Environmental Location Assessment for Seaweed Cultivation in Ghana:
A Spatial Multi-Criteria Approach

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ABSTRACT

This study was designed to select potential areas for the cultivation of seaweeds on the Ghanaian coastline. The challenge of selecting suitable sites for the cultivation of seaweed along the coast was investigated, using spatial multi-criteria approach in GIS. Environmental and physical parameters based on spatial multi-criteria decision for the best sites suitable for seaweed cultivation were used. The parameters used included Sea-depth (1-10)m, (11-20)m, (21-30)m and (31-40)m, sea-surface temperature (24-26) degree Celsius, proximity to settlements (0-8) kilometers and sheltered coves (areas sheltered from strong wind and waves) as variables for the various models. The study identified twelve suitable sites along the coast of Ghana for seaweed cultivation. Five of the selected sites were ground-truthed for model validation. All five validation sites have agreed to the GIS models indicating that GIS is the most appropriate tool to use for selecting most suitable environment for seaweed cultivation especially when dealing with a complex coastal environment like Ghana's coastline.

KEYWORDS

GIS, Ground–Truthing, Proximity, Sea Surface Temperature, Sea-Depth, Seaweeds, Spatial Multi-Criteria

INTRODUCTION

Seaweeds provide food products for human consumption and can be used as fertilizers, animal feeds, and serve as inputs to pharmaceuticals (Fisheries and Aquacultures, 2013). Seaweeds have been acknowledged as the feedstock of the future and algae is attracting increased investment interest from biofuels, petroleum and agribusiness industries. However, seaweeds have become a menace to fishers along Ghana's coastline. In an effort to manage the seaweed menace along the coast and at the same time derive economic benefits from seaweeds, the Seaweed Bio-refinery Project of Ghana (SeaBioGha), a Biorefinery Project being implemented by the Technical University of Denmark (DTU), Kwame Nkrumah University of Science and Technology (KNUST), and the Water Research Institute (WRIG) of Centre for Scientific and Industrial Research (CSIR) Ghana intend to engage in massive seaweed cultivation in the coastal marine waters.

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In order to transform what is now considered a menace to a sustainable and profitable alternative livelihood activity through the collection, sorting and sale of freely arriving seaweeds on the coast, the SeaBioGha Project seeks to establish cultivation of seaweeds along Ghana's 540km coastline and establish relevant technology for the cultivation and processing of seaweed products in Ghana, and utilize the residues for bio-energy production.

In considering the social and economic prospects from seaweed cultivation, selecting the right environmental location for stable growth is paramount. For example, In Brazil, de Sousa et al. (2012) used Geographic Information System (GIS) to select appropriate locations for Seaweed (*Gracilaria birdiae*) cultivation. In another study, Sulma *et al.* (2008) also used remote sensing data to identify ecologically suitable sites for the cultivation of seaweeds. These selected sites were primarily based on water biophysical parameters, which include sea surface temperature, total suspended matter, bathymetry, sheltered coast and current movement. According to Kronen (2010), incorrect sea surface temperatures could result in seaweed loss due to filamentous epiphyte polysophonia and ice-ice disease.

Seaweeds (macro algae) have been inundating the shores of Ghana for decades now and among them are green, brown and red algae which includes *Ulva fasciata, Sargassum vulgare* and *Hypnea musciformes* (Nunoo and Ameka, 2005; Gbedemah, 2014). *Hypnea* originates from Trieste in Italy, and is now spreading throughout the world including Africa (IUCN/SSC/ISSG, 2004, Holst *et. al*, 1994). The practice of aquaculture and movements of boats and vessels influence the distribution of the *Hypnea* seaweed (IUCN/SSC/ISSG, 2004). On the other hand, the invasion of *Sargassum* seaweed along the coast of Ghana is believed to have originated from the Sargasso Sea. Its spread is facilitated by current flow along the West African coastline from Senegal, Cote D'Ivoire all the way to Ghana. The presence of *S. vulgare* was detected in Ghana in 2009. This seaweed later increased in quantity in 2012-2014 especially, in the western part of the country with serious implications for continued coastal activities. In addition to *Hypnea* and *Sargassum*, Ghanaian fishermen in the Western region have observed that the prevailing Guinea current has moved *U. fasciata* to within 2 km offshore of New Town (Granger et.al 2012).

In Ghana, the increasing influx of seaweeds (*Ulva*, *Sargassum* and *Hypnea*) spp. on the beaches has become a major concern and worry to many people living near the coast. This phenomenon, which clogs fishermen's nets, has affected the livelihoods of local inhabitants, largely fisher-folks, whose lives depend mainly on fishing activities. According to the Ghana Environmental Protection Agency (2014), beach seine fishermen in the Western region almost abandoned their activities when seaweed densities became too high. Similarly, hotel and tourism businesses were badly affected when seaweeds took over Cape Coast beaches in 2014 and prevented revelers from beach activities like swimming in the sea during Easter festivities (Tutuah Mensah, 2014).

Other physical factors like water depth and sheltered coves could also determine which type of seaweed farming may be applicable along the coast. Seaweed is an autotrophic plant and thrives well in shallow waters within the range between 1-10 meters sea depth, temperature range between 19-30º Celsius, free from pollution, fair weather, and protected from strong waves and current (Cohen, 2011; Sarker, 1992; Ding et al., 2013).

One method of selecting the right environment for seaweed cultivation is by choosing the required environmental variables and ranking them according to their importance. This can be done by using spatial multi-criteria analysis (SMCA). SMCA is one of the approaches in a Geographic Information Systems (GIS) that is used to achieve the selection of best sites for aquaculture. It examines and weighs multiple considerations over a study area (Malczewski, 1999). SMCA can use simple hierarchical models like analytical hierarchical process (AHP) to evaluate the criteria for selection of sub-models to prioritize the best areas for aquaculture activities (Malczewski, 1999; Chackher 2008). For example, Gimpel (2005) used an Ordered Weighted Averaging (OWA) model to geo-locate suitable sites for windmill and aquaculture, while (Silva et al., 2011; Malczewski, 1999; Kerrison, 2015; Holst, 2015; Nath et al., 2000; Kapetsky and Manjarrez, 2007 Perez et al., 2003) used analytical hierarchical process (AHP) to identify suitable areas for aquaculture establishment.