there are a number of highly qualified officials at various levels, especially Foresters and RFOs recruited in the recent years, who will be in a much better position to become proficient in the new technologies than the average employee. Even though they may not always be in posts which enable or demand the use of a GIS, still there would be no harm, and definitely there would be benefits to the organization, if those of them who were interested, were also given the opportunity to develop higher than average professional expertise in GIS. This component would have to be voluntary, and there should be no illusion that their services would necessarily be available to run the core GIS facility of the department.

4.3.5 Relative merits of out-sourcing and in-house work

One of the institutional issues raised is whether it would not be better to out-source the whole gamut of GIS activities. In effect, something like this has happened by Government's decision to make KSRSAC the nodal agency for GIS, and a central repository and clearing-house for all GIS data, maps, satellite images, etc. for all departments. KSRSAC has already undertaken forest cover mapping (in a standardized GIS framework) of all the districts. The option naturally arises of entrusting everything – including day-to-day maintenance and operation of the GIS, updating, upgradation, producing maps, reports and other outputs -- to KSRSAC, and not proceeding with any more development or installation of GIS in the field units of KFD.

But we recommend against such complete outsourcing. Our reasoning is that as KFD uses maps and surveying in the field, and will continue to do so in the future, it is necessary that these functions be strengthened with advanced or new technology (like GIS) that will help KFD carry out these functions more efficiently. KFD is primarily a land manager, and at present keeping the land database up-to-date and easily accessible and query-able, will be a major objective in the department. On the other hand, KFD need not devote resources or manpower to doing frequent interpretation of satellite imagery – FSI already produces a forest cover map once every two years, and no doubt with more computer-driven automation and better satellite images, FSI will be able to include more details as has been done by KSRSAC, like forest type (deciduous, evergreen etc.), in addition to canopy density. Such information, as already demonstrated, is not of central importance to FLS in the field, who need basically a facility to keep track of all land parcels, prepare maps on the village map or forest survey maps, overlay up-to-date boundary information, and so on. These are local uses which need a local GIS facility, just as we have at present local draftsmen and surveyors doing various jobs in the divisions and working plan offices.

KSRSAC could, however, well be given a central role in carrying out the bulk of the GIS development work – standardizing the RS interpretation (as indeed they have already done during the recent years), digitisation of maps not done so far (village maps, forest survey maps, etc.), registering them in a co-ordinate system where possible, developing a user front-end, devising a data cataloguing and storage system, devising and carrying out quality checks, and organising training at various levels. It may even be suggested that specialist staff be seconded from KSRSAC to KFD on a continuing basis in order to bring

about a certain level of uniformity and consistency in the approach to the task, and the efficiency with which the job is done.

In this context, it will be relevant to refer to the **Land Resources Information System (LRIS)** project of KSRSAC (based on a note provided by the Director, KSRSAC dt.19 July, 2005). A KSRSAC proposal to be implemented over a period of 6 years, at a cost of Rs.65 crores, is under discussion in the Government. A pilot LRIS project for Mysore District is being carried out by KSRSAC at an estimated cost of Rs.4 crores provided by the Department of Information Technology, Govt. of India and Govt. of Karnataka, expected to be completed in a period of 2 years. The aim is to show the land parcel divisions (down to individual holdings) in a large scale spatial GIS (on 1:4000 scale) based on village (cadastral) maps in their digitized and geo-referenced form. Clearly, this overlaps with our proposal of developing a geo-referenced database of cadastral maps in forested areas as one component of our FLIS. However, it does not appear necessary to wait for this project to materialize for the limited purpose of the forest lands GIS. **If KSRSAC could take up digitization of those villages (estimated at around 7000 by FSI, or around 3000 in Venkatasubbaih's note) which have notified forests within their boundaries, on a priority**, this would significantly speed up the work and reduce the cost of the proposed FLIS.

4.3.6 Managing the data: building up metadata

The world over, one of the problems in dealing with or setting up a computer-based GIS is the proliferation of data and the difficulty in getting data from different sources and vintages to work together, if at least to minimize the costs of data acquisition. In this evaluation study itself, it has been seen that older data products have been relegated to the cupboards, and even though KSRSAC may have based its work on these existing data-sets, there is no documentation of how they fit in with the new database (if at all). It is therefore desirable to build up a database of data-sets, what is termed 'metadata'.

The metadata will not only list out the area covered, projections and scales used, layers available, type of files, etc., but should also ideally have some objective indication of accuracy or reliability. The source of the data should also be clearly stated. There are international standards prescribed for building up this sort of metadata. It is advisable to mount a separate and specific exercise to build up this sort of database, and make it available to all users; KSRSAC has the expertise to do this. In addition, there should be standardized system of physical storage and cataloguing of products and associated documents, so as to get the maximum value out of them. A master set of the data should be maintained, preferably at HQ.

5 Summary of recommendations

In summary, the following are the recommendations coming out of this review:

1. The GIS facility in KFD should now focus on building up a digital collection of large scale maps like village maps and forest survey maps, with forest boundary details marked in relation to village boundaries and survey numbers. The department should accept that it may not be possible to put together all these individual maps in one composite geo-referenced map, but efforts can be made to develop a facility to put together a few adjoining villages to make a composite layout or view. Scanned and digitized versions of cadastral maps for the relevant villages could be obtained from

the ongoing projects of KSRSAC or other agencies like SoI, state Department of Land Survey, etc.

2. These digital large scale maps can be linked to the existing 1:50,000 GIS to enable calling up of the relevant map images for specific purposes.This will amplify the utility of the existing GIS as well as the proposed large scale digital maps resources.
3. A parallel exercise is needed to build up a comprehensive database (which can be termed the **Forest Lands Information System,** FLIS) of forest lands, village-wise and survey number-wise, designed to be in concordance with the revenue land databases already developed in the state, i.e. Bhoomi. A concurrent exercise is to be taken up to rationalize the land database in collaboration with Bhoomi cell of Revenue Dept. and the Bhoomi software developers, i.e. NIC. The textual data connected to each forest parcel (may be just scanned images of documents) like the forest notifications, boundary description, etc. may also be provided in the FLIS to provide a ready reference to these archival documents for each notified area.
4. In the immediate future, there need not be any massive exercise in building up management history or ecological data of each land parcel; development of such a larger, more elaborate and detailed **Forest Management Information System** (FMIS), for forest management purposes, can be thought of at a later stage, once the land database is stabilized.
5. The GIS and the proposed land database (FLIS) can be integrated at a later stage by providing suitable links in the software.
6. The Working Plans offices will be the nodal locations where the digital database (GIS/MIS) will be maintained during the developmental phase (anticipated to be the duration of the JBIC Phase-2 project). They will provide the respective territorial jurisdictions the relevant GIS/MIS services. A master GIS/MIS centre can be set up at HQ, and all centres can be linked to the land database (Bhoomi) of the State Data Centre.
7. Adequate technical staff will have to be provided to the Working Plans (nodal) offices and to the central unit. There will have to be at least one GIS specialist and one computer technician at each nodal location, and one senior GIS professional and two technicians at HQ. Adequate complement of draftsmen and surveyors (many posts of which are at present vacant) needs to be provided. These personnel will be the immediate users of the GIS, for preparing maps, entering data of local interest in specific cases, etc. The larger task of updating the GIS periodically, may however be entrusted to a professional organization (presently KSRSAC is meant to serve the whole state).
8. The post of Conservator of Forests (GIS & Evaluation) at HQ may be revived in order to give leadership to the technical staff, give proper orientation and momentum to the process of further developing the GIS programme, and above all for providing a medium of communication and interface between the rank and file of KFD on the one hand, and technical wing of the GIS in KFD, KSRSAC, and Bhoomi in the Revenue Department of Government.
9. The training given to surveyors and draftsmen will be at professional, higher level to make them more efficient at using the GIS. Training to forest staff other than surveyors and draftsmen, and to officers at various levels, can be of shorter, general nature to familiarize them with the capabilities and uses of the GIS. Training opportunities should also be provided to the professional and technical personnel maintaining the GIS and computers, apart from providing adequate promotional opportunities in case they are provided permanent positions.

10. Upgradation of hardware and software will be done in stages based on present facilities and on capabilities of personnel using them, and future requirements. It will be sufficient to build up now on Windows-based GIS software, and with existing package like ArcView 3.2, which is considered sufficient for most of the functions that can be anticipated in the forest department in the near future. However, computer systems would need to be replaced urgently to have systems with extra memory, fast graphics, big screen etc.
11. A separate exercise is required to build up a proper data resources management system, including screening and cataloguing the existing data and map resources, and building up the metadata database, so as to minimize repetition of work already done, and make existing resources known and accessible to all potential users.
12. A mechanism may be put in place to take running decisions on technical issues, including quality control, maintenance of metadata, management of the data resources, avoiding repetition and minimizing costs, drawing up terms of reference and specifications, deciding or recommending award of contracts, etc.

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Appendix I: List of team members and contributors

The report was prepared by a Core Team consisting of:

Dr.P.J.Dilip Kumar, IFS, Principal Chief Conservator of Forests (Evaluation, Working Plans, Research & Training): Chief Investigator

S.Nagaraj, IFS, Addl. Principal Chief Conservator of Forests (Working Plans): Chief Co-ordinator

Dr.Sharachchandra Lele, Senior Fellow and Coordinator, CISED (Centre for Interdisciplinary Studies in Environment and Development), ISEC Campus Bangalore: Consultant Investigator

Dr.K.S.Shashidhar, IFS, Director, IWST, Bangalore: Consultant Investigator

With inputs from:

A.K.Verma, IFS, Principal Chief Conservator of Forests (Wild Life), Bangalore

C.S.Venkatasubbaiah, IFS, previously Conservator of Forests, GIS, Working Plans wing, KFD, Bangalore and presently with KSFIC, Dharwad

K.S.Sai Baba, IFS, Conservator of Forests, at one time Working Plans Officer, Dharwad, and presently with State Pollution Control Board, Bangalore

S.K.Kangeyam, Assistant Conservator of Forests, GIS, Working Plans wing, KFD, Bangalore

C.B.S.Dutt, Project Director, Astro-Biology Experiment, Indian Space Research Organisation, Bangalore

Muthatha Ramanathan, Doctoral Student, University of Washington, Seattle and Visiting Student, CISED, Bangalore

Santosh Hegde, Research Assistant (RS/GIS), CISED, Bangalore

Working Plan Officers and their staff of KFD

Assistance and information is warmly acknowledged of all the officers and staff of the various organisations visited and consulted, including:

Karnataka State Remote Sensing Applications Centre, Bangalore

Forest Survey of India, Bangalore

Department of Survey Settlement and Land Records, Bangalore

Andhra Pradesh Forest Dept., GIS Centre

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Appendix II: List of maps and data layers prepared under various RS/GIS activities of KFD till date

	Map Series	Scope	Map Preparing Agency	Layer Name	Contents/Categories	Scale	Year	CD No	Data Format	Source
1	Intergrated GIS Using Remote Sensing and Collateral Data 1998-99	Karwar, Honnavar, Sagar, Mercara, Chikmagalore, Bhadravti, Sirsi, Khanapur (Part of Belgaum)	IN-RIMT	Administrative Boundary	State, District, Taluk boundary		1998-99	xxx	Arc Coverage / E00	SOI toposheets
			IN-RIMT	Contours	Contours @ 100 m interval, Bench Marks, Spot and Triangulated heights		1998-99	xxx	Arc Coverage / E00	SOI toposheets
			IN-RIMT	Drainage	Major drain, Minor Drain, Canal, Tank bund, Perennial Rivers, Reservoir, Waterlogged Area,		1998-99	xxx	Arc Coverage / E00	SOI toposheets
			IN-RIMT	Forest Administration Boundary	Circle, Division, Range, Section, Beat, Block, Compartment		1998-99	xxx	Arc Coverage / E00	
			IN-RIMT	Forest type and Density	EG, SemiEG, Moist Deciduous, Dry Deciduous, Scrub - (0-10%, 10-40%, >40%) Acacia Plantations, Agril. Land, Mixed vegetation, Grassland		1998-99	xxx	Arc Coverage / E00	IRS - 1C/1D Liss III + PAN of March/April 1998/99 visual interpretation

	Maps Series	Scope	Map preparing Agency	Layer Name	Contents/ Categories	Scale	Year	CD No	Data Format	Source
2	Fully integrated GIS in 1999-2000 (ORG-GIS)	Kolar Forest Division - 11 Taluks:Bagepalli, Bangarpet, Chikballapur, Chintamani, Gauribidnaur, Gudiband, Kolar, Malur, Mulbagil, Sidnagatta, Srinivaspur	ORG - GIS	Beat	Boundary, Area, Range name		1999-2000	xxx	Arc Coverage / E00	
			ORG - GIS	Contour	Contours @ 20 m interval		1999-2000	xxx	Arc Coverage / E00	
			ORG - GIS	Density	Water Body, Plantation, Open Forest, Degraded Scrub		1999-2000	xxx	Arc Coverage / E00	Visual and Digital Interpretation of IRS 1C/1D and PAN merged data of Nov.1998-Dec.1999
			ORG - GIS	Drain	No Description		1999-2000	xxx	Arc Coverage / E00	
			ORG - GIS	Forest	No Description		1999-2000	xxx	Arc Coverage / E00	
			ORG - GIS	JFM Class	No Description		1999-2000	xxx	Arc Coverage / E00	
			ORG - GIS	Range	Boundary		1999-2000	xxx	Arc Coverage / E00	
			ORG - GIS	Road	No Description		1999-2000	xxx	Arc Coverage / E00	
			ORG - GIS	Slope	No Description		1999-2000	xxx	Arc Coverage / E00	
			ORG - GIS	Type	Acacia, Degraded Scrub, Eucalyptus, Miscellaneous Forest & Plantations, Water Body, Non-Forest		1999-2000	xxx	Arc Coverage / E00	Visual and Digital Interpretation of IRS 1C/1D and PAN merged data of Nov.1998-Dec.1999
			ORG - GIS	Village	Boundary		1999-2000	xxx	Arc Coverage / E00	

	Maps Series	Scope	Map preparing Agency	Layer Name	Contents/ Categories	Scale	Year	CD No	Data Format	Source
3	Development of fully integrated Geographical Information System using Remotely Sensed and Collateral data	Shimoga Division & Hassan District	ESRI-NIIT	Type and Density for 1987 and 1999			1999-2000	xxx	Arc Coverage	1C/1D, LISS III, LANDSAT TM and PAN imageries of Dec.98, Feb-March 99
			ESRI-NIIT	Forest Administrative Boundary	Beat, Compartments, Division, Range,		1999-2000	xxx	Arc Coverage	
			ESRI-NIIT	Contours	Contours @ 20 m interval		1999-2000	xxx	Arc Coverage	
			ESRI-NIIT	Drainage Network			1999-2000	xxx	Arc Coverage	
			ESRI-NIIT	Transport Network			1999-2000	xxx	Arc Coverage	
			ESRI-NIIT	Village Locations and Boundary			1999-2000	xxx	Arc Coverage	
			ESRI-NIIT	Canals			1999-2000	xxx	Arc Coverage	
4	Geo-Spatial Database for 19 forest divisions - Phase 1- (Forest Vegetation map & Forest Administration Map)	Bagalkot, Belgaum, Bellary, Bidar, Bijapur, Chitradurga, Dharwad, Gadag, Gokak, Gulbarga, Haveri, Kollegal, Koppa, Koppal, Kundapur, Mangalore, Mysore, Raichur, Virajpet	KSRSAC	Revenue Administration Boundary	State, Dist, Taluk, Village Boundary		2004	xxx	Arc Coverage / E00	SOI toposheet/ADLR maps
			KSRSAC	Drainage	Major drain, Minor drain, Canal, Water tanks, Reservoirs, Water logged area		2004	xxx	Arc Coverage / E00	
			KSRSAC	Forest Administration Boundary	Circle, Division, Range and Section		2004	xxx	Arc Coverage / E00	

	Maps Series	Scope	Map preparing Agency	Layer Name	Contents/ Categories	Scale	Year	CD No	Data Format	Source
			KSRSAC	Forest Management Boundary	Block and Compartment		2004	xxx	Arc Coverage / E00	
			KSRSAC	Soil type			2004	xxx	Arc Coverage / E00	NBSS soil map
			KSRSAC	Slope	0-10%, 10-35%, and >35%		2004	xxx	Arc Coverage / E00	
			KSRSAC	Transport Network	Railway line, National Highway, State Highway, Metalled Roads, Non-Metalled Roads, Cart tracks, Foot tracks		2004	xxx	Arc Coverage / E00	
			KSRSAC	Forest Types	Evergreen, Semi-Evergreen, Moist Deciduous, Dry Deciduous, Mangroves, Shola/grasslands, Scrub Forest, Forest Blank, Plantations		2004	Xxx	Arc Coverage / E00	IRS - 1C/1D Liss III + PAN for visual interpretation
			KSRSAC	Forest Cover Density	<10%, 10-25%, 25-40%, 40-70%, >70%.		2004	xxx	Arc Coverage / E00	IRS - 1C/1D Liss III + PAN for visual interpretation

	Maps Series	Scope	Map preparing Agency	Layer Name	Contents/ Categories	Scale	Year	CD No	Data Format	Source
			KSRSAC	Protected Areas	Forest roads, Water holes, Protection camps, Grasslands, Core zone, Fire affected area, Elephant migration route mapping, Buffer zone, Tourism zone.		2004	xxx	Arc Coverage / E00	
			KSRSAC	Point features	Circle, Division, Range, Section, Beat Head Quarters, Forest Rest Houses, Permanent Nurseries, Watch Towers, Check posts, Timber/Firewood Depots, Preservation Plots/Research Plots		2004	xxx	Arc Coverage / E00	

Note: Some information in this table still needs to be filled in after detailed examination.