DEVELOPMENT OF GEOSPATIAL TOOLS FOR TIDAL CURRENT ENERGY RESOURCE ASSESSMENT: A CASE OF VERDE ISLAND PASSAGE, PHILIPPINES

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ABSTRACT

Given the current and projected global demand for power, marine energy conversion projects offer viable alternatives as they are clean and renewable. Several projects and technologies are emerging worldwide to convert the energy from the vastly unexploited ocean tides and current to electric power. Resource assessment is a fundamental step for the development of these projects given the distributed nature of these resources. Nowadays, the use of geospatial tools for energy resource assessment has gained unprecedented interest globally and locally. This paper presents the development of geospatial tools for tidal current energy resource assessment. A multi-criteria assessment model that accounts for the physical, environmental and socioeconomic constraints is proposed to assist in the selection of the most suitable locations for tidal current power conversion projects. The proposed model is applied to the Verde Island Passage to find and rank the best locations for power conversion using a ranking procedure with equal weighting factors for all criteria. This model is also applicable to other sites where sufficient geospatial data are available.

1. INTRODUCTION

The vertical rise and fall of tides, caused by the gravitational force of the moon and sun acting on the oceans waters, also creates a horizontal motion of the water called tidal currents (NOAA, 2010). With the presence of geographic phenomena such as islands, continents and depth variations, the response of the oceanic waters to the astronomic tide generating forces differ (Bryden et al.). In many parts of the world, coastal and seabed conditions result in extreme acceleration in the currents associated with the tides. In many locations, the flow is sufficiently fast for the possibility of using them to generate energy (Bryden et al.).

Tidal current energy is one of the alternative energy sources that are renewable and clean. It has become one of the more promising energy sources due to their continuous, predictable and spatially-concentrated characteristics (Georgia Tech Research Corporation, 2011).

Given the current and projected global demand for power, marine energy conversion projects, specifically tidal current energy, offer viable alternatives as they are clean and renewable. Several projects and technologies are emerging worldwide to convert the energy from the vastly unexploited ocean tides and current to electric power. The Philippines, being an archipelago, has a huge potential for this type of energy source. Earlier in 2006, the Department of Energy (DOE) identified potential sites for ocean renewable energy (ORE) extraction in the country, as well as a potential theoretical capacity of 170 GW, as estimated by the Mindanao State University (Rodriguez).

One fundamental step for the development of tidal current energy conversion projects is an extensive resource assessment given the distributed nature of these resources. Nowadays, the use of geospatial tools for energy resource assessment has gained unprecedented interest globally and locally.

This paper presents the development of geospatial tools for tidal current energy resource assessment. A multi-criteria assessment model that accounts for the physical, environmental and socioeconomic constraints is proposed to assist in the selection of the most suitable locations for tidal current power conversion projects.

2. VERDE ISLAND PASSAGE

Verde Island Passage is a strait between the provinces of Batangas, Oriental and Occidental Mindoro, Marinduque and Romblon. It connects the West Philippine Sea with the Tayabas Bay and Sibuyan Sea and is one of the busiest sea lanes in the Philippines because it is the main shipping route between the port of Manila and the Visayas and Mindanao in the South.

3. DEVELOPMENT OF MULTI-CRITERIA ASSESSMENT MODEL

This section describes the development of a multi-criteria assessment model for tidal current energy resource assessment. First, data from various sources were compiled and standardized using the same format and projection in a GIS environment and the themes in each dataset were classified into conceptual layers. Then, map regions were identified according to the role of each theme in tidal current energy extraction and conversion. Finally, suitable locations were determined and a ranking algorithm was applied to calculate the score for each location and determine the best areas for tidal stream power project siting. Figure 1 shows the framework for the multi-criteria assessment methodology developed.

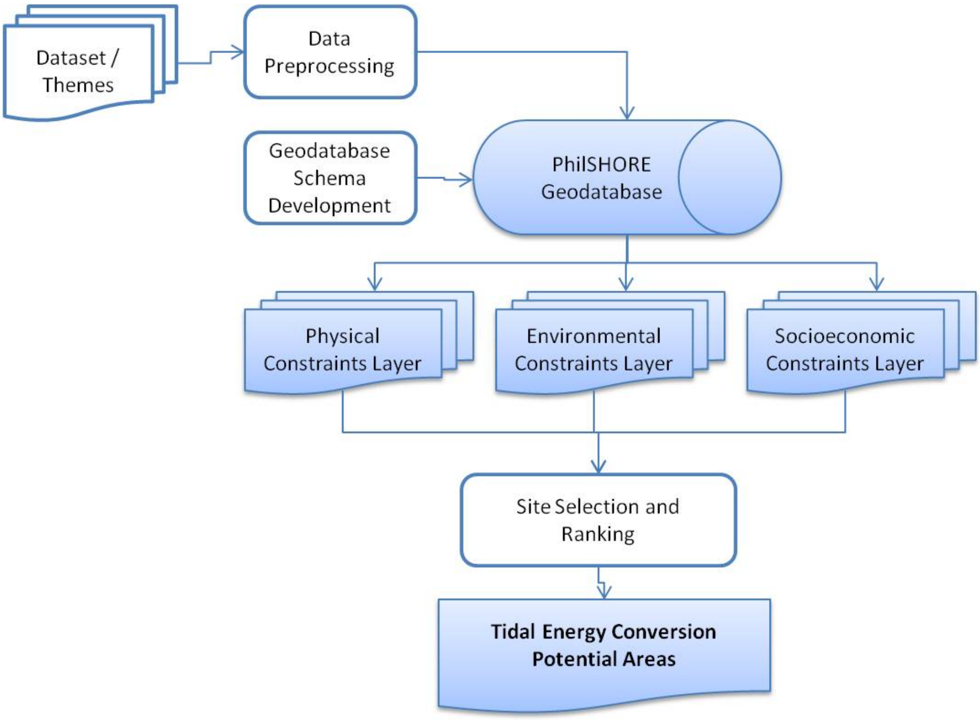

Figure 1. Framework for multi-criteria assessment methodology.

3.1. Data, sources and standardization

Data relevant to tidal current resource assessment are available from different sources. They can be found online, scattered between government offices, academic institutions and private companies. Because of their varying nature of origin, they need to be compiled and standardized into the same datum and projection. Realizing this, a geodatabase was developed where all the relevant data will be stored after pre-processing and standardization. The spatial reference used is the WGS 1984 datum and Universal Transverse Mercator projection. Table 1 shows a summary of the data used and their sources.

Table 1. Summary of data used and their sources.

Theme	Source
Coastline	NAMRIA
Bathymetry	PhilGIS
Tidal Power Density	Delft 3D Simulations
National Road Networks	DPWH
Built-up areas	PhilGIS
Seaports	PhilGIS
Recreation areas and access locations (resorts, boat ramps, diving sites, marinas)	DOT / NAMRIA
Management areas (marine sanctuary, national parks, wildlife refuge, special management areas)	Coral Triangle Dataset and PhilGIS

3.2. Classification into conceptual layers

The geospatial data gathered from different sources were categorized into three conceptual layers namely: the physical constraints layer, the environmental constraints layer and the socioeconomic constraints layer. These layers include the information on the geometry and physics of the area, areas that are of environmental concern, and areas of social and economic concern, respectively. They will define the role of each theme in the site selection. Table 2 shows the different themes categorized into the three conceptual layers and their roles.

Table 2. Themes categorized into conceptual layers and their roles.

Theme	Conceptual Layer	Roles
Coastline	Physical Constraints	Outlines and Filters
Bathymetry		
National Road Networks	Socioeconomic Constraints	Favorable Areas
Built-up areas		
Seaports		Restricted Areas
Recreation areas and access locations (resorts, boat ramps, diving sites, marinas)		
Management areas (marine sanctuary, national parks, wildlife refuge, special management areas)		

Physical Constraints Layer

The physical constraints layer consists of the coastline theme from the 1:250,000 NAMRIA (National Mapping and Resource Information Authority) topographic map and bathymetry data from PhilGIS (Philippine GIS Data Clearinghouse; http://philgis.org/). This layer defines the physical boundaries and contains the most essential data for the site selection scheme (Defne et al., 2011). Figure 2 shows the themes under the physical constraints layer.

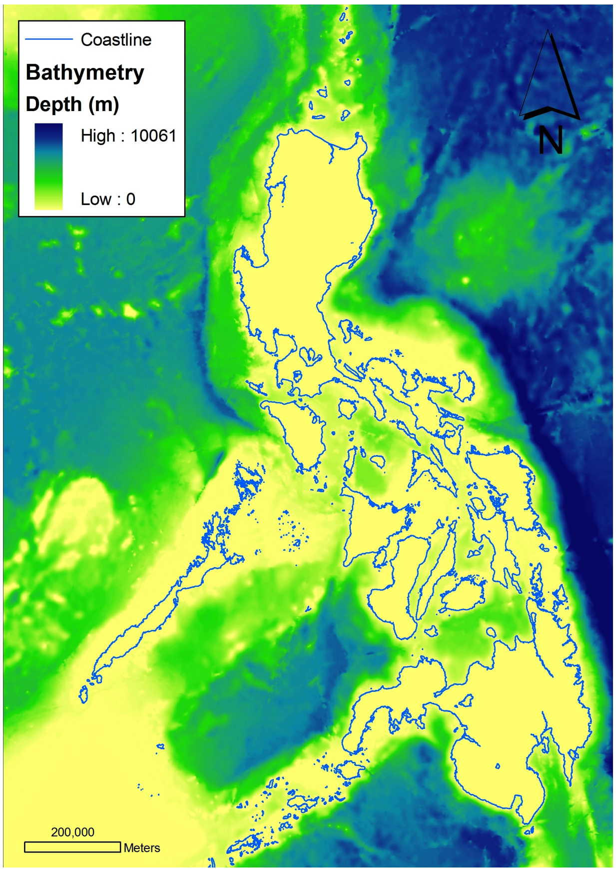

Figure 2. Philippine coastline and bathymetry.

Environmental Constraints Layer
The slow motion of tidal current power converters, which may easily be avoided by fish and other sea animals, and their low noise levels are expected to have low impacts on the ecosystem of an area. Nevertheless, it is still necessary to evaluate the possible impacts they may introduce to the environment especially where endangered species are present. This study does not attempt to answer these questions because a separate and more in-depth environmental impact assessment study is being conducted. For the purpose of this paper, the environmental constraints layer will not yet be included in the site selection until results of the EIA have been determined.

Socioeconomic Constraints Layer
The socioeconomic constraints layer contains the related human activities in the area (Defne et al., 2011). This layer includes the national road networks theme from DPWH (Department of Public Works and Highways), locations of built-up areas and seaports from PhilGIS, locations of recreation areas and access points such as resorts, marinas and diving sites from DOT (Department of Tourism – acquired through NAMRIA) and locations of management areas such as marine protected areas and sanctuaries from PhilGIS. Figures 3 and 4 shows the themes under the socioeconomic constraints layer.

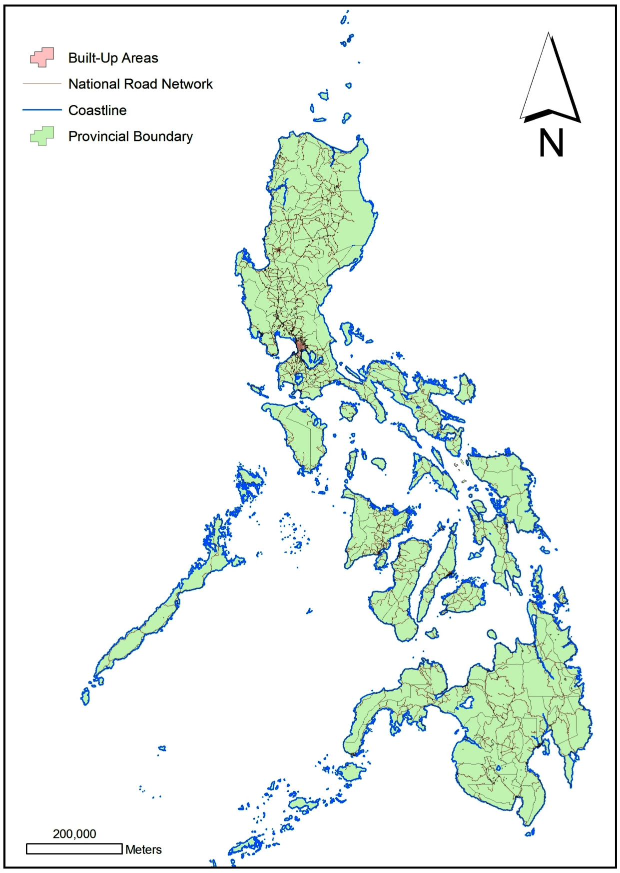

Figure 3. National road network and built-up areas.

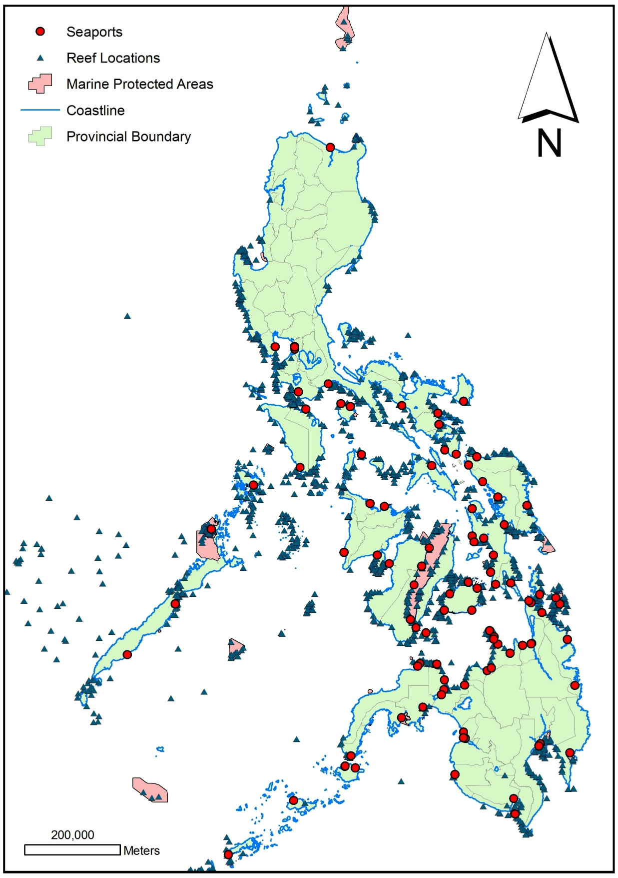

Figure 4. Seaport and reef locations and marine protected areas.

3.3. Site selection and ranking

Suitable areas are determined based on the level of power density, ease of accessibility and the level of environmental concerns within the area (Defne et al., 2011). Based on this, each theme was tagged according to its role in the site selection. The list of themes and their roles are shown in Table 2.

The themes in the physical constraints layer were used to set the physical constraints and boundaries of the problem and were tagged as “outlines and filters” (Defne et al., 2011). Those themes in the socioeconomic constraints layer where it is socioeconomically more advantageous to have tidal stream power conversion projects closer were tagged as “favorable areas” and the themes where tidal stream power projects would not be allowed or should be avoided were tagged as “restricted areas” (Defne et al., 2011).

A more detailed process flow diagram of the site selection methodology is shown in Figure 5.

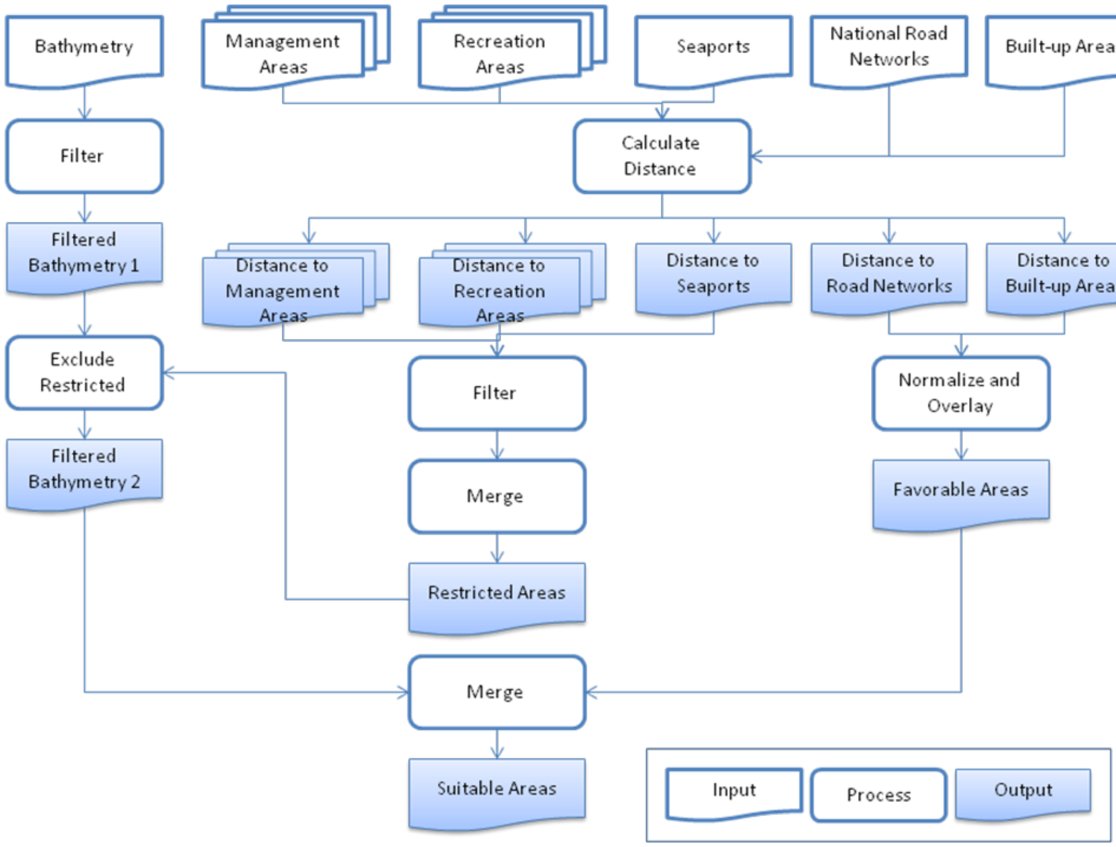

Figure 3. Detailed process flow diagram of the site selection methodology.

The bathymetry is filtered by minimum values because most of the tidal current power converters have a minimum depth requirement based on their dimensions. The themes whose roles are restricted are merged after applying a certain buffer around the features and then excluded from the filtered bathymetry. Likewise, distances to themes with favorable roles (i.e. road networks and built-up areas) are computed and then normalized and overlaid using the same measurement scale to determine favorable areas. The favorable areas are then merged to the filtered bathymetry to determine suitable areas based on accessibility.

4. SITE SELECTION METHOLOGY APPLIED TO VERDE ISLAND PASSAGE

The site selection methodology was applied to the entire Verde Island Passage. The bathymetry was filtered to depth values between 5 and 100 meters (Figure 6) to consider the depth requirements of most tidal current power converters. A buffer of 800 m was applied to all the themes with restricted roles (Defne et al., 2011). These themes were then merged to form the restricted areas layer (Figure 7). The restricted areas layer was then excluded from the filtered bathymetry (Figure 8). Distances to favorable themes were computed, normalized and overlaid to facilitate the calculation of accessibility scores. This was merged to the filtered bathymetry to determine suitable areas. The suitability score map based on accessibility is shown in Figure 9. Most suitable areas within the passage have suitability scores between 0.97 to 0.98.

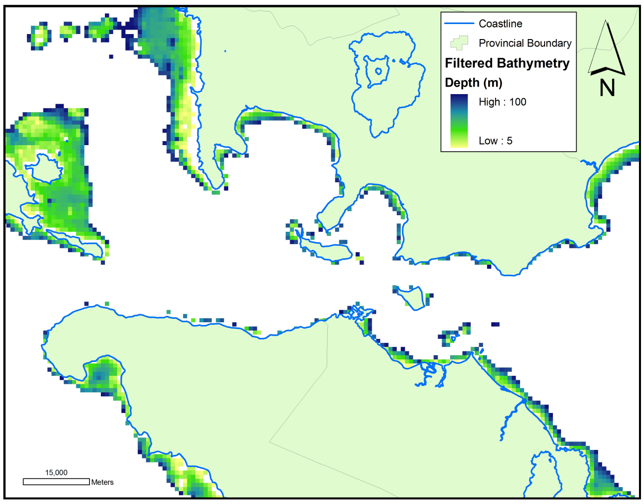

Figure 6. Filtered bathymetry by a minimum value of 5m and maximum of 100m.

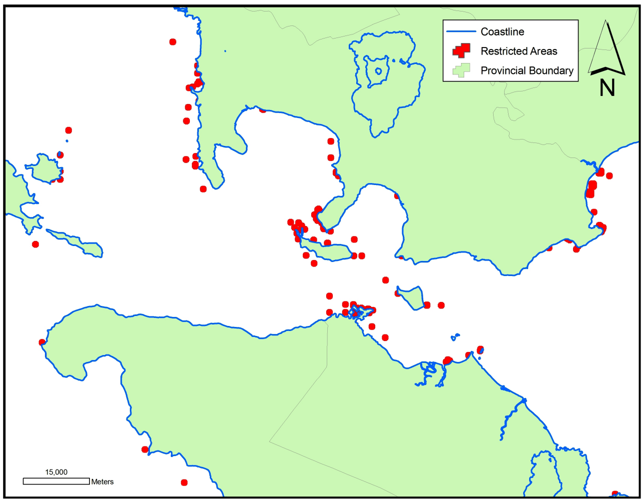

Figure 7. Restricted areas.

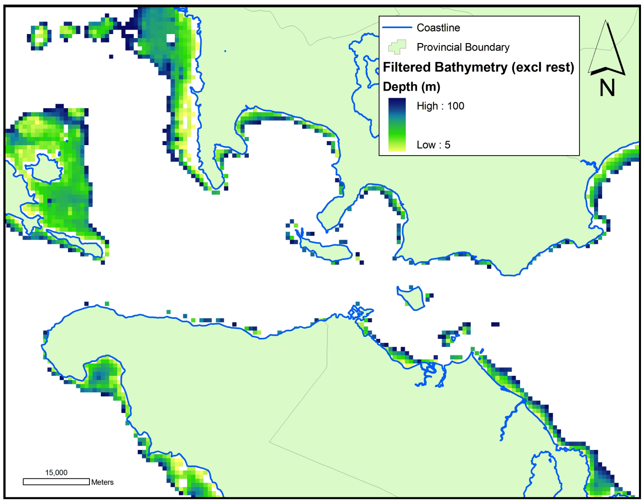

Figure 8. Filtered bathymetry with restricted areas removed.

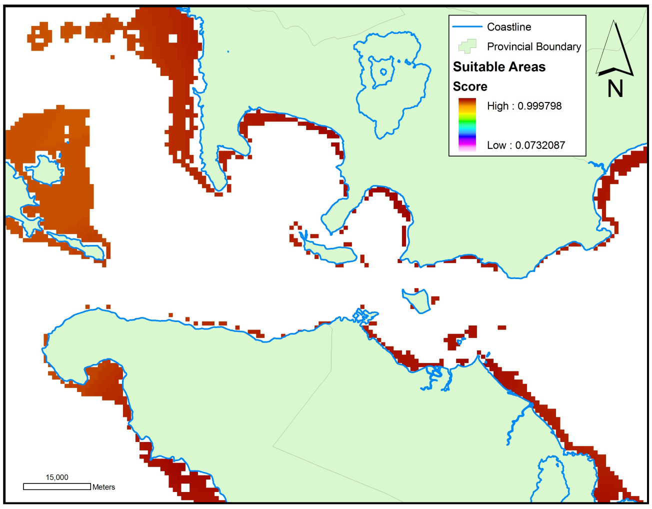

Figure 9. Suitability score map for tidal current energy conversion.

5. CONCLUSION

A model for multi-criteria assessment of tidal current energy was developed and implemented using the available geospatial data and relevant GIS tools. It is applied to the Verde Island Passage where suitable areas based on accessibility were determined.

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