GEOGRAPHICAL INFORMATION SYSTEMS: A Tool for Rural Electrification Projects in Developing Countries: Potential Applications

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ABSTRACT

Electrification Projects in Developing Countries are increasingly including a spatial dimension (planning at a regional or national level, …) and a cross-sectoral approach. Geographical Information Systems (GIS) offer an interesting tool for energy planning and decision making. GIS allows the end-user to view a range of socio-economic and energy characteristics through a visual medium thus illustrating the present situation, mapping out potential solutions and illustrating attractive investment opportunities. The different datasets (layers of information) that can be superimposed include demand, socio-economic characteristics, existing and planned electric, telecommunication and road networks, distribution of public services and the available natural resources and agricultural residues, etc. This information plus analytical tools integrated within the GIS program can help identify options for any given locality, village or town in terms of the technical and economic viability for grid extension or decentralized rural electrification (including technical choice). This information is also important for potential investors who are looking for business opportunities (clusters of economically active towns) with a low risk portfolio. The GIS is a tool that can easily be made accessible on the internet and can be used as a basis for monitoring of project implementation.
This paper aims to provide an overview of the basic characteristics and functionalities of GIS, the potential applications for electrification projects as well as the present challenges for its wider application.

1. INTRODUCTION

A data series can always be split into two categories: first geographical data, in other terms the data, which include a spatial dimension, and non-geographical data, i.e. classical data.
Geographical Information Systems softwares are programs, which allow to store geographical data linked with some attributes. This co-existence of these two types of data within the same system provide the user of a GIS software with a lot of functionalities. These can be classified in three main parts:

i. Functionalities related to the geographical data: representation on a map, possibility of zoom, …
ii. Functionalities offered by most of database softwares (possibility to do a query, to link some tables together, etc..)
iii. Functionalities related to the relationship or link between geographical and "classical" data.

The following sections explore some of these functionalities and discuss their potential use for rural electrification projects in developing countries.

2 BASIC FUNCTIONALITIES OF GIS TO BE USED FOR ELECTRIFICATION PROJECTS

2.1 A tool to display decision-aid maps according to attribute data

Due to the fact that geographical data, which can be displayed on a map, are linked with other attributes, the display format of some data can be done according to some attributes. As an example, for a map of a province, sizes of settlements can be related to their population, line widths of an electric network can be according to their voltage level, departments' or districts' color related to the inner population or population density…..
This representation of spatially-based objects on a map, according to attribute data make the GIS a decision-aid tool for people in charge of rural electrification projects.

2.2 A tool to superimpose multi-sectoral data

The GIS allows for the organization of data across different sectors, which are then superimposed on maps. On a same map, the user can thus visualize not only the population settlements, power infrastructures, road network, rivers and lakes, but also existing and planned social and productive infrastructures, …
Issues related to the necessary inter-linkages of rural electrification projects with other sectors in order to achieve maximum impact appear clearly, and hence the case for "accompanying" measures (eg micro-credit services, training, …) can be better made .

2.3 A tool to do some analysis integrating the spatial dimension

In cases where the user wants to go further than a simple representation of data on a map, GIS programs provide him with a lot of analytical tools. Through one or a couple of mouse clicks, a planner can for instance easily select "all the localities having more than 5000 inhabitants and being at less than 5 kilometers from the existing lines". And a private company in charge of the maintenance of a series of PV systems can automatically find the optimal route to visit a series of systems for maintenance, ….

2.4 A tool to update data through a geographical representation, or to visualize updated data

GIS systems are very useful to operate and monitor a system, which has a spatial dimension, such as electrical systems. Attribute data of this system (such as power production of a unit), can be updated either through a database interface (corresponding to the attribute data) or through a geo-graphical display (by a click on the point representing the power production unit). The operator of a grid could thus through a GIS see at a glance the status (load flow solution and/or stability) of the whole grid.

2.5 A tool to disseminate easy-to-understand data on various formats

Finally, at a time, where data and information are more and more exchanged in computerized formats, GIS are a means to facilitate the exchange of spatially based information between various people.

All these GIS functionalities can be used for rural electrification projects in developing countries. The following section discusses, for each stage of a rural electrification project - i.e. from the planning stage to the monitoring and evaluation – the potential use of GIS.

3 A VARIETY OF POTENTIAL USES OF GIS AT DIFFERENT STAGES OF A RURAL ELECTRIFICATION PROJECT'S LIFE TIME

From planning stage to the evaluation one, Geographical Information Systems offer a variety of useful possibilities for rural electrification projects. This section aims at presenting some potential uses of GIS for each phase of a rural electrification process, based on some experiences.

3.1 Rural Electrification Planning (on a large area)

At each step of a rural electrification planning process, GIS tools can provide the planner with a precious help, given the high importance of the spatial dimension in the planning process.

Strategic planning, i.e. identification of main potential options for electrification of a broad area (typically a whole country) is a often a complex task, due to the large amount of data to analyze. The Rural Electrification Strategy Study conducted in 2002 in Burkina Faso[1] identified – with the help of GIS – various feasible options for rural electrification (i.e. decentralized grids fed by an electricity production option and delivering electricity to several villages, medium-voltage extension of existing urban grids, and isolated solutions)

Electricity demand forecasting should often be based on field surveys conducted on a sample of the population settlements. First, Geographical Information Systems, through its analysis tool, can provide the planner some information to design the samples and assess their accessibility (presence or not of natural barriers, …). Then, these field surveys can be easily monitored through the spatial representation. Finally, forecasted electricity demand can be easily displayed on a map, facilitating the identification of main load points by the planner.

By superimposing on the same map information on rivers, forests, wind potential, existing production units, location of biomass residues and a numerical terrain model, identification and preliminary costing of production options can be facilitated. In the case of renewable energy options, such as wind or small-hydro power, potential location of production sites can be identified thanks to the GIS, by superimposing various (environmental, aeronautics, …) constraints on potential resources. IED is developing such approaches for a Wind Master Plan for the "Champagne-Ardennes" region in France.

GIS can also be used as a support for generation and transmission planning. Even if programming the total generation and transmission planning phase within a GIS would be a complex and time-consuming task, GIS can provide the planner with a help for this phase by allowing a visualization of various layers of information and presence of various simple analysis tools. As an example, effective road distance between two settlements is

[1] « Stratégie d'Electrification Rurale du Burkina Faso – Projet de Réforme du Secteur de l'Energie – Direction Générale de l'Energie. » A study conducted by IED and financed by the World Bank.

automatically known by the user. Some analytical tool such as "Minimum spanning tree" can even be used for first approximation of the network mapping, given the fact that low-voltage rural networks are radial.

The relevance of economic and financial analysis is based mainly on accuracy of costs. Access costs to production units can for instance be better evaluated taking into consideration the presence and quality of roads, the location of natural barriers (such as mountains and main rivers), etc…

3.2 Data dissemination on status of electrification and planned investment in development infrastructures

In the context of the decentralization process being put in place in a large number of the developing countries, information about present and planned developments of infrastructures between national authorities of various sectors (health, education, roads, agriculture, industry and handicrafts, etc..) as well as between them and local authorities is of crucial importance. With the development of the Internet communication system, GIS tools can be very useful to exchange these spatial information quickly and precisely. Dynamic web application can indeed be developed upon GIS, working as geographical databases. The electricity utility of the Ivory Coast SOPIE[2] is besides developing such an application with IED.
Such data can be used as well by potential actors (investors or operators) of the electricity sector to define their action location.

The REDEO project[3], which has started in June 2003, aims at developing a methodology as well as a GIS-based decision aid-tool for Rural Electrification Planning for a better development. The project is based on case studies of provinces in Cambodia, Lao PDR and Vietnam.

3.3 Feasibility study for an area

GIS can be useful as a tool for a project feasibility study for the design of either a generation option (namely mini-hydro power production or biomass electricity production) or a network configuration.

In cases where mini-grids, demographic and socio-economic data on population settlements, as well as location and characteristics of roads and rivers, their feasibility studies could be facilitated. Indeed, detailed length – and thus the related costs - of real electric lines (i.e. along the roads, according to the elevation data, …) could namely be directly known, total loads and electric losses could be calculated and automatically updated ….

3.4 Implementation, operation and maintenance phase

GIS tools can also be very helpful for the operation and maintenance of electrification infrastructures in rural areas, where population settlements can be quite far from each other. A updated GIS developed on a local grid or set of decentralized (such as PV) systems will

[2] SOPIE : Société d'Opération Ivoirienne d'Electricité – « Electricity operation compagny of the Ivory Coast »
[3] REDEO : Rural Electrification Decentralized Energy Options. This project, supported by the European Community, has been developed in the framework of a collaboration between IED, the Asian Institute of Technology of Bangkok, and the Centre for Energy Studies of the Paris School of Mines in France. http://www.ied-asean.com/ieda.asp?chapitre=2&partie=1&id_projet=10

enable the company in charge of the operation and maintenance namely to (i) better plan and organize the reparations on the infrastructures – by analysing the best way to reach various locations given the existing roads and rivers (some analytical tool already exists for this within most of GIS software programs) (ii) manage the fee collection in a relevant way, and (iii) analyse the spatial distribution and characteristics of the customers in order to attract new ones… Such a list is of course not exhaustive.

3.6 Monitoring and evaluation

Finally, since rural electrification projects in Developing Countries are conducted in the perspective of a contribution to (sustainable) development, Geographical Information Systems, as advanced databases including spatial dimension of objects, can be used to assess the relationship between access to electricity and development. Sustainable Development Indicators, such as population having access to health or education facilities, or to electricity, gas emissions, … can easily be updated in the database behind the GIS and thus displayed. Such maps can be important input for discussion between a developing country and the international cooperation institutions about the development programs.

Thus, potential uses of GIS for rural electrification projects in developing countries are quite important. But all these are only relevant if based on some detailed and reliable data, with a high level of precision.

4 RECOMMENDATIONS

Availability and quality of data is the core question of each GIS application. Information on rural areas in Developing countries are however often quite difficult to obtain. Efforts have therefore to be made in those countries to develop a framework enabling the large access at a national – or even international - level to high-quality data (i.e. updated and precise data) on all sectors related to rural development and particularly the electricity sector. Some initiatives in this direction have to be noted: the Data User Service Center of National Institute of Statistics in Cambodia is for instance selling CDs with results of last population census (conducted in 1998) in GIS formats.

Concerning the use of GIS for Rural Electrification, two main recommendations have to be made:

First, expectations and output from GIS data analysis must always be adapted to the quality level of data, which are available. Improvement of availability of high-quality GIS data useful for rural electrification (i.e. globally on rural development status and policies) will take some time, and even if one can be tempted by performing complex analyses, their relevance will mainly be a function of the quality level of data which were used.

Capacity building activities on GIS software have also to be developed for the stakeholders of rural electrification. Stakeholders (utilities, ministry or government agencies, private companies, consultancy firms, …) have indeed to be able to manipulate and analyze GIS data by themselves. One can easily become quite familiar with some GIS software in a few months.