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CONSULTANCY REPORT

RECOMMENDATIONS ON GEOGRAPHIC INFORMATION SYSTEM FACILITIES FOR THE PAKISTAN FOREST INSTITUTE PESHAWAR, PAKISTAN

Submitted to:

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by

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RECOMMENDATIONS ON
GEOGRAPHIC INFORMATION SYSTEM FACILITIES
FOR THE
PAKISTAN FOREST INSTITUTE
PESHAWAR, PAKISTAN

INTRODUCTION

The Pakistan Household Energy Strategy Study (HESS) project was requested by the Office of the Inspector General of Forests, Ministry of Forests, Agriculture and Cooperatives of the Government of Pakistan, to provide consultancy advice on the provision of Geographic Information System (GIS) facilities at the Pakistan Forest Institute, Peshawar. Agreement was reached between the Inspector General of Forests and officers of the World Bank in August 1992 that assistance would be provided as part of an ongoing programme of technology transfer to Pakistan Government institutions.

An expert from the HESS project visited the Pakistan Forest Institute and the NWFP Forestry Pre-Investment Centre on August 1, 1992, for initial discussions. A preliminary discussion paper was circulated in early September 1992 and a seminar on GIS applications in forestry was held with staff and students at the Pakistan Forest Institute on September 5, 1992. Feedback sessions were also held with PFI staff. A briefing meeting was held with the Inspector General of Forests, the Deputy Inspectors General and USAID staff on September 17, 1992. The final report was then prepared.

OBJECTIVES

Provision of GIS facilities at the Pakistan Forest Institute, Peshawar, should meet the following objectives:

- Improve the utilisation of spatial information for forest management and research in Pakistan.

- Reduce dependence on foreign specialists by developing in-country expertise in GIS.

- Establish a national GIS centre at PFI with the capability to:

  (i) provide adequate GIS services to the federal and provincial forest departments and other organisations responsible for the management of natural resources;

  (ii) support major research projects at PFI and elsewhere.

- Set up training facilities for:

  (i) Federal and Provincial staff responsible for forest

management and research;

(ii) forestry undergraduate students at PFI.

BACKGROUND

(i) What is GIS?

A Geographic Information System (GIS) is a computer-based tool for the storage and manipulation of spatial data from maps and other sources, which can be effectively used in disciplines such as forestry for the management of natural resources. A GIS stores and manipulates both spatial data and attribute data. For example, the boundaries of forest areas (spatial data) can be included together with details which describe each forest area (attribute data), such as age, species composition, canopy height, crown closure and so on. The attribute data is stored in a computer database which is linked to the spatial or map data. The principles are illustrated in Figure 1.

A fundamental difference exists between two types of data handled by a GIS: **vector** data, which consists of polygons and lines such as forest areas and boundaries; and **raster** data, which is made of of grid cells or squares all of the same size. In general, vector data is more accurate than raster data, because irregular map boudaries can be accurately represented, whereas the accuracy of raster data is limited by the size of the grid cell. Processing of vector data generally requires more computer power than raster data, but recent reductions in the cost of computers has made this difference less important than in the past.

(ii) GIS Capabilities

Use of a GIS allows large quantities of spatial and other data to be efficiently summarised and used for resource management decisions. Different maps can be overlain and combined during computer analysis with a GIS; for example topography, soil drainage, forest type and age might be combined with data on road networks to develop forest working plans; or rainfall, slope, vegetation cover and soil texture might be used to predict erosion hazard. 'Buffers' can be defined around features such as roads or streams; for example, if it is proposed to prohibit logging within a given distance from perennial streams a GIS could estimate the volume of all timber within distances of, say, 30 metres, 50 metres or 100 metres from such streams.

Data from a variety of sources can be fed into a GIS. Information from ordinary paper maps or aerial photographs can be entered by manually 'digitising' with special equipment. Point data can be entered and used for interpolation, e.g. data from weather stations can be used to generate rainfall maps. Map data which is already in digital form, such as from computer aided drafting systems, can be read in. Spatial and attribute data can be transferred from another GIS. And land cover information derived from satellite imagery can also be used as an input.

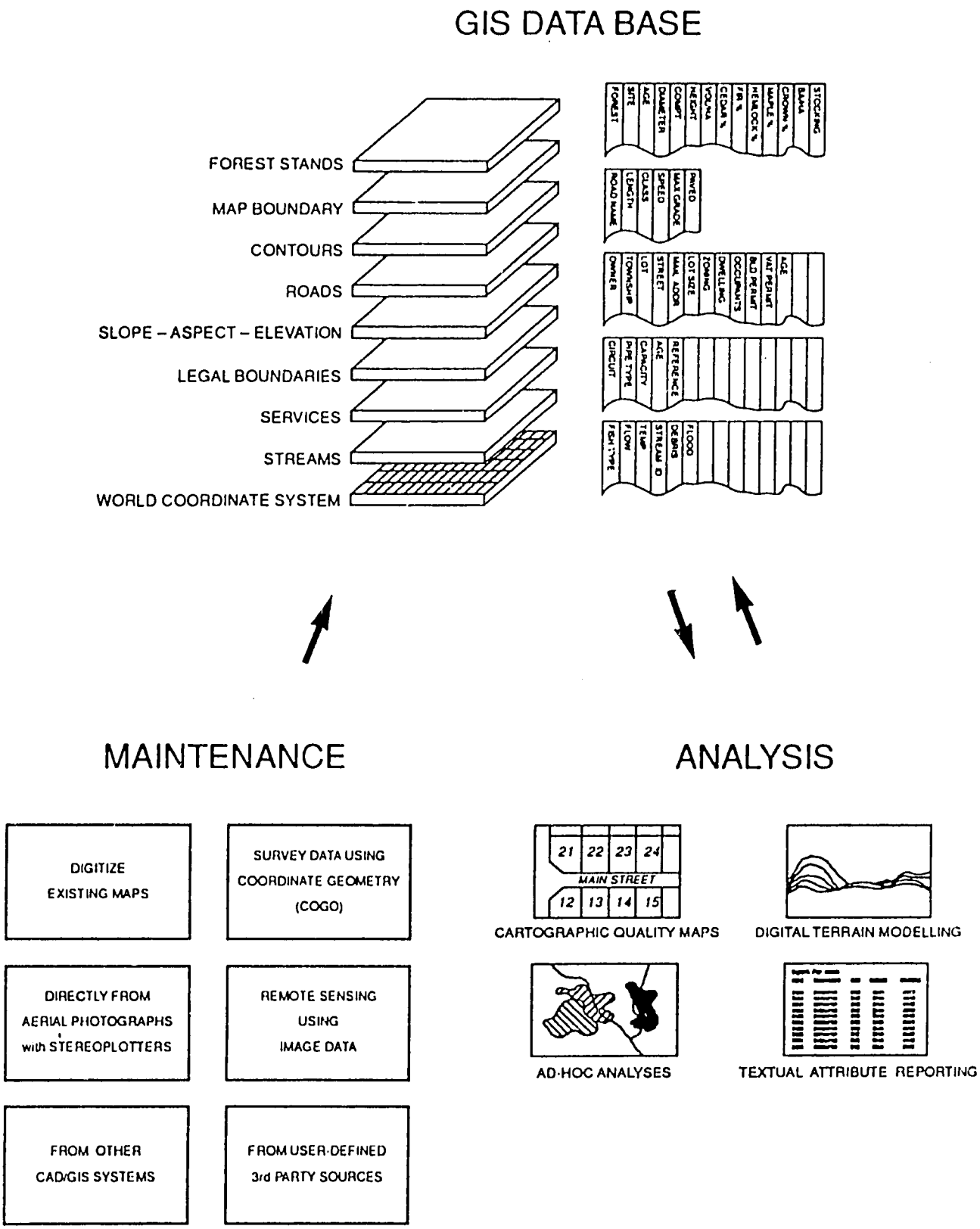

Figure 1. Components of a Geographic Information System.

The GIS can easily combine map data from a variety of scales and types of maps. Any type of attribute data can be associated with delineated areas. Output can be in the form of maps at any required scale, within the limits of accuracy of the data, and/or in the form of printed reports.

Data input is generally the most time-consuming task in any GIS project. However, once the data has been entered the GIS can be used for a wide variety of different analyses. Because the data is stored in digital form it can be readily updated when necessary, and new maps and reports generated immediately afterwards.

(iii) Use of GIS in Forestry

Forestry organisations usually possess large amounts of spatial and attribute data, for example in the form of topographic maps, aerial photographs, forest maps, forest management records and the like. Often, because of the sheer volume of information and the form in which it is kept, it is not used to maximum efficiency. For example, it may be too difficult and time-consuming to manually combine a map of forest compartments at one scale with a soil type map at a second scale and then overlay the result on a topographic map at a third scale, even though the result may be of great value for forest management. And even if such maps are produced they will rarely be updated, because of the time and effort involved in doing so.

A GIS can make existing information more accessible, and make it possible to use the information more efficiently, by:

(a) automating the process of accurately matching map data from different sources;

(b) allowing analyses to be carried out which are too lengthy or complex to be performed manually;

(c) storing attribute data from forest records in a computer database from where it can be easily retrieved.

Use of a GIS can assist a forest manager to explore the consequences of different management strategies, and a researcher to search for relationships in biological systems.

FORESTRY APPLICATIONS OF GIS IN PAKISTAN

(i) Improving Natural Resources Management

Pakistan faces a number of important challenges in the areas of natural resources management. Both the National Conservation Strategy and the Forestry Sector Master Plan reports have highlighted the problem of forest decline in the country, and have made recommendations aimed at improving forest management. GIS is a planning tool which will help to achieve this.

Recent successes of the Forestry Planning and Development Project have clearly demonstrated that solutions to at least some of Pakistan's forestry problems are achievable. GIS facilities will further strengthen the planning capabilities of Federal forestry institutions in Pakistan.

(ii) Available Data

The Pakistan Household Energy Strategy Study has set up a GIS database from maps and satellite imagery which could be made available to natural resources managers in Pakistan. Additional data sources are discussed below.

Existing maps are important sources of GIS data. These include topographic maps produced by the Survey of Pakistan and maps produced by provincial and federal forest departments. Because of the time required to accurately digitise data from large numbers of maps, each GIS project needs to have clearly defined objectives, with clear definitions of the data required and realistic estimates of the time for data input. The availability of up to date maps is also important. Information which does not change over time, such as topography and soil type, can be taken from outdated maps, but the value of other information such as roads, settlements or forest cover should be carefully assessed if it is not recent.

Map data in digital form can be generated by mapping agencies, from sources such as computerised stereoplotters and computer aided drafting. Such data can often be input directly into a GIS. The Survey of Pakistan may be able to advise whether such data is now available and/or when such data may become available in the future.

If recent aerial photography is available, information such as forest type boundaries can be digitised from aerial photographs and corrected for overlaying on existing maps, which can be more accurate and efficient than manually transferring the information from photo to map. If the GIS already contains accurate topographic data, this can be used to correct the air photo information for relief displacement.

Satellite imagery is a useful data source for forestry GIS applications. Because the imagery is being continuously collected by remote sensing satellites it is up to date. The cost per square kilometre for satellite imagery is much cheaper than having an area reflown for air photos, and the data is already in digital form. Satellite imagery can either be manually interpreted in the same way as aerial photography and then digitised, or can be computer classified into land cover types which can be fed into the GIS in digital form. If thorough field checking ('ground truthing') is carried out to ensure that the results are reliable, satellite imagery can provide cost-effective and up to date information. It can therefore be extremely useful to have image processing software with the capability to readily transfer data from satellite imagery to a GIS.

(iii) Interactions With Other Institutions

GIS facilities at PFI will provide the capability to carry out project work for federal and provincial forest departments and other institutions involved in natural resource management. Staff from such institutions could also be trained at PFI. If forestry graduates from PFI are given training or even GIS overview courses and then posted to provincial forestry departments, they will be able to advise senior staff on the potential applications of GIS. Periodic seminars on GIS for provincial staff could be valuable, especially if illustrated with successful GIS case studies from work carried out at PFI.

If provincial forestry departments begin using GIS, their needs may ultimately develop to the point where they seek to establish their own facilities. Every effort should be made at an early stage to ensure that any such facilities, if established, should complement those at PFI. If compatible systems are installed, GIS data could be exchanged and training could be centralised and shared.

GIS FACILITIES REQUIRED

(i) GIS Project and Research Facility

Any GIS facilities established at PFI for national project and research work need to have the capacity for carrying out analytical work at a reasonably advanced level. Both GIS and remote sensing software should be included. Because of recent developments in computer hardware and software, this type of capability can now be obtained at moderate cost.

The following facilities are recommended (details are given in Annex 1):

- a powerful microcomputer for analytical work, with a large hard disk, high resolution monitor, advanced graphics card, colour printer and plotter;
- a microcomputer of moderate power, with digitiser for data capture, networked to the main machine for data transfer;
- data backup facilities which can be used with both machines;
- full featured GIS software;
- image processing software with the capability to exchange data with the GIS.

A fully enclosed room with air conditioning and stable power would be required. A space of approximately 25 square metres would allow room for future expansion.

(ii) GIS Training Facility

Any training facilities which are established should provide for training federal and provincial forestry staff, forestry undergraduates and possibly staff from other natural resources institutions. If limited facilities are established initially they can later be expanded as required.

The following facilities are recommended (see Annex 1 for details):

- four microcomputers of moderate power and capacity;
- one medium sized digitiser and plotter;
- base level GIS software, compatible with the GIS in the project/research laboratory;
- low cost image processing software with some capability to exchange data with the GIS.

A computing laboratory of approximately 30 square metres would be needed, with air conditioning and a stable power supply.

MANPOWER REQUIREMENTS

To maximise the value of GIS facilities at PFI, staff involved in the use of GIS should have backgrounds in forestry or other biological sciences. Specialist GIS staff who lack such a background will not communicate effectively with forest managers and researchers. Because of the highly specialised skills which must be developed, it is also essential that GIS staff have a long term commitment to the work. Before any GIS facilities are established, the staff to be involved should be clearly identified. Full training would follow the installation of equipment.

Two staffing models are proposed.

(i) Model one: project and research facility

A GIS project and research facility as proposed, with both GIS and image processing systems, would need adequate staffing by personnel with the time to devote to the work. Backup staffing would avoid the facilities being closed down when one staff member is absent. The minimum staff requirement would be:

(a) a professional staff member with a higher degree in forestry or a related biological field, who would be fully trained in GIS and given introductory training in remote sensing;

(b) a professional staff member with a higher degree in forestry or a related biological field, who would be fully trained in remote sensing and given introductory training in GIS;

(c) a technician with a degree in computer science, or with a degree in forestry and well developed computer skills, who would be given introductory training in GIS and remote sensing, and whose duties would include digitising, simpler analyses under direction, and other duties such as plotting of maps and data backup; a backup technician would be desirable.

Staff members (a) and (b) above could act as backups for each other. The total requirement would be three to four staff.

(ii) Model two: project and research facility, plus training facility

The project and research facility would need staff as outlined above. Training staff would be in addition to this. A training laboratory would not necessarily require full time staffing, but would still require a reasonable level of expertise. Minimum staff requirement would be:

(d) a professional member of the lecturing staff who would be trained in GIS and remote sensing and would have the responsibility for undergraduate and other basic training in GIS and remote sensing;

(e) a tutor/technician with qualifications and training as in (c) above, to assist with training and maintaining the facilities.

Staff member (e) from the training facility could act as backup for staff member (c) from the project/research facility. The member of lecturing staff would not necessarily need a backup, because training courses could be coordinated with his availability. The total requirement for model two would therefore be five staff.

TRAINING REQUIREMENTS

(i) Initial Training

Initial training should be timed with the establishment of GIS facilities, and could involve staff from other institutions as well. It is recommended that short basic courses in GIS and remote sensing be conducted in Pakistan by visiting experts; staff could then be given several months to use the systems and put their training into practice. Details are given in Annex 2.

(ii) Specialist Training

Individuals who intend to specialise in advanced applications of GIS and/or remote sensing should be sent overseas for further training, after they have undergone introductory training in Pakistan and have developed a reasonable level of proficiency with the technology. This would allow time for the PFI to evaluate and select the staff most suited for further training,

and would give staff members time to decide on their preferred areas of specialisation.

Specialist training could be included as part of the regular USAID programme of overseas fellowships.

ANNEX I

RECOMMENDED SOFTWARE AND HARDWARE

A. SOFTWARE

(i) GIS Software

Fully featured GIS software is required for the project and research facility at PFI. This should be vector-based, with powerful analytical capability and efficient data input and output, including a well-developed capability to exchange raster and vector data with image processing systems for satellite imagery.

Base level GIS software is required for the training facility at PFI, compatible with the GIS software used for the project and research facility.

GIS software tested and/or reviewed included: Atlas, MapInfo, IDRISI, ARC/INFO and SPANS. Atlas and MapInfo are vector based, but have little or no capability for handling raster data. IDRISI is strongly raster oriented. SPANS uses a hybrid raster-vector approach, but its maximum map accuracy is limited by the smallest raster size permitted by the system.

ARC/INFO is a vector based GIS, with the capability to handle raster data from sources such as satellite imagery. It place no practical limits on map accuracy, and includes all analytical tools required for advanced project and research work. In addition, a "live link" is available between ARC/INFO and the powerful image processing system ERDAS, which allows both systems to be used simultaneously on the same computer.

The purchase of ARC/INFO is recommended, in the form of a fully featured system linked with dBASE IV software for the project and research facility and a university Lab Kit for the training facility. Estimated costs are:

Software	**Estimated Cost (US$)**
PC ARC/INFO version 3.4D, including Starter Kit, ARCEDIT, ARCPLOT, Data Conversion and Overlay modules	12000
dBASE IV database software	1200
Networking software (LANtastic or similar)	2000
5 PC ARC/INFO license bundle (University Lab Kit)	5500

Suppliers for ARC/INFO:

Environmental Systems Research Institute
380 New York Street
Redlands California 92373

Phone: (714) 793-2853
Fax: (714) 793-5953

(ii) Remote Sensing (Image Processing) Software

Fully featured image processing software is required for the project and research facility, with powerful capabilities for exchanging raster and vector data with the GIS. Lower cost image processing software can be used for the training facility, but it should have at least some capability for exchanging data with the GIS for training purposes. Both systems should have the capability to display the full range of colours available from satellite imagery, so that subtle features can be seen and interpreted; this requires a 24-bit (16 million) colour display.

Image processing software tested and/or reviewed included: Resource, R-CHIPS, PC-A-Image, RSVGA, ERDAS and Dragon. Resource is subject to system crashes and has less than satisfactory image classification capabilities. R-CHIPS lacks a number of advanced features such as unsupervised classification and 3D manipulation. PC-A-Image is available with only an 8-bit (256-colour) display which is not adequate for accurately interpreting satellite imagery. RSVGA lacks some of the most basic image manipulation functions such as roam and zoom.

ERDAS is a fully featured image processing system with advanced analytical capabilities. An important feature is its "Live Link" with ARC/INFO, which allows both systems to be used simultaneously on the same computer, with GIS graphics and imagery displayed on the same screen and "real-time" data exchange between the two systems.

Dragon is a good low-cost system suitable for training purposes. It is at present available only in a 256-colour version (Dragon Level 2), but a 24-bit (16 million) colour version is due for release before the end of 1992. It has the capability to exchange data with ARC/INFO, although it does not have a "live link".

The purchase of ERDAS with the "Live Link" with ARC/INFO is recommended for the project and research facility, and an 8 seat site licence for Dragon Professional for the training facility. Estimated costs are:

Software	**Estimated Cost (US$)**
ERDAS system software, PC version, all modules	22000

Dragon Level 2 (24-bit colour) 8 seat site licence, with TIFF Library, Rosetta Library and Vector Library	6000

Suppliers for ERDAS:

ERDAS
2801 Buford Highway
Suite 300
Atlanta GA 30329

Phone: (404) 248-9000
Fax: (404) 248-9400

Suppliers for Dragon Professional:

Goldin-Rudahl Systems, Inc
Six University Drive, Suite 213
Amherst MA 01002

Phone: (413) 367-2016
fax: (413) 549-6401

Total estimated software cost	**48700**

B. HARDWARE

The cost of IBM PC-compatible computer hardware has fallen dramatically within the past year. This makes it possible to purchase considerable computing power within a reasonable budget. The project and research facility will need one powerful PC with special hardware for GIS/image processing and one less powerful PC for use as a digitising workstation. The training facility will need four PCs of moderate power.

(i) GIS Project and Research Facilities

Equipment	**Estimated cost (US$)**
486/50 PC with 8 Mb RAM, 600 Mb HDD	5000
IMAGRAPH Image Processor 1024x1024x32 plus 20 inch RGB monitor	15000
A0 digitiser	4000
A1 plotter	3000
HP PaintJet XL300 colour ink jet printer	3000
9-track tape drive	7000
650 Mb eraseable rewritable optical disk drive	4000

486/33 PC with 100 Mb HDD, for use as a digitising workstation	3000

	44000

(ii) GIS Training Facility

Equipment	**Estimated cost (US$)**
4 x 486/33 PCs with 4 Mb RAM, 100 Mb HDD, Hercules Graphics Station GB1024+2 card	16000
A1 digitiser	3000
A1 plotter	3000
HP PaintJet printer	2000

	24000

Total estimated hardware cost	**68000**

C. RUNNING COSTS

Item	**Estimated cost (US$)**
Maintenance contract on all equipment	7000 per year (from year 2)
Software maintenance	5000 per year (from year 2)
Satellite imagery: 6 Landsat scenes per year	25000
4 SPOT scenes per year	15000

ANNEX II

INITIAL TRAINING

The most cost effective method of arranging initial training is to wait until all equipment has been installed, then assemble a group to be trained by a visiting expert from the software vendor company. It also allows training to be carried out in the environment in which the equipment will later be used.

With four computers in the training laboratory it will be possible to have one computer between two trainees for initial training with ARC/INFO and base level image processing with Dragon.

Initial training for advanced level image processing with ERDAS and the "Live Link" to ARC/INFO would be limited to four participants, because only one computer would be available to run the software. It would still be more cost effective to carry out initial training in Pakistan than to send four participants overseas.

Estimated costs are:

Item	**Estimated cost (US$)**
ARC/INFO introductory training course for 8 participants at PFI	14000
Dragon introductory training course for 8 participants at PFI	12000
ERDAS and "Live Link" introductory training course for 4 participants at PFI	14000
Total estimated cost of initial training	**40000**