Renewable Energy 35 (2010) 852–861

Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene

Technical Note

Site location analysis for small hydropower using geo-spatial information system

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ARTICLE INFO

Article history:
Received 18 August 2008
Accepted 8 August 2009
Available online 24 October 2009

Keywords:
Small hydropower
Location analysis
GSIS
Energy
Resources survey

ABSTRACT

Recently, the necessity for developing small hydropower (SHP) plants has emerged due to the increase in environmental concerns. Although there remains an abundant of potential sites for SHP plants in Korea, SHP development has scarcely been performed since the 1990s due to the absence of a suitable approach and economic feasibility. Such a situation encourages decision makers to develop a systematic approach for SHP development. The purpose of this study is to propose a new location analysis methodology to search for potential SHP sites using GSIS (Geo-Spatial Information System). The location analysis in this study focuses on establishing the criteria and methodology for searching for alternative locations rather than selecting the most suitable site among the alternatives. By applying the newly developed methodology, a large area can be precisely surveyed within a short period of time and we expect to be able to use the method in policy making for SHP development by improving the convenience for the user. The newly developed methodology was applied to the upper part of Geum River Basin, in Korea, and found six potential SHP sites. As a fundamental work, this study will be beneficial to the future activation of SHP development.

1. Introduction

Small hydropower (SHP) provides one of the most environmentally clean forms of energy with the least emissions of green house gases among all the types of new and renewable energy. In addition, about 70 percent of economically feasible hydropower potential still exists to be developed in the world [1]. It is also expected that SHP generation could potentially provide sufficient amounts of alternative energy, especially in Korea, where efforts are being made to reduce the use of fossil fuels and where there is an abundance of potential sites. The success of SHP development depends on its economic efficiency determined by the performance characteristics of power generation according to types of SHP plant and their installed capacity. Many studies [2–8] are present in which the sensitivity analysis or the economic analysis for optimizing the design and the operation of SHP plant is performed. Since the performance characteristics considerably depend on the geographical and hydrological conditions, accurate location analysis is critical to SHP development.

A general definition of location analysis is the evaluation of a variety of needs for the prospective location and suggesting an alternative on the basis of a proper assessment of the land. Therefore, location analysis for SHP can be defined as the process of examining candidate locations that are deemed to have fewer obstacles to the project and that are more profitable at the initial stages of the development. Considering that location analysis is to be performed at the initial stages, it is reasonable to use the existing geographical and hydrological data in order to reduce time and cost. In the past, this type of analysis had been carried out using onsite surveys and paper maps. However, such an approach is less efficient when analyzing a large area because of the long analysis time and low objectivity. In addition, the reliability of the results might be diminished due to mistakes made by the researcher when conducting manual work and the influence of subjective judgment and errors.

Korea's SHP resources survey began with a government-initiated project, the 'Survey on the mini-hydropower resources in Korea' [9]. In this survey, more than 3000 locations in total were selected through two nationwide onsite and aerial surveys. Research on SHP had been actively performed until the beginning of the 1990s [10–15] and Kwon and Kim [16] recently analyzed the impact of the SHP on environment and suggested a policy alternative with respect to the location. However, there was no methodological progress in the procedure and standard for SHP development in Korea.

Meanwhile, the Geo-Spatial Information System (GSIS) has recently started to be used for location analysis, meaning that

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doi:10.1016/j.renene.2009.08.003

a more precise analysis at the initial stages of SHP planning is possible. GSIS is the integrated operating system of hardware, software and GIS database controlled by qualified manpower, which can comprehensively and systematically collect, store, search for and analyze complex spatial information. Gismalla and Bruen [17] stressed the efficiency of the GIS in developing SHP development for various countries, and Kaijuka [18] predicted the demand for electric power in rural areas by using the GIS and analyzed the priority in construction and investment scales in SHP planning. Ramachandra et al. [19] based on the use of GIS technology, have used Spatial Decision Support System (SDSS) for assessing SHP potential. With the sustainability of SHP development being more significantly emphasized, especially focused on its three basic dimensions: social, economical and environmental [20], studies have been carried out for analyzing the GIS data of the factors affecting the environment and searching for the locations [21,22]. In addition, several studies have been performed for the SHP development location analysis system by inquiring, managing and analyzing the spatial information collected by the RS data by means of the GIS [23–25]. In Korea, most of the studies using GSIS have been carried out to determine locations for obnoxious facilities [26–32].

While location analysis methodology for SHP development has previously depended upon onsite surveys and manual work, this study is aimed at developing an objective and precise location analysis methodology for SHP development using GSIS. Hence, the location analysis in this study focuses on establishing the criteria and methodology for searching for alternative locations rather than selecting the most suitable site among the alternatives. By applying the newly developed methodology, a large area could be precisely surveyed within a short period of time and we expect to be able to use the method in policy making for SHP development by improving the convenience of the user.

2. Location analysis process for SHP development

The location analysis for SHP development in this study is summarized in Fig. 1. The analysis starts with preparing spatial data, some of which is used to create a stream network grid map, while other data is used to perform an overlay analysis. Spatial analysis, especially grid analysis, is required to create the stream network grid map which is created from the DEM (Digital Elevation Model) of the study area. The stream network grid map is used for searching SHP locations. The searching process sequentially advances from an upstream grid cell to a neighboring downstream gird cell. Therefore, each grid cell can function as a searching point in location analysis.

The stream network grid map is used for searching potential SHP locations. After creating the searching points, the criteria for location analysis and their relative weights are determined. In this study, two criteria were considered including constraint and location criteria. The constraint criteria are used to exclude undesirable sites that are legally restricted or likely to cause a dispute. We therefore included national parks, water supply source protection areas, agricultural facilities, and residential districts in the constraint criteria. In the location criteria, the hydrologic, topographic, and eco-environmental factors that are used to grade each searching point were included in order to evaluate the adequacy of a location.

Table 1
Location Criteria and their relative weights.

Criteria	Topographic factor		Hydrologic factor	Eco-environmental factor	Sum
Type	Natural head	Storage capacity-dam width limiter	Runoff contributing area	National Environmental Assessment Map	
Reservoir	0	0.3	0.3	0.4	1.0
Run-of-river	0.5	0	0.3	0.2	1.0

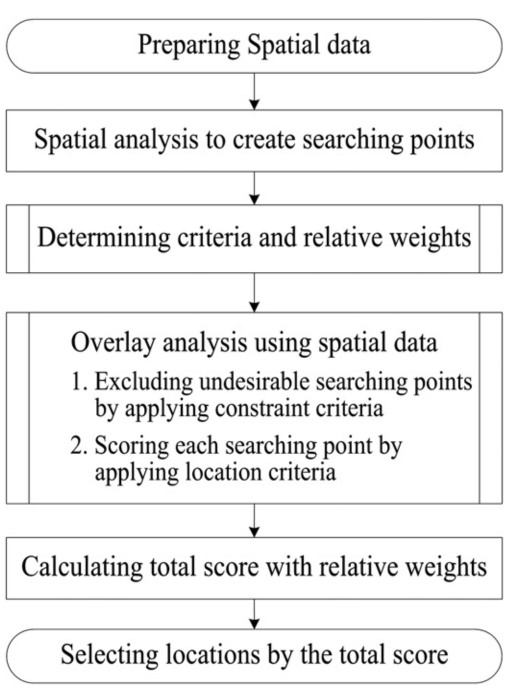

Fig. 1. Process of location analysis.

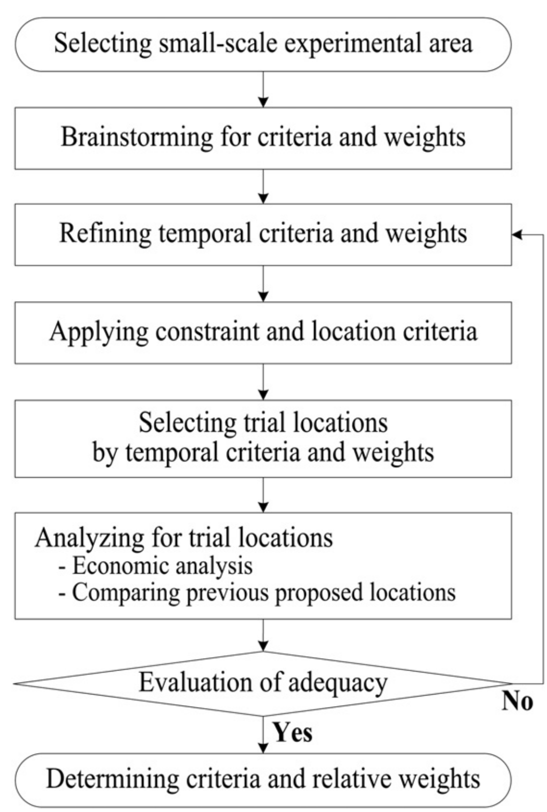

Fig. 2. Determination of criteria and relative weights.