The Integration of A Geographic Information System (GIS) Into the *Dessarollo Forestal Campasino* (DFC) Project: A Pilot Study

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I. Introduction

For the past four years FAO's DFC Project and its national counterpart INEFAN, have been working in 250 communities in the high Andes of Ecuador, located in seven different provinces: Imbabura, Pichincha, Chimborazo, Bolivar, Azuay, Canar, and Loja. The project promotes forestry development activities and the management of renewable natural resources through agroforestry, the management of native and planted forests, and the management of family gardens and small business development. It implements all these activities through the use of participatory development methods.

In 1999 DFC is set to begin its second phase in which it intends to expand the management focus from the community level, to what this document will term as an 'Area of Influence'. It is necessary to clarify an 'Area of Influence" as it is still under discussion in the DFC project. Areas of influence are determined by three major factors. First, is the relationship between water resources and a geographic area. The watershed defines a water drainage system and serves as a base, but often communities outside of the watershed play a major role in the use and management of a watershed. Thus, the 'Area of Influence' often includes areas outside of defined watersheds. Second, DFC communities and the relationships between these communities both geographically and organizationally. Third, is inter-institutional cooperation. There are two levels of inter-institutional cooperation. The first is at the level of a group of communities, such as farmer’s cooperatives and water user associations. The second level is government and non-government organizations, which operate in given areas of DFC nucleus. These three factors define an 'Area of Influence' and allow for the expansion of management and cooperation over a larger area. Thus, the definition of these areas on the basis of a combination of physical, social and organizational factors improves the possibility of sustainable management of larger areas in the future.

Seguimiento y Evaluacion de Planes Agroforestales Comunales (SEPAC), is the information system that DFC currently uses for planning, management and evaluation. There is very little spatial information entered into SEPAC, therefore it is difficult to use spatial information in the planning, management and evaluation process. For this reason DFC has initiated this pilot study in an effort to explore the use of geographic technology as a way to improve its monitoring and evaluation system, SEPAC.

This document discusses the objective and methodology in this pilot study as well as the recommendations and conclusions reached, which are presented in a practical how-to format to be utilized by technicians, disicionmakers, and other institutions interested in integrating geographic technologies into their projects.

II. Pilot Study Objective

Develop and integrate a Geographic Information System (GIS) into the existing structure of the DFC project for the purpose of improving the planning, monitoring, and evaluation process of the project.

III. Major Conclusions

In the case of the DFC project an information system, SEPAC, already exists. The questions this pilot project answered was the compatibility of SEPAC with a given GIS application and the need for spatial information in the DFC project, especially in its transition to a second phase. Without going into the technical details of SEPAC / GIS compatibility, which will be expanded on later in this document, a brief explanation of how SEPAC fits into a GIS will given here.

All vector GIS's have a database for attribute data. In other words every line, point or space (polygon) in the GIS can be assigned a specific value or name which can be retrieved in various ways. This connection of attribute data to geographic entities is the power of a GIS. SEPAC data is not connected to geographic entities (points, lines, polygons), therefore it can not be represented in a map. However, using a given point, line or polygon that is "georeferenced" in a vector GIS, SEPAC data can be represented in a spatial context by linking the two. For example, data in reference to the number of hectares of native forest managed in Molleturo is in the SEPAC database, but only when it is linked to a georeferenced polygon can it be displayed in the form of a map, analyzed in connection to other spatial information, and better meet project needs. In summary, raw data is not information, only when it is reduced, analyzed and displayed in a usable format can it aid in the management, planning and evaluation processes. A GIS allows for data to be displayed in a format that can be more useful for project needs than a table or chart. It creates the connection of data to reality in the form of a map.

Furthermore, as the project increases its scale to include 'Areas of Influence' in the second phase, the need for geographic spatial data becomes imperative to meet planning, management, monitoring and evaluation goals, along with creating a geographic base for the future.

IV. Context

Initial information for this pilot study was collected from August 1997 to February 1998 with the collaboration of DFC's Azuay team and community promoters in the field. With the objective of creating maps to select watersheds to be managed in the second phase of the project, spatial, qualitative and quantitative data was collected and used for immediate project goals and for the planning of the second phase. This data included, Instituto Geografico Militar (IGM) topographical maps, Instituto National de Estadisicas Y Censos (INEC) political maps, and Ministerio de Agicultura (MAG) actual use of the soil maps. In addition, field data such as limits of DFC communities and socio-economic data pertaining to the DFC project was put into a spatial context.[1] Training in manual GIS, map creation, analysis and use was also conveyed to the Azuay team during this time. The experiences, information, and lessons learned during this six months period in Azuay laid the foundations for this GIS pilot study - an INEFAN and DFC joint effort.

V. What is a GIS?

A Geographic Information System (GIS) is a tool to collect, store, retrieve and analyze information that has been referenced to a geographic location. The output of a GIS is a map, but the process of creating this map is where a GIS differs from cartographic drafting. A GIS uses a variety of sources and techniques to answer spatial questions. Geographic sources may include existing maps (digital & paper), aerial photographs and satellite images. Information contained in these maps can originate from a variety of databases. When data is applied to a map they become known as map attributes. The main GIS technique utilized for spatial analysis is, overlay, in which maps or portions of maps are superimposed and combined to obtain spatial data and answer related questions. Queries of attribute data can also be made to provide the user with a spatial representation of a specific attribute. Note that a single geographic entity can have numerous attributes assigned to it. These attributes can be combined or isolated and displayed in map form.

Because of this technology's ability to be used as a planning and evaluation tool, the last few years have seen an increased interest by the development field particularly in the areas of food security and natural resource management to incorporate GIS technology into projects and programs.

Types of GIS

In general there are two types of Geographic Information Systems: a manual GIS and an automated GIS.

A manual GIS uses tools such as a light table, compass, and drafting tools to create, analyze and alter maps. Maps of the same scale can be overlaid with the use of a light table and thus the characteristics contained in each map can be combined to provide a higher level of information.

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[1]Alspach,A.,Waard,T. *Manejo de Microcuencas: Estudio de Los Criterios para seleccionar las microcuencas, y el uso de mapas y dataos socio-economicos en la seleccion y el manejo.* FAO/DFC, Quito, Ecuador, 1998.

Manual GIS pro’s :

- Material for the creation and analysis of maps is low cost.
- Personnel training is quick, low cost and can be utilized at all levels of the project, from headquarters to the community promoter.
- Geographic data is readily available and low cost.

Manual GIS con’s:

- The process to combine database information (SEPAC) with location maps is labor intensive.
- Map scales must be the same for overlay and changes in scale are time consuming and expensive.
- Map creation is time consuming.
- Complex analysis is time consuming beyond benefit.

An automated GIS uses tools such as digitizing tables, computers, software packages, Global Positioning Systems (GPS), and plotters to create, analyze, and alter maps. This system utilizes the same inputs as the manual GIS, but transforms data into a digital format.

Automated GIS pro’s:

- A link can be created to databases, (SEPAC) that allows for instantaneous update of geographic attributes in the GIS when the database is updated.
- After Georeferencing data, scale changes can be made by the move of a mouse.
- After geographic and attribute data are entered into the system, thematic maps can be created easily in a matter of hours.
- Complex analysis can be performed.

Automated GIS con’s :

- Initial hardware and software costs are high.
- Personnel training is complex, high cost and is restricted to sites with proper hardware and software.

VI. Pilot Study Methodology

Preparation

1) Formulate work plan for pilot study
2) Setup hardware and software at INEFAN office tailored to project needs
3) Identify geographic data sources
4) Identify attribute data sources

Data entry & Preparation

5) Convert map and aerial photograph data into a digital format

6) Install SEPAC database at INEFAN.

7) Georeference map layers

8) Add attribute data to georeferenced digital layers

Analysis / Creation of draft maps

9) Construct three-dimensional models of watersheds.

10) Extrapolate map layers to create thematic maps for field validation.

Field validation

11) Using maps created from base maps and aerial photographs, verify geographic boundaries and attribute data with extensionists and community promoters in the field.

12) Collect GPS data in the field for new geographic information and verification of geographic location of existing map features.

Map Update

13) Update digital databases to reflect changes made by extensionists and community promoters in the field.

14) Enter GPS data into the GIS

Creation of final maps & GIS system.

15) Using DFC project objectives as a guideline, create final maps to be used as examples in this pilot study.

16) Link thematic digital maps to fit into the existing data structure of the SEPAC. (i.e. country, zone, area of influence, community)

Socialization

17) Create GIS 'Datashow' presentation for INEFAN and DFC. Write a comprehensive document with programmatic recommendations.

VII Results

This pilot study produced a significant amount of digital data in a very short time period. In general, the entire zone of Azuay has been digitally transformed at a level of detail that is acceptable for work in DFC communities. The community of Turucucho in Pichincha was also digitally transformed for examples at the parcel level. In addition to these digital base maps, Digital Terrain Models (DTM) were also created for all nucleuses in Azuay and the community of Turucucho in Pichincha. This digital data is saved on 3.5

floppy disks and can be used by the project for training, inter-institutional cooperation, and the base for DFC's GIS. All data is in the ArcInfo "coverage" format, which is compatible with many GIS programs. Bitmaps where also create for DFC symbology and various photographs in Turucucho. Programs for a sample GIS, and various thematic maps where also produced. The programs would become valuable to the project if it decided to use the same software as the INEFAN office in the future. As the maps are solely for examples, there is little need for them to be saved on disk. (Some maps for this pilot study can be found at: http://www.clarku.edu/~aalspach/DFCpres/index.htm)

VIII Integrating a GIS into the DFC project: How to, and Recommendations.

Based on lessons learned while implementing the pilot study methodology, the following section explains the steps needed in order to incorporate a GIS component into the DFC project. [2]

Identification and Conceptualization

1) Commitment

DFC's and INEFAN's commitment has been vital to this process. With very little financial outlay the project has gained valuable cooperation from INEFAN as well as wide variety of system, logistical, and software functions in a very short time. It is rare that managers and dicisionmakers have such insight in which to base decisions to implement a GIS in their projects.

2) Requirements Analysis

GIS is a tool used to enhance DFC's ability to collect and utilize spatial information in conjunction with the SEPAC database. This pilot study uses project "needs" or objectives as a base to adapt the GIS tool.

3) Feasibility Evaluation

Feasibility factors must be considered before the implementation of a GIS in the DFC project. For each factor in this pilot study the availability of data, and the potential cost to benefit ratio was weighed when making project recommendations.

[2] These steps are a variation of methodology developed by, Antenucci, J.C. Geographic Information Systems: A Guide to the Technology. New York: Van Nostrand Reinhold; Macmillan, 1991, p.301.

4) Geographic data base Acquisition

The majority of the geographic data base acquisition was completed during the initial information gathering stage with DFC's Azuay team.[3] Because of the two month time restraint of this pilot study, as much existing geographic data was used as possible. There are four major considerations when acquiring geographic information.

a) Scale

The scale of the geographic data is directly dependent on project needs. For instance, if a project is solely working at a national scale then maps at 1: 1,000.00 scale may be sufficient. In the DFC project there are four levels at which information is collected, country, zone, nuclei and community. Each of these levels has different amounts of information, in fact, there is a gradient of information from country to community. For example, information at the country level is aggregated and small-scale (large area) maps are sufficient to give context to the information, but information at the community level is dis-aggregated and requires a large-scale (small area) map to show context. The aspect of scale is very important and there is a fine line between having to much information (unused information), and not enough information. Field use of maps is the best way to get an accurate picture of the utility of certain map scales. The map should be detailed enough to orient users to the theme of the map but not cluttered with unnecessary information.

The following is a guide to map scales at the different levels of the DFC project.

Country:	1: 1.000.00
Zone:	1: 500.000 - 1: 250.000
Nuclei:	1:100.00 - 1:50.000
Area of Influence:	1:50.000 - 1:25.000
Watershed:	1: 25.000
Community:	1: 5000

It should be noted that the scale of geographic data is an important consideration during the digital transformation process in creating a GIS. Even though a GIS can change scale from 1.000.00 to 5000 with the move of a mouse, the original scale of the digitally transformed data remains the same. For example, topographic elevation lines digitally transformed at a scale of 1:1.000.00 create a detailed

[3] Alspach,A.,Waard,T. *Manejo de Microcuencas: Estudio de Los Criterios para seleccionar las microcuencas, y el uso de mapas y dataos socio-economicos en la seleccion y el manejo.* FAO/DFC, Quito, Ecuador, 1998.

picture of topography at the country level but when viewed at the community level at a scale of 1:5000 only two or three general topographic elevation lines can be displayed, and a poor presentation of topography is depicted. Thus, it is important to clearly outline geographic data at each level of the project and enter data into the GIS that are useful at its respective levels.

b) Availability

The availability of paper maps and aerial photographs in Ecuador is quite good. However, there must be a distinction made between availability and access to data. For political, and institutional reasons access may be restricted to geographic data. In this case a letter of introduction with project objectives opens a lot of doors. Geographic data in a digital form can be obtained from CLERSIN and the IGM. However, when obtaining digital data it is very important to clearly understand the format of the data and its compatibility with the project's system.

The availability of geographic data is very important to keep costs and time spent gathering data in the field low. It is worth the effort to contact additional institutions that may have the data that you are looking for before embarking on a costly, time consuming field survey.

c) Quality

Of course, the best quality data available should be used. It is recommendable that the project devises its own quality standards. These standards should be based on project needs. For example, geographic data at the country level showing general data about location of zones does not need to be as accurate as community level data showing land tenure. The quality of geographic data decreases with the generation of the map due to distortions during copying, and maps that are enlarged or reduced from their original scale suffer even more distortion. For this reason original maps should be used when ever possible for digital transformation.

The digital transformation of maps for use in a GIS introduces a certain amount of error. However, this error can be kept to a minimum if certain "acceptable error" standards are adhered to. In addition, "projecting" the earth's oblique spheroid shape onto a flat surface introduces a certain amount of distortion. It is recommended to use a “Universal Transverse Mercator”(UTM) projection because it is the standard projection used in Ecuador.

d) Cost

The cost of geographic data depends on any combination of the above mentioned factors. In the cases of quality and scale there is an increase in cost directly related to the increase in scale or quality. However, in the case of availability this is reversed creating a situation of increased availability lowering cost. For the project to maximize its benefits of geographic data with a minimum of monetary expenditure there is a simple formula, " Purchase only what the project needs, keeping in mind the above mention factors".

Planning and Design

1) GIS Structure

This pilot study has provided valuable insight into exactly how a GIS can be integrated into the existing information systems of the DFC project. Using SEPAC and project objectives as guidelines, a sample GIS was constructed. There are five levels that make up this model, country, zone, nucleus, area of influence and community.

The following is a break down of the GIS structure, with its respective base layers of geographic information.

a) Country

- Ecuador boundaries
- Provincial boundaries

b) Zone

- Provincial boundaries
- Major rivers
- Major towns
- Major roads

c) Nucleus

- Political boundaries (Parroquial, Cantonal, Provincial)
- Watershed boundaries
- DFC town boundaries
- Rivers
- DFC towns and non-DFC towns
- Major mountains
- Roads
- Topographic elevation lines

d) Areas of Influence

- Political boundaries (Parroquial, Cantonal, Provincial)

* Watershed boundaries
* DFC town boundaries
* Rivers
* DFC towns and non-DFC towns
* Major mountains
* Roads
* Topographic elevation lines

e) Communities

* Political boundaries (Parroquial, Cantonal, Provincial)
* Watershed boundaries
* DFC town boundaries
* Rivers
* DFC towns and non-DFC towns
* Major mountains
* Roads
* Topographic elevation lines

This geographic information provides a context in which to input DFC SEPAC data. It gives physical form to numbers in a chart or words in a file. When representing real world, three-dimensional features on a two-dimensional map there is a transformation that takes place. All information in a map assumes one of three forms, line, point or polygon. Each geographic layer contains information about the type of entity being depicted. For example, rivers are depicted as lines, town limits represent areas and are best depicted in polygon form and town centroids take the form of a point. SEPAC data can easily be linked to one of the geographic entities mentioned above, georeferencing it and giving it exact spatial form. Note that the number of geographic layers increases as scale increases. This parallels SEPAC information that increases in the same way. Various thematic maps can be created using a combination or all of the layers listed above.

2) Inter-Institutional Cooperation.

To lower costs and to foster inter-institutional cooperation; government, non-government (NGOs) and private organizations with agendas that complement or parallel DFC's should be contacted and probed for support. There is also the possibility of support from various universities in the country. This pilot study should offer a detailed explanation of what DFC intends to do with a GIS and will aid tremendously in the effort to negotiate with other organizations. The support of INEFAN has been outstanding throughout this study and should encourage a closer working relationship for the mutual benefit of DFC and INEFAN. Another example of support is Empresa de Telefono, Agua Potable y Alcantarillado (ETAPA) and its willingness to offer a Global Positioning System (GPS) for use in the zone of Azuay. Before the purchase of any equipment, software, or digital data all avenues of cooperation should be explored. This is the next logical step that should be taken if the project decides to go ahead with the implementation of a GIS in the project.

3) System Design & Acquisition

This is the step that many organizations jump to before they conduct a needs based feasibility study and exhausted all avenues of cooperation with other institutions. Again, DFC has an excellent base in which to formulate decisions on whether or not to integrate a GIS in the project in the form of this pilot study. There are two parts to system design; hardware (computers, digitizing tables, etc.) and software (GIS programs, word processing programs, statistical packages etc.)

a) Hardware

The majority of this project can be completed with a 486 processor and 46k RAM with a SVGA monitor. For more complex analysis and editing the use of a Workstation is recommended. A large format digitizing table was used for geographic data input along with a flatbed scanner for photographs and DFC icons. A large format black and white, ink jet plotter is suggested for printing hard copy maps. A GPS was also used for field data collection. (This document specifically omits the name brands of all hardware used in this study, because it is not the purpose of this study to endorse any one manufacture.) It is strongly recommended that at least a 586 processor or better, with as much RAM as possible is used if the hardware is to be purchased in the future. The 486 processor was not sufficient to run GIS programs quickly and cost a significant amount of time. Furthermore, 16k of RAM was added to the computer giving it a total of 46k at the start of the project which still was not enough for some of the more complex operations in the GIS. The FAO publication, " Computer-Assisted Watershed Planning and Management" offers these guidelines for the purchase of hardware. [4]

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[4]Food and Agriculture Organization of the United Nations (FAO) *Computer-Assisted watershed planning and management: Technologies for National Planning.* (FAO) Rome, Italy, 1996, p.42.

CPU-	Intel Pentium or 586 by other manufactures running at least 90 MHz.
RAM-	16 Megabytes minimum, 32 Megabytes recommended.
Hard Disk-	540 Megabytes Minimum, 1 Gigabyte recommended.
Input/Output-	3.5 inch, high-density floppy disk drive and a CD-ROM drive (Double to Quadruple speed CD-ROM drive)
Graphics-	SVGA minimum, 24 bit planes of graphics recommended for image processing; Resolutions of 1280 x 1024 recommended.
Monitor-	15-20 inch monitor capable of supporting 1280 x 1024 non-interlaced: 17-inch minimum recommended.
Other-	Keyboard, 2 or 3 button serial mouse, at least one parallel port and two serial ports, and a back up tape drive for data storage, exchange, and system backup.

b) Software

A brief explanation of the software needed for this project will be elaborated below. However, no specific GIS software package will be recommended. Instead, desirable traits of GIS software will be elaborated on so that the project can make an educated choice when obtaining it in the future.

INEFAN has access to three "Environmental Systems Research Institute Inc." GIS products, PC ArcInfo, ArcInfo for a workstation and ARCVIEW.[5] The two versions of ArcInfo can perform practically the same tasks, but the workstation version is much faster and can handle 3d modeling and other operations that would take an extraordinary amount of time on the PC (this had a lot to do with processing speeds of the workstation, but our PC version did not have some of the 3d tools available in the workstation version.) ArcInfo is a fairly complex program that has various sub-modules to perform a variety of GIS tasks. ArcInfo is mainly a command line based software, (although there are "tools" that allow interactive, "point and click" operation). ARCVIEW, uses a windows type environment, that allows the selection of

[5]Environmental Systems Research Institute, Inc. 380 New York Street, Redlands, California 92373, USA

tools from various icons to allow interactive manipulation of data. ARCVIEW is compatible with ArcInfo and all geographic layers created in ArcInfo can be imported for the creation of maps.

As stated before ArcInfo is a complex program, however, it offers a wide variety of tools to build geographic data sets. For the input and editing of geographic data, ArcInfo provides everything needed. ARCVIEW on the other hand, allows for easy attribute edition and manipulation and provides excellent map making tools. Furthermore, ARCVIEW is easy to learn and the windows type operating system allows for easy access to other databases to be incorporated into maps. (In the case of this study, the importing of SEPAC .dbf files is very important.) The combination of these two softwares in this pilot project allowed for digital transformation, geographic entity editing, attribute editing, connections to other data bases, creation of maps and the printing of hard copy maps. In summary, these two programs provide all the tools needed to create, analyze and print maps for the project.

Desirable traits in a GIS software for the DFC project.

- Compatibility with other GIS programs. (especially programs that are used by other organizations in Ecuador)
- User friendliness and training requirements based on users in the project.
- Ability to import and utilize tabular data from other programs (i.e. SEPAC)
- Cost of software within acceptable range, based on project needs.
- Compatible with input and output hardware (Digitizing table, Plotter)
- Analysis capabilities that meet project needs.
- Hardware requirements within the means of the project.
- Cost effective and available upgrades for system expansion.

4) Organization, Staffing, and Training

This step in the methodology is dependent on inter-institutional cooperation as well as the expansion of the DFC project to accommodate the new GIS tool.

a) Organization

When the support of institutions outside of the DFC project is obtained it is imperative to outline specific tasks, timelines and results. It may be the case that an institution loans the project a GPS unit for field data gathering, which does not involve a complex outline of objectives. However, more complex involvement may be created, where for example, an institution is in charge of digital transformation of a zone in the DFC project. This would involve a detailed outline of products within a given time period along with benefits to the collaborating institution for this task. As for DFC organization, it needs to have the same sort of structure. If personnel in DFC are clear on their role in the GIS portion of the project and have reasonable guidelines and time frames to complete their tasks, a geographic aspect can be added to the project successfully. This organization is not limited to the operators of the actual system but extends to the entire staff of DFC, from the SEDE to the community promoters in the field. Feedback from all levels of the project will help to improve the GIS system and integrate it into the project quickly and efficiently with benefits by all pertinent actors.

b) Staffing

It is recommended that at least one trained GIS specialist, preferably with experience in forestry projects and participatory methodologies be hired to work in the DFC project. It is possible that a current staff member in the DFC project could be trained to operate a GIS, however, due to the current workload of DFC staff this may not prove to be a realistic option. The existing information system in the project, SEPAC, is centralized in headquarters (Conocoto), therefore this individual would also be located at headquarters. As mentioned before the possibility for inter-institutional cooperation could provide other trained specialists within other organizations, which could decentralize the organization of the GIS, system. For example, if cooperation of other institutions in Azuay or Loja could be fostered, then flow and up dating of geographic information could be divided into a north south type of organization. Where Azuay or Loja handles the southern zones in the country and Conocoto handles the northern portion. This would reduce the load of a more centralized organization and increase efficiency.

c) Training

After a GIS software is selected by the project there may be the need for additional training of staff to operate this program. The largest in-country training facility is CLIRSEN. Contact with this organization indicates that they can create training sessions using DFC data, both geographic and tabular, to instruct groups of 10 to 20 individuals in ARCVIEW, ArcInfo and IDRISI for $250.00 per person. [6] Through more in-depth dialog the cost per person may be reduced and other software packages could be offered. In addition to software training, and probably more important to the project, is the training of the entire staff in the gathering, analysis and use of geographic information. In Azuay the team quickly integrated a geographic aspect into their work in both the office and in the field. In the zones Azuay and Rio Bamba the teams have taken the initiative to gathered an excellent map base and currently use manual GIS techniques for analysis. The zones must build their own map bases to be entered into a GIS and linked to SEPAC data. It is recommended that the experiences in Azuay and Rio Bamba be transferred to every zone of the project to integrate a geographic aspect into the project and ultimately a GIS.

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[6] The IDRISI project, The Clark Labs for Cartographic Technology and Geographic Analysis. Clark University, Worcester, MA 01610-1477, USA. In Cooperation with UNITAR and UNEP/ GRID

5) Operating Procedure Preparation

If the previous steps in this methodology have been executed with the participation of the entire project, then everyone involved in DFC should have a fairly good idea of how GIS can be used at their respective level of the project. The next step is to clearly layout how the GIS system will operate within DFC's present structure. This should include resource allocation, operating procedures, tabular data transfer (SEPAC), geographic data transfer (Maps), field data gathering, equipment maintenance and the flow of all this information.

a) Resource Allocation

This includes funding and equipment allocation at the various levels of the project. It may be as little as funds for photocopying maps or as large as the investment as large as the purchase of a computer. Regardless, planning at this stage is crucial and should be done within DFC and its collaborating institutions. Careful preparation and documentation will help avoid unexpected "needs" that may stall the implementation process.

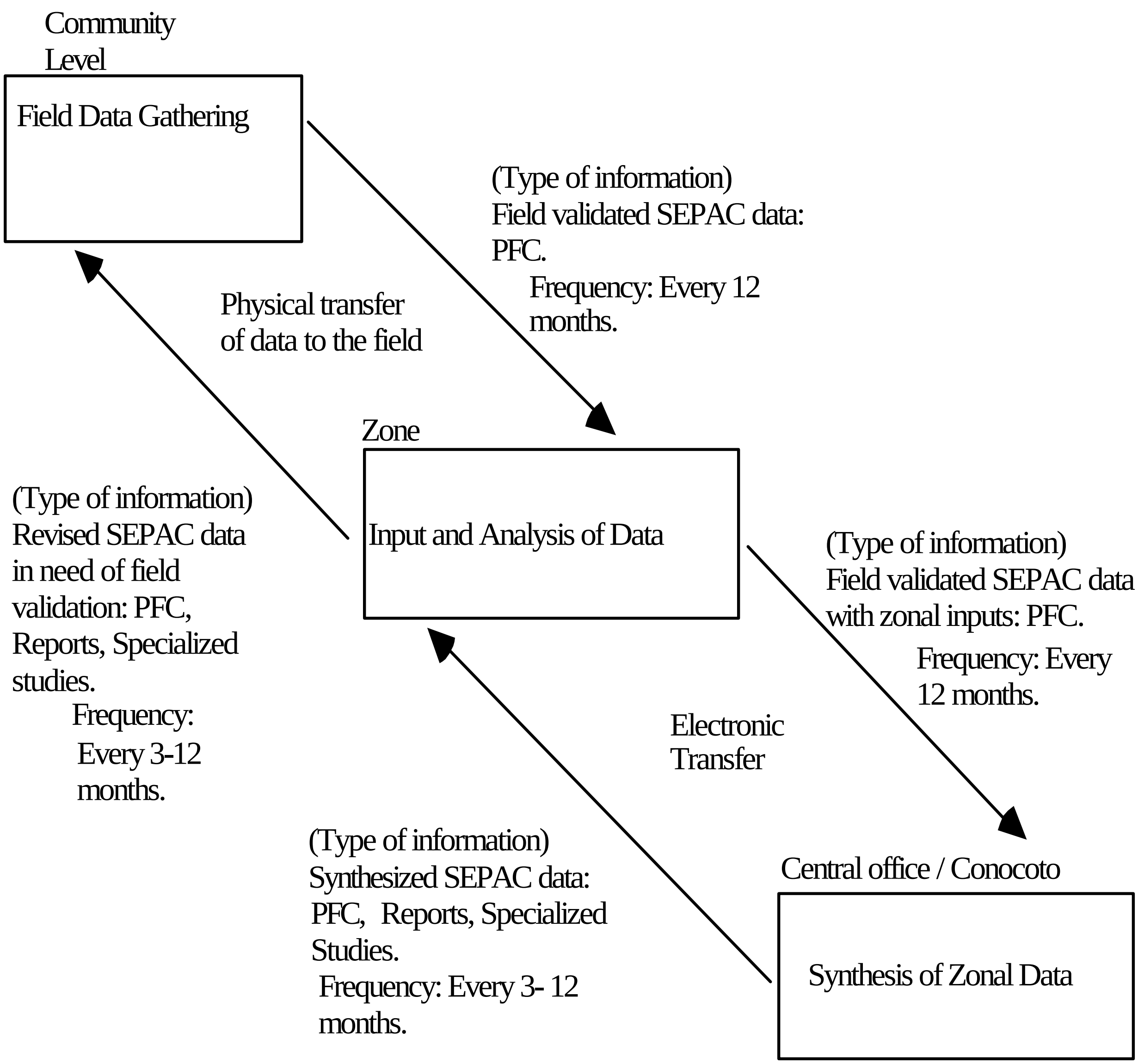
b) Operating Procedures

The following two diagrams are intended to give an overall picture of how a GIS aspect in the project can function and provide a general vision of how day-to-day operating activities can proceed. This vision can be used only as a guideline or base of discussion, because many of the operating activities will hinge on inter-institutional cooperation developed in the future, and the extent to which the project intends to proceed with a GIS integration.

Flowchart #1 depicts the flow of SEPAC data in the project and indicates the basic type of information being transferred along with the means in which it is transferred and a general time frame.

Flowchart #1

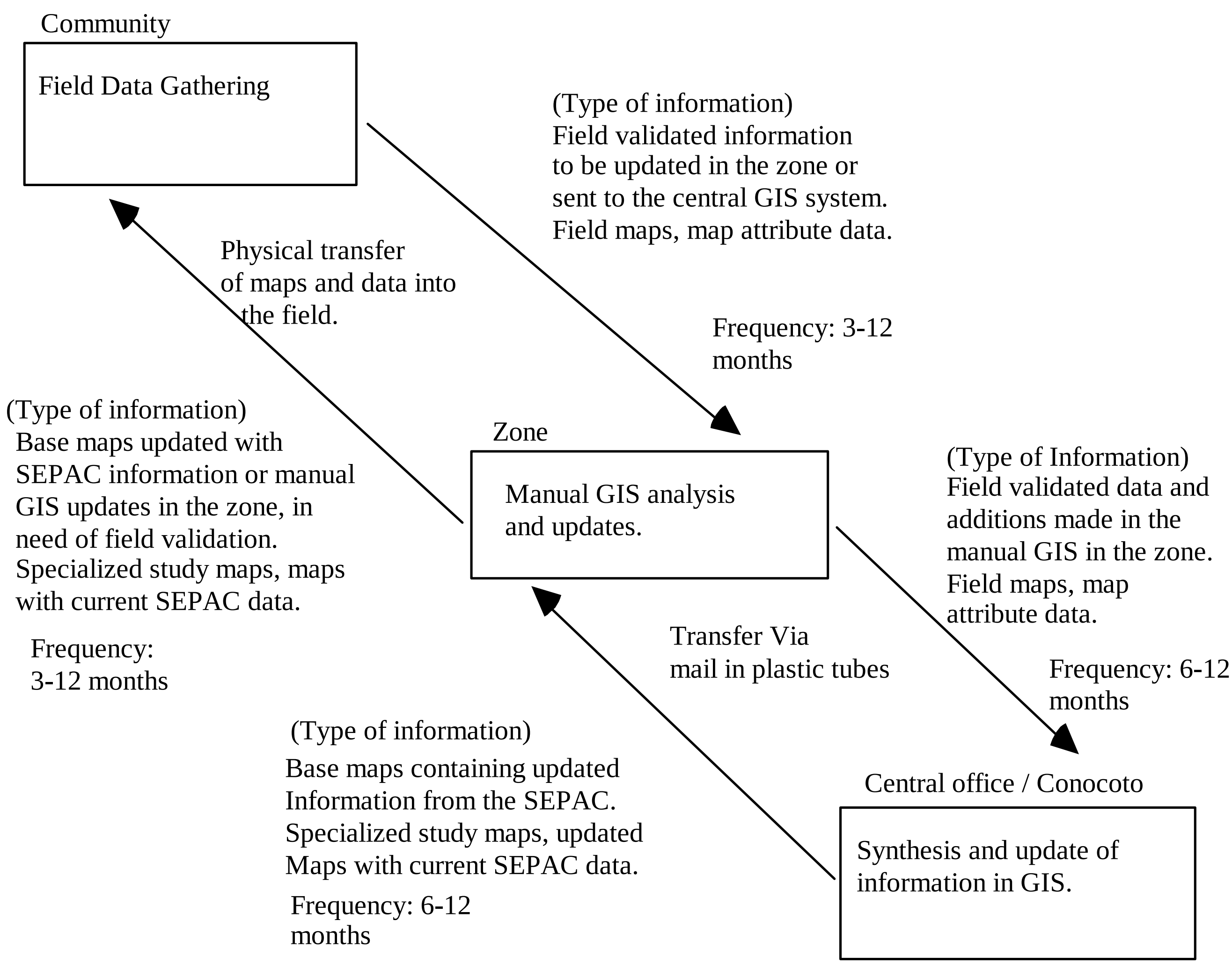
Flow, Type and Frequency of SEPAC Data within the DFC Project



The hardware and software available at present in each of the zones allows for the direct input of SEPAC data from the field. Due to cost restraints it is not possible to install the hardware and software needed for a GIS in every zone of the project. Thus, the flow and means of transfer of geographic information will differ slightly from SEPAC data. Flowchart #2 illustrates the flow and type of geographic information to be integrated into the project along with the means of transferring this information.

Flowchart #2

Flow, Type and Frequency of GIS Data in the DFC Project



Note that information, both geographic and SEPAC can cycle exclusively through the field and zone levels, being updated in the zone's manual GIS systems as well as being cycled trough the central GIS system. This model can easily be modified to incorporate a decentralized type of system if another GIS hub is established through inter-institutional support.

6) Equipment Maintenance

Computers can develop viruses, plotters can become dirty, and in general problems can develop with various software. Regular virus checks and maintenance of hardware can avoid costly losses of data and high repair bills. All computers and equipment should be powered through a surge protection device, because of the frequency of power surges in Ecuador. With this said it is still a very good idea for the project to invest in some form of back-up system to archive data. (i.e. zip drive, CD writer)

7) Field Data Acquisition and Methodology

It is recommended that a multistage approach be taken for field data acquisition. The multistage approach was used to collect data during this pilot study and studies that preceded it. A multistage approach means that data is gathered from sources at appropriate scales through a variety of survey methods. A geographic database can be compiled that meets project needs from existing maps in two institutions. The most important of these, and the one that sets the standard for base maps in the country is the Military Geographic Institute (IGM).[7] The IGM has topographic maps of all zones of the project at 1:50.000. The National Institute of Statistics and Census (INEC) is the other major source of geographic data for the project. INEC has maps at varying scales detailed enough for project needs. [8]

The first step all zones must take to build their geographic database is to acquire maps of their zones from these two institutions. The next step is to conduct a rapid rural assessments in each community to gather community limit data, other data can be gathered at this time that will help adapt SEPAC to a GIS. The use of INEC maps in this process proved to be very effective in a study done in Azuay and is taking place now in the Rio Bamba zone. With IGM topographical maps and INEC maps with field validated community limits the project has every thing that it needs to build a digital GIS system. This pilot study is based on the above-mentioned geographic information.

Another valuable tool for use in the field, which is outside of the GIS's scale, is the use of aerial photographs for mapping resources and parcels inside of communities. These aerial photos can be acquired at the IGM. It has been proven through studies conducted by the project, (Turucucho, Joyapa,

[7] Instituto Geografico Militar (IGM), Quito, Ecuador.
[8] Instituto Nacional De Estadisticas y Censos (INEC), Cuenca, Ecuador.

etc.) that the aerial photographs are very useful for planning and mapping of areas inside of the community. However, this detail of data will not be entered into a GIS. For this reason it is suggested that activities pertaining to aerial photographs be carried out separate from the collection of data for use in building a GIS. This recommendation is mostly due to time constraints. It will take considerable time to acquire aerial photos for all of the communities in DFC and even more time to collect field data. If aerial photos where used to collect community limit data, which they can be used for, it would stall the process of building a GIS in the project.

A GPS unit is a powerful tool when used with a GIS and input from the GPS can be directly entered into a map without the need for timely and costly transformation. A ground survey was conducted during this pilot study in which DFC activities and ground control points where collected. An x and y coordinate was collected during a ground survey in Turucucho, and this information was then entered directly into a map. A GPS can also collect a series of points that are represented in a GIS as lines or polygons. This means that rivers, represented as lines, or areas of forest, represented as polygons can also be collected in the field. However, because the GPS must be carried along these features to collect the data it probably is not feasible that the project can use this feature of the GPS to collect limits of for example, forests. The use of this tool for collecting data in the field is only limited to the labor involved and should be considered as a viable option whenever geographic field data is obtained. Inter-institutional support should provide access to GPS units and the purchase of this tool should not be needed. As previously mentioned, ETAPA / Azuay offered to loan DFC a GPS unit and INEFAN has a number of GPS's.

Installation and Operation

1) System Installation

After all the previously mentioned material has been decided upon and the project as a whole understands their role in the new GIS scheme the purchase and installation of the of hardware and software can take place. The previous point is crucial to the success of the GIS's integration into the DFC project. Equipment and software do not provide processed information to help the project, even worse, unused equipment because of poor planning provides nothing but a monetary drain. At this stage the project should know exactly what software will be used along with the hardware to run the programs. The GIS technician along with SEPAC managers should be present at this stage to test the new equipment and work out any initial problems. Configuration of all equipment should be done at this time to insure all equipment is functioning properly.

2) Applications Development

This pilot study had very little time to focus on the analysis aspect of a GIS, which is its strong point, but was able to produce some solid examples of specific applications of GIS following the major objectives of the project in the second phase. In the section "GIS Structure", outlined earlier in this document, a list of geographic layers at each level of the project was elaborated on. This structure is in essence a container in which to hold SEPAC data and represent it in a georeferenced spatial form. The process in which to derive these containers is a task in itself, but only when filled with project information do they become truly useful for desicionmakers, planners and evaluators.

VIIII Conclusions and general programmatic recommendations

1) General recommendations

Throughout the previous methodology recommendations pertaining to each step have been interjected. This should help future technicians that use this methodology to address issues as they arise at each phase of implementation. The following recommendations summarize various points made in the previous section and will give an overview for planners to begin the implementation process.

- Socialization of this GIS pilot study should take place within the project and feedback pertaining to feasibility and structure changes should be incorporated.

- Each zone should begin to gather a geographic map base, INEC and IGM topographical maps, and conduct a rapid rural assessment with these base maps to acquire limits of all DFC communities.

- This pilot study should be used to approach various institutions identified in each zone to foster cooperation.

- INEFAN should be presented with a proposal for their cooperation in digitally transforming the remaining zones of the project from base maps acquired and updated in each zone.

- Purchase of hardware and software for the centralized GIS and training or hiring of operators should be indicated and the system should be installed. (The purchase of equipment and software will weigh heavily on INEFAN's participation. If they accept the proposal for digital transformation then the project should only purchase hardware and software that analyzes, updates and prints GIS information. Using this pilot study as a reference it would only purchase for example, ARCVIEW, and the hardware to run the program. Along with some type of large format black and white plotter to produce hard copies.)

- Analysis guidelines to create thematic maps that meet project needs should be developed.

- The flow of GIS information should begin as outlined earlier in this document. Evaluation of the GIS's functions and analysis should take place and changes should be made accordingly.

Annex (1), in broad terms, elaborates what the project has and what the project needs for the integration of a GIS in the project.

2) Conclusions

In conclusion this pilot study has provided valuable cooperation and experiences with INEFAN and has shed light on the use of this relatively new GIS tool in planning, management and evaluation at the project level. Probably the most important aspect of this project is its integration with a project database (SEPAC). The combination of SEPAC and a GIS will serve the project in various ways and help to transform previously unused data into a usable spatial format. The feasibility of integrating a GIS in to DFC's project to improve SEPAC and add a spatial component to the project is well within its means and will prove to be cost effective over the next four years of the project. Based on experiences in Azuay the spatial aspect alone has proved to be a valuable tool for planning, and fostering inter-institutional cooperation. Finally, project objectives dictate that there should be a move to the management of larger areas, which transcend community boundaries and focus on water issues. To effectively plan, monitor, manage and evaluate this process it is imperative for the project to adjust its present system of monitoring and evaluation to accommodate this mandate. A GIS integrated with the SEPAC data base offers the solution to these adjustments.

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Annex (1)

What the project has

- Access to all geographic information to create a base for the GIS.
- A GIS pilot study and other geographic studies on which to base decisions.
- A data base (SEPAC) which can be used directly with a GIS and updated easily to facility additional geographical information.
- Valuable experience in INEFAN in respect to the use of a GIS in the project.

What the Project Needs

- Develop a comprehensive analysis agenda with the input of all zones in the project.
- Inter-institutional support.
- Geographic data pertaining to vegetation cover at a scale that can be used in the project.
- GIS Hardware and software.
- Trained personnel in GIS.