Development and Application of Renewable Energy Map Analysis Program in the Philippines

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Abstract
Accurate renewable energy (RE) data, such as solar, hydro, wind, and biomass resources data are important to assess for the proper sizing and life cycle cost analysis of RE systems technologies. A geoinformatics-based decision support system (DSS) called Renewable Energy Mapping Analysis Program (REMAP) was developed to build a wealth of geo-referenced data and information on RE resources in the country. Geo-referenced databases and thematic RE maps, as major outputs of REMAP showed various indicators on assessment, monitoring and evaluation, and efficiency thrusts that are useful for energy planning and policy options for rationalization of energy development and investment plans of the country. A case study is presented to demonstrate the application of REMAP.
Keywords
affiliated renewable energy center, decision support system, GIS, GPS, renewable energy, REMAP, remote sensing

I. INTRODUCTION

The Philippines being an archipelago coupled with diverse geography and varying regional socioeconomic conditions, renewable energy (RE) basic data and information availability, accessibility and affordability are some of the major issues that affect RE development in these areas in the country. Aside from this, the diversity of the target groups requires different treatments and packaging of RE information to facilitate adoption and assimilation. These complement the information barriers that hinder the development and implementation of RE systems (electricity and non-electricity) projects in the country. These include technical information that are required in the conceptualization/design of potential RE projects (e.g., wind speeds and other meteorological data, volume of biomass resources), and market information that are necessary in evaluating the economic/financial viability of RE projects (e. g., electricity prices, fuel prices, electricity demand).

Thus, there is a need to conduct a systematic RE resource assessments in the country and update such RE data and information that can be utilized by project developers/ investors in conceptualizing, designing and evaluating RE projects(DOE, 2007). To continue the implementation of the medium- and long-term plans, rationalization of programs and projects on RE in the country, the Department of Energy (DOE) emphasized the importance of systematic collection, storage, analysis and annual updating of voluminous data and information on RE sources and systems through its twenty-one Affiliated Renewable Energy Centers (ARECs), formerly Affiliated NonConventional Energy Centers (ANECs). To manage such voluminous database, systematic tools should be used and assembled as a decision support system (DSS). A DSS is a computer-based system integrating database and analytical modelling methods such as artificial intelligence, decision analysis, optimization, modelling, etc. to support decision making(Aldeman L, 1991) and using geoinformatics tools(Pascual C M, et al., 2001, 2002). The structure of geoinformatics can be understood in many ways, what can be seen from the more or the less complex schemes published in various articles. Geoinformatics creates new possibilities of combining geographic information systems, global positioning systems, and remote sensing for the precise analysis of spatial phenomena, such as for following their dynamics or defining the associations existing between their components. The use of remote sensing data (land satellites) in such research, takes to another level those areas of knowledge, in which are becoming reliable materials in concerned agencies or could be accessed through internet. It also enables the current monitoring of those phenomena which cannot be investigated and estimated in any other way, as well as the modelling of spatial (geographical) phenomena to build an expert system or DSS. However, such DSS had been applied mostly on agricultural land use planning options, crop suitability, and natural resources management and being considered just lately in higher education and policy researches. Likewise, there are some attempts for such energy resource assessments, but such are static, not user-friendly and could not be updated at will to have continuing RDE activities on RE(NREL, 2000a, 2000b). Thus, the MMSU–AREC has started to conceptualize

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a geoinformatics-based DSS on RE resources and systems in Ilocos Norte, Ilocos Sur and Abra provinces in 2005. Likewise, there are some atlempts for such energy resource assessments, but such are static, not user-friendly and could not be updated at will to have a continuing RDE activities on RE. Thus, a study was conducted to: 1) develop a geoinformatics-based DSS methodology to build geo-referenced data and information of RE; and 2) make operational such DSS and pilot to implement regular updating of RE databases.

II. METHOD

A. Sources of digital data

Previous digital data and published reports made by the Philippine Department of Energy and the National Renewable Energy Laboratory (NREL), U.S.A. Digital Chart of the world (DCW), GTOPO3O elevation data, and International Steering Committee on Global Map (ISCGM) Global map database (ISCGM, 2007) as shown in Table 1 were extracted to compile base maps and thematic maps of solar, microhydro, biomass (PNOC-ERDC, 1985) and wind. Other geo-referenced datasets were also acquired at various agencies such as Department of Agriculture-Bureau of Agricultural Research, and the National Mapping Resources and Information Agency (NAMRIA). Other sources of input databases came from primary GPS-based surveys conducted by AREC while secondary sources (Landsat, digital basemaps, available RE statistics, etc.) were gathered from various agencies such as United Nations, World Bank, DOE, NAMRIA, NREL-USA publications, internet, other ARECs and previous database files from DOE projects. ArcView GIS software was used for the spatial query analysis(ESRI, 1999) while Visual Basic programming version 6 was used to develop graphic user interface to compile the georeferenced input data, as well as linking relational databases to GIS application query modules. Structured questionnaire which contained major data elements profile of RE systems from the previous National Energy Survey Census (NESCON) software DOE was revised and used by AREC staff during field surveys. A GPS receiver was used to locate the latitude and longitude coordinates taken at each RE system, which represent the geo-reference point data of a RE system as an input database in the ArcView GIS software. Such geo-referenced data conform to the standard map projection (universal traverse mercator or UTM) for spatial query and overlay analysis.

B. Estimation of RE sources

For solar energy, the Climatological Solar Radiation (CSR) Model of NREL was used(NREL, 2000b). This model converts information on satellite- and surface derived cloud cover data collected at a 40-km spatial resolution to estimate the monthly and average daily total global horizontal solar resource. In hydropower resource, the total resources available to this technology can be specified according to the potential power output (Ps) defined by the equation; $Ps = \varepsilon g \rho QH$; where ε is the overall system efficiency, g is the acceleration of gravity, Q is the flow rate of the water being used by the system, ρ is the density of water, and H is the effective head of the water. The level of the wind power resource is defined in terms of the wind-power-density value, expressed in watts per square meter. This value incorporates the combined effects of the wind speed frequency distribution, the dependence of the wind power on air density, and the cube of the wind speed as defined by NREL(NREL, 2000a, 2000b). To estimate biomass resources, some conservative assumptions were made to make a practical and reliable estimate of the biomass resources in the country. For example, crop straw and stalk outputs are calculated based on crop outputs and the ratio of grain production to stalk mass. These assumptions were related to the type of processing done for a particular commodity(NREL, 2000b; PNOC-ERDC, 1985). Other geographic data from land satellites, digital landuse/boundary maps, hydrometeorological data were gathered and compiled as input databases and basemaps.

III. RESULTS AND DISCUSSION

A. Decision support systems(DSS) on renewable energy

A set of geoinformatics tools was assembled to gather, store, easy retrieval and analyze spatial geo-referenced data/ information and generate/disseminate information about RE sources and systems. RE sources refers to energy resources that do not have an upper limit on the total quantity to be used. Such resources are renewable on a regular basis, and whose renewal rate is relatively rapid to consider availability over an indefinite period of time. These include, among others, solar, wind, hydropower, geothermal and ocean energy. RE systems refers to energy systems which convert renewable energy resources into useful energy forms, like electrical, mechanical, etc. The methodological framework of the study is presented in Figure 1 showing the input database, process

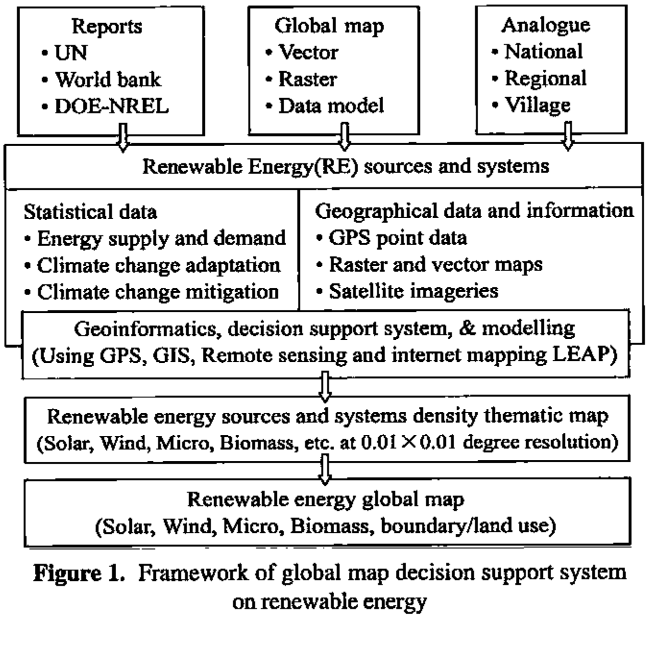


Figure 1. Framework of global map decision support system on renewable energy

Table 1. Data sources for the construction of geo-referenced base maps of the Philippines

Data type	Source/Generator of data	Scale	Format	Projection	Media type
Philippine map	National mapping and resource information authority(NAMRIA), Department of agriculture-bureau of agricultural research); DOE-NREL project	1:50,000; 1:250,000; 1:1mil	Analogue, digital (raster, vector); satellite, DEM	Universal Transverse Mercator(UTM)	Media (Analogue and digital)
GTOPO30	U.S geological survey EROS data center	30 arc seconds(1km) resolution	Raster(.BIL, 1 channel, 16 bit/pixel)	Geographic (lat/long)	Digital internet, CD-ROM
The digital chart of the world	ESRI incorporation global coverage GIS database	1:1mil (5 × 5 deg tiles)	Vector	Geographic (latitude/longitude), decimal degrees	Digital CD-ROM
Global land cover database	USGS	1 km resolution 94 vegetation classes	raster image transformed to .TIFF (.TFW file, required to set the geographic location of .TIF image)	Geographic(lat-long)	Digital internet

or analysis and the expected outcomes of the analysis. Special emphasis is given to the step from geo-referenced data to spatial analysis that is tailored to the type and quality of readily available attribute of data gathered (Table 1). Once the various data entries, GIS query modules, report generation and other pertinent documents were assembled and fine-tuned, a graphic user interface of Visual Basic and GIS software was applied to automate such DSS.

B. Development of DSS methodology

With the input-process-output relationship, the DSS on RE was developed to build wealth of data and information of RE resources and systems called Renewable Energy Map Analysis Program or REMAP. The REMAP is a dynamic, user-friendly window-based software for ease in data encoding/editing/updating, transaction, GIS query, output printing and linking other related documents such as its user guide, tutorial lessons in visual basic programming and other documents (Figure 2). Such on-going development was presented to major stakeholders, such as the heads and staffs of DOE, other 20 AREC staff and researchers, as well as colleagues in the academic and other research institutions. Their comments and suggestions were considered in the development. Such productive interactive process development of REMAP with other stakeholders also brought interest for similar thinking and other applications. Some colleagues indicated their interest to learn such emerging tools for use in their offices.

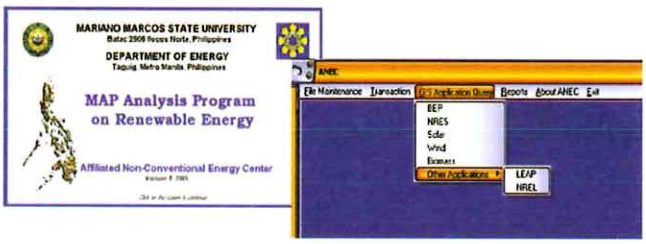


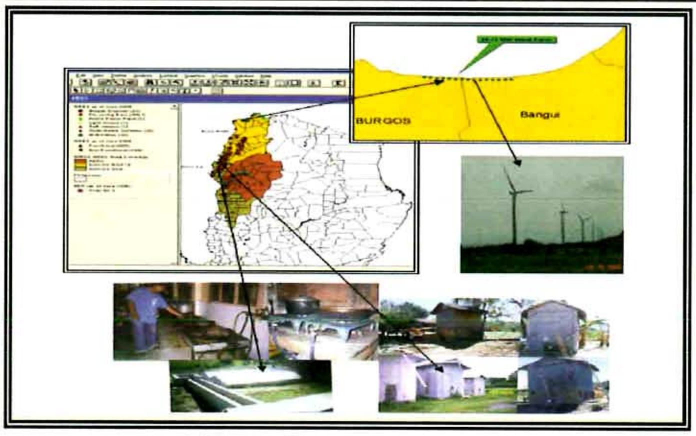
Figure 2. Graphic user interface showing splash menu and window-based modules, and structure of RE-MAP

C. Applications of REMAP in northern philippines

The MMSU AREC is one of the 21 RE centers in the country and served 18 years as partners of DOE to promote the use and commercialization of RE. Each AREC is strategically located nationwide and being hosted mainly by state colleges and universities. Hereunder are some of the applications of REMAP on some mandated tasks such as annual inventory and assessment of RE resources, GPS survey/monitoring of RE systems, and monitoring of barangay electrification program (BEP).

GPS-Survey/Monitoring of RE. Inventory of RE systems at Ilocos Norte, Ilocos Sur and Abra, in northern Philippines was conducted to determine the contribution of these systems installed in the aforementioned three provinces and energy mix in general. In 2006 inventory, utilization of biomass, particularly fuelwood for fluecuring of Virginia tobacco got the highest share (97.73%) and the least resource utilized was the manure for the biogas plants. Other resources such as wind, hydro and solar were utilized in a very minimal amount(2.17%, 0.08% and 0.012%, respectively) although they are increasing as compared to the past years(MMSU AREC, 2006). To date, there were 779 RE systems that were georeferenced using GPS and Figure 3 (upper map/photo) shows some typical outputs on RE sources and systems using REMAP. Such RE inventory databases were incorporated already in REMAP for data banking for easy retrieval, monitoring, evaluation and analysis by DOE, AREC and other interested parties.

BEP in Off-Grid Areas. The MMSU AREC is also mandated



(a) Renewable energy sources and systems

(b) Barangay electrification program (BEP) during field monitoring and GPS-survey

Figure 3. Thematic maps outputs of RE-MAP showing geo-referenced

to energize at least two off-grid barangays in the Ilocos (Ilocos Norte, Ilocos Sur and Abra, Philippines). From 1999-2005 budget operations funded by DOE under the BEP, the MMSU AREC was able to install battery charging stations (BCS) in 12 off-grid barangays(MMSU AREC, 2006). Thus, for the 4.53 million pesos budget from DOE, it generated a total 10,050 Wattpeak BCS serving more than 300 households, 12 barangay (village) halls, churches, cooperative and rural health unit in those far-flung communities that could only be reached through trail feet hiking for 4 to 10 hours and back. Figure 3 (lower map/photo) shows BCSs in far-flung barangays of eastern interior towns of Ilocos Sur during annual field monitoring.

D. Implications

Despite the DSS methodology development of REMAP, it is of utmost importance to involve stakeholders and end-users from the beginning in the system design and frequent interactions between funders, policy researchers from DOE, ARECs and other stakeholders during development. The REMAP developed served as a DSS to share data, information and knowledge in support for policy issues and concerns to rationalize RE in the country. Such dynamic and user friendly DSS could also be linked to other RE-related software such as the long range energy application program system (LEAP) software and other RE databases from DOE. Initial trainings of the concept were already disseminated to some ARECs, colleges and universities, and research institutions here and abroad. Likewise, staff among private and government agencies was equipped on these tools for their land use planning, tax mapping, planning activities through advanced training, here and abroad. Thus, such methodological framework should be introduced to other professionals to equip such emerging tool for possible collaborative works.

Thus, in line with the country's energy independence and security objectives, the development of indigenous energy resources, such as RE, is given priority focus. The Philippines has vast natural resources that can be harnessed as renewable sources of energy. Among these, solar, wind, hydro, and biomass are the most potential for developing into clean development mechanism projects for climate change mitigation and adaptation strategies in the near future.

The convergence of our energy needs and its space technology capabilities makes it a logical choice not only to become familiar with these applications, but to share their resources and expertise for other countries, such as Philippines and others. There is a need to continue bring together and provide more fora for discussions and networking among scientists and stakeholders on issues related to global change and the impact on the environment and feedback processes in the Pacific Rim and Asia. With the continuing efforts of the Asia Pacific on its global concern on sharing resources and best practices on data resource management, capacity building, the Philippines cannot only realize the social welfare of RE resources for themselves alone, but also the other countries for harnessing such renewable sources towards achievement of sustainable development.

IV. CONCLUSION

The MMSU AREC developed a user-friendly and dynamic operational DSS software called REMAP to replace the old version NESCON. More importantly, REMAP can reuse the old database files of NESCON through reformatting/ conversion of input files. The DOE and ANECs should focus on ready-to-update database for a national compilation or atlas showing important RE data elements coupled with spatial context so that researchers, planners and investors can access such operational data and information with good quality, accuracy and security in sharing such wealth of RE data and information. This needs an investment support before collaboration in further methodology development of REMAP comes to the forefront. Thus, the institutionalization use of REMAP is important for ARECs, DOE and other interested entities that lend geo-referenced data and information support in pursuit of the government independence in energy. Most importantly, such initiative on continued international cooperation with others in earth observation and natural resources should be strived, with the noble objective of acquiring greater competence in using space technology for RE, among other fields of interests in water and energy systems.

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