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Sustainable transition in small island developing states: Assessing the current situation

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ABSTRACT

Transitioning to sustainable energy systems is an overriding challenge for small islands. Indeed, these territories must succeed within the next decades with the objective of energy independence and transitioning to a sustainable situation. In this research, a statistical approach is performed to explore and discuss a comprehensive study on small islands' sustainability from the standpoint of renewable energy. This paper aims to first identify whether small islands are moving toward a sustainability path. A principal components analysis (PCA) is first investigated to identify which explanatory variables have a significant contribution on the percentage of data variance. Then, PCA-based hierarchical clustering highlights the island organization in two different years (2010 and 2014). This paper investigated the classification by considering a set of 35 small island developing states (SIDS). Finally, a sustainability indicator is proposed to qualify the level of sustainability of each group of islands. Sustainability is understood through the lens of the share of renewables, the electricity situation, economic development and geographical localization. The obtained results clearly show that the dynamics of transition is not clearly engaged for the small islands. Most of them have actually become more vulnerable during the 2010–2014 time span.

1. Introduction

Adaptation to climate change is the greatest challenge of our century. Much academic research has discussed the adaptation to climate change through the study of renewable energy potential. In our society, energy is a crucial point for many economical and development activities. In a context of the rarefaction of fossil resources and frequent economic crises, the strong variations in the short-term energy price and its long-term predictable increase have had an increasing impact, (Pacesila et al., 2016), (Tan et al., 2016). The UN-DESA[1] currently lists 57 SIDS (37 UN Members and 20 non-UN) spread over the Caribbean, the Pacific and Africa, the Indian Ocean, the Mediterranean and the South China Sea. In the last two decades, the islands have developed some ambitious energy policy frameworks to switch to renewable power. There recently was a particular focus on SIDS during the COP23 conference, (Small Island Deve, 2016). The report highlights the urgency of action to build resilience in small islands. Islands give the opportunity for a forward-looking basis and suggest directions for a sustainable solution to the problems with which all the territories that will have to face climate change are confronted, (Wolf et al., 2016), (Praene et al., 2017), (Michalena and Hills, 2018).

Most of these territories are not connected to any continental electricity network due to their geographic situation. Thus, their geographical context (area, location) induces a high level of vulnerability because of many natural or economic circumstances (Encontre, 1999). An early study investigated by (Briguglio, 1995) focused on the vulnerability of such remote territories by defining an economic index in order to classify islands and understand their vulnerability level. Oil price volatility is significantly detrimental to electricity generation mainly based on fossil fuel sources, (Dornan and Jotzo, 2015). In 2012, the United Nations reiterated the importance of promoting access to sustainable energy-based production. Indeed, due to their relatively small energy demand, these territories are in a precarious situation. Electricity facilitates economic activity, public health services and education. Thus, the sustainable development of the islands involves three major aspects, which are low environmental impact, economic viability and social acceptance. Many scholars have investigated the concept of energy vulnerability. Most of them have addressed the

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deployment of renewable energy sources (RES) in the electricity generation mix, (Kuang et al., 2016), (Gils and Simon, 2017). The studies focus on an overview of RES potential and prospective analysis. In line with this, the concept of *renewislands* was introduced by (Duić et al., 2008) and highlights the necessity to define methodology tools for decision makers and policymakers to better target development aid. These procedures help to increase the sustainability of the electricity mix.

Sustainable development is currently closely linked to sustainable assessment. This last point is particularly complex to define. Indeed, a sustainable assessment must necessarily be performed to understand whether a territory is really under an energy transition. The definition of an index is not harmonized. This can be easily understood by the various standpoints on the comprehensive information contained within sustainability indicators, (Bossel, 1999). Recent studies have highlighted the importance of understanding what the driving factors of energy transition for SIDS are through the lens of robust energy policy development to promote the potential of renewable sources, (Shah et al., 2016). Thus, the question of sustainability must be studied via dynamic approach measurement.

The main purpose of this study is to analyze, in a short period, whether a sample of 35 islands is currently engaging in a sustainable energy transition. This paper therefore seeks to examine the degree of sustainability of the islands. The purpose of this work is to propose a two-step approach to qualify sustainability:

- Use a PCA-based approach to perform clustering in order to identify the islands that have the same profile.
- Define a sustainability index (SI) mainly based on variables that have a significant influence on the principal components.

The paper begins with an overview of the data collection and the main characteristics of the studied islands. We also focus on the hypothesis that helps us to define the SI. Then, a multivariate data analysis is presented to both reduce the dimension of the data set and identify which variables have a significant influence on the principal components. Based on this first step, hierarchical clustering highlights the main characteristics of the classes of the islands. Finally, using the results of PCA, a multi-regressive model is conducted to define the SI. The study is conducted for two different years, 2010 and 2014, to determine whether any early signs of energy transition in these insular territories could be observed.

2. Materials and method

2.1. Data collection

This study was conducted on a sample of 35 islands. The first set of data was initially based on 57 islands, but a reduction was necessary due to the lack of information for some of them. The objective of the study is to define an *"easy-to-use"* index that will be defined with accessible variables. The geographical locations of selected SIDS are shown in Fig. 1.

The exploratory analysis was conducted over the 9 quantitative parameters detailed in Table 1. The guiding idea of the method is to focus on the exogenous variable that could be found for each SIDS through the year. The first group of data consists of some geographical information. The isolation index, which is the ratio of the exclusive economic zone to the total island area, explains how the ocean isolation is pronounced, (Taglioni, 2006), (Doumenge, 1985). Thus, this variable shows the island's remoteness from the principal commercial maritime routes. The second group addresses social and economical information. These parameters focus on the economic dynamism and the level of urban development. Finally, the energy cluster represents the energy production and consumption of each territory. The concept of sustainability could be understood by the energy need and share of renewable sources.

2.2. Data analysis

Principal component analysis (PCA) is a multivariate statistical technique widely used to describe a set of quantitative data. This approach is particularly interesting for performing dimensionality reduction of a data set, (Ndiaye and Gabriel, 2011). The information contained in a data set corresponds to the total inertia it contains. The objective of PCA is to identify the directions along which the data variation are a maximum. This procedure is achieved by projecting the eigenvectors of a correlation matrix. The principal components, called dimension (Dim), are some macro factors based on a linear combination of the variable set, defined as follows:

$$Dim_i = \sum_j \alpha_{ij} X_j \quad (1)$$

where α_{ij} is the contribution of the exogenous variable X_j to the construction of the principal component i. These dimensions are uncorrelated and orthogonal. PCA is also a method frequently used as a regressive model, (Romano et al., 2016). Much research has investigated the definition of an index based on PCA, (Gupta, 2008), (Gnansounou, 2008). Our study aims to define a composite sustainability index (SI), and the model described from the principal components is defined as follows:

$$SI = 1 - \frac{\lambda_1 Dim_1 + \lambda_2 Dim_2 + ... + \lambda_j Dim_j}{\lambda_1 + \lambda_2 + ... + \lambda_j} \quad (2)$$

Then, the dimension could be decomposed by the variables weighted by their contribution to the principal component. The objective of our study is to observe the evolution of the island sustainability between 2010 and 2014. Thus, the data analysis is done in three steps. First, PCA of the original data set is performed. This step allows us to understand the global profile of the islands and select the most significant variables. Then, hierarchical clustering presents the number of classes that characterize the data. This clustering gives useful information on the similitude between islands. Finally, the SI is investigated for the period between 2010 and 2014 to discuss the dynamic of sustainability. This indicator summarizes the overall sustainability information, (Burck et al., 2009). The two step analysis (PCA and hierarchical clustering) has been achieved using the *FactoMineR* package under the R environment, developed by (Lê et al., 2008). The last step is to normalize the value between 0 and 1.

3. Results and discussion

3.1. PCA results

This section focuses on the results of the application of PCA to the full data set of 2010. This year is considered the reference year to calculate the regression coefficient for the indicator. The results of the calculation of eigenvalues are depicted in Table 2.

The inertia of the factorial axes suggests that the first two axes of the PCA express 54.9% of the total inertia of the data set. The fourth component is not considered, as its variance is less than 10%. Thus, the number of variables is meaningfully reduced with a minor loss of information. The first three components will be the macro factors usable later for the regressive index model, as the eigenvalues are greater than 1. The selection of variables to describe the principal components is basically based on two parameters: cos^2 and *contribution*. cos^2 represents the quality of projection of the variables on the chosen principal components plan. Each principal component, a latent variable, is characterized by the observed variables as follows:

- Dim 1 is mainly defined by the GDP, electricity consumption and