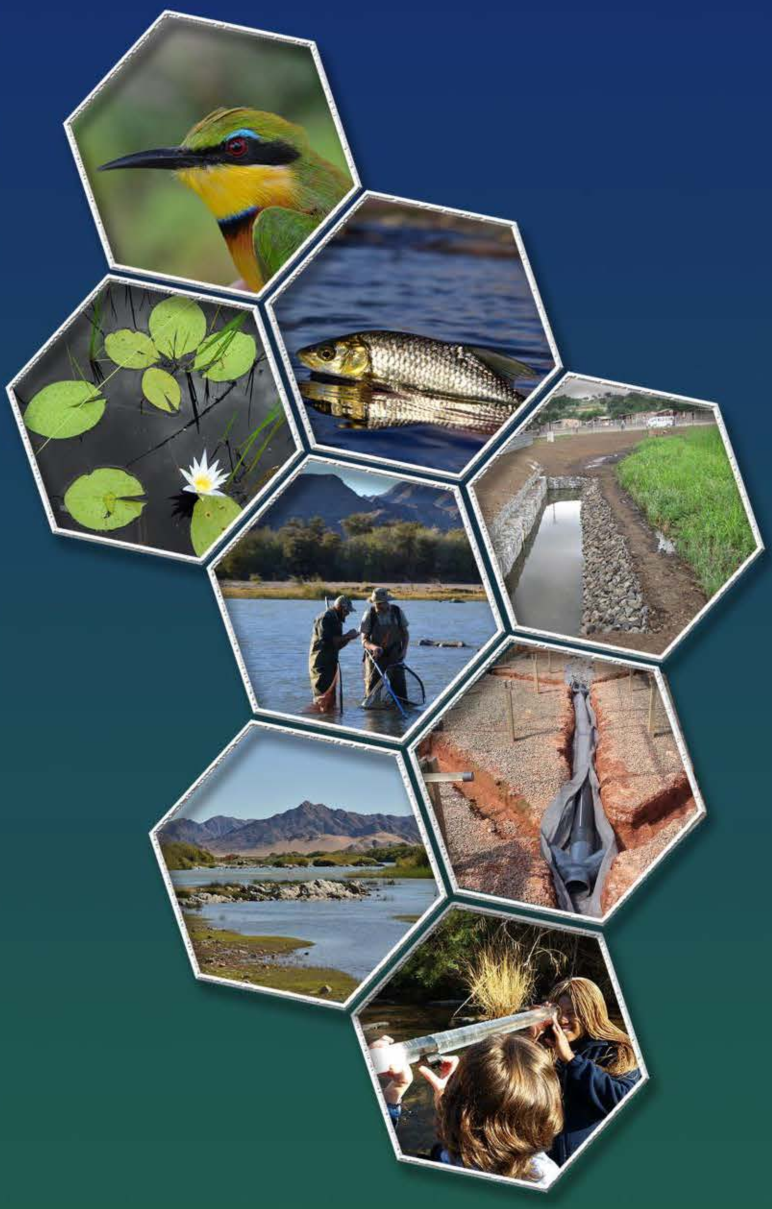
# A SPATIAL ANALYSIS OF BASIC INFRASTRUCTURE AS A PREREQUISITE FOR LOCAL BLUE GROWTH IN THE WESTERN INDIAN OCEAN REGION

FINAL REPORT



GroundTruth

Water, Wetlands and Environmental Engineering

Head Office KwaZulu-Natal

P.O. Box 916, Hilton 3245, South Africa

Tel: +27 33 343 2229 - Fax: +27 86 599 2300

admin@groundtruth.co.za

www.groundtruth.co.za

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| **Prepared by** | GroundTruth Water, Wetlands and Environmental Engineering | | |
| **Consultant sign-off** | **Name / Prof. Reg.** | **Signature** | **Date** |
| **Author(s)** | Adrienne Louw | | 3 June 2021 |
| | | | |
| | | | |
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# EXECUTIVE SUMMARY

The Western Indian Ocean (WIO) is one of the world's richest oceans, possessing a plethora of coastal and marine resources. The WIO region comprises ten countries: Comoros, Kenya, Madagascar, Mauritius, Mozambique, Reunion/France, Seychelles, Somalia, South Africa, and Tanzania. Coastal communities in the WIO are often poor, rural communities that are highly dependent on coastal and marine resources for their livelihoods. There is a need to identify mechanisms by which to improve socioeconomic development in these communities and thus alleviate poverty and improve livelihoods. Given the rich oceanic environment available it is likely that the development of a sustainable blue economy might prove to be the key to improving the socioeconomic status of these communities.

It is theorized that basic infrastructure may prove to be an important prerequisite for achieving blue socioeconomic growth. This, however, has not been investigated in rural coastal communities in the WIO region. The aim of this study was thus to address this knowledge gap through answering the following question: does the presence of basic infrastructure correlate with local blue economic growth and/or socioeconomic development in rural coastal communities? To answer this question 11 case studies were selected from five countries in the WIO region and relationships between basic infrastructure and socioeconomic development examined using Principal Component Analyses.

The results indicated that a positive correlation between basic infrastructure and economic wellbeing exists, indicating that the better the suite of basic infrastructure present in a community, the better its economic wellbeing. Specifically, the presence of roads and supply of electricity were found to be the most important types of basic infrastructure related to economic wellbeing. This study also revealed that the presence of strategic planning is closely correlated with both economic wellbeing and social wellbeing, indicating that communities that show evidence of being strategically planned tend to have higher levels of economic and social wellbeing.

Additionally, the study found that the type and intensity of the marine economic activity in which communities engage also plays an important role in their economic wellbeing. Communities engaged in tourism tended to have higher levels of economic wellbeing. Communities in which aquaculture was the primary economic activity had small populations and relatively low social and economic wellbeing. Villages that engaged in artisanal fishery largely lacked basic infrastructure and had poor social and economic wellbeing. Conversely, where fishery was undertaken at a commercial scale there was more basic infrastructure present and greater social and economic wellbeing.

This study provides some valuable insights to help guide investment in rural coastal communities and forms the basis for further studies. It must, however, be noted that the

correlations observed in the study do not necessarily imply causation. Ideally, to adequately investigate whether basic infrastructure drives blue economic growth and/or socioeconomic development, communities need to be examined over time.

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## ACRONYMS

| | |
|---|---|
| EEZ | Exclusive Economic Zone |
| FAO | Food and Agricultural Organization |
| GDP | Gross Domestic Product |
| LDC | Least Developed Country |
| PCA | Principal Component Analysis |
| SIDS | Small Island Developing State |
| SwAM | Swedish Agency for Marine and Water Management |
| UNEP | United Nations Environment programme |
| WIO | Western Indian Ocean |

# 1. INTRODUCTION

GroundTruth Water, Wetlands and Environmental Engineering (GroundTruth) have been appointed by the Swedish Agency for Marine and Water Management (SwAM) to undertake a spatial analysis of prerequisites for local blue economic growth in the Western Indian Ocean (WIO) region.

This report sets out the study background and aim, methodology, results, and findings of this work.

# 2. BACKGROUND AND STUDY AIM

## 2.1 Western Indian Ocean region

The Western Indian Ocean (WIO) covers approximately 30 million km$^2$ (8.1 percent of the global ocean surface), six million of which are exclusive economic zones (EEZs) (Obura et al., 2017). It is one of the regional seas identified by the United Nations Environment Programme (UNEP) Regional Seas Programme, which aims to address the accelerating degradation of the world's oceans and coastal areas and maintain, restore and enhance marine and coastal resources in such a way as to support human well-being through sustainable development (Obura et al., 2017; UN Environment Regional Seas Programme, 2016). It possesses a high diversity of species, ecosystems and endemic species, making it one of the world's richest oceans and the second richest marine biodiversity hotspot (Levin et al., 2018).

The WIO region comprises ten countries: Comoros, Kenya, Madagascar, Mauritius, Mozambique, Reunion/France, Seychelles, Somalia, South Africa, and Tanzania (**Figure 2-1**). South Africa, Mozambique, Tanzania, Somalia, and Kenya are mainland continental states, whilst Comoros, Seychelles, Mauritius, and Reunion are small island states, and Madagascar combines elements of both (Obura et al., 2017). The total population of the WIO region was estimated at 220 million in 2017, of which over a quarter (60 million) reside within 100km of the shoreline (Obura et al., 2017).

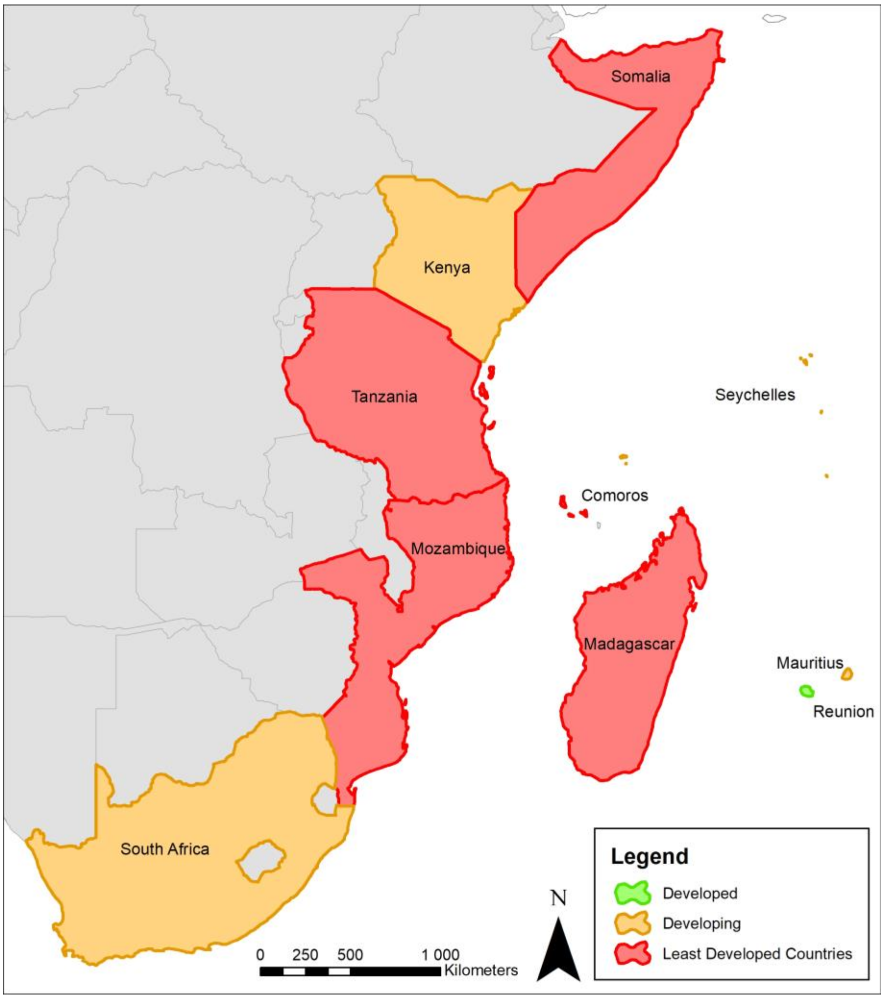



**Figure 2-1 Countries in the Western Indian Ocean region and their development status as defined by the World Bank**

## 2.2 The blue economy

The ocean and coastal environments are extremely important for many coastal communities in the WIO region. Estimates suggest that 30-60 million people in the region are dependent on the coastal environment for the goods and services that it provides, such as food from fish and shellfish resources, carbon sequestration, coastal and marine tourism, and marine fishery nurseries (Obura et al., 2017; Taylor et al., 2019; Van der Elst et al., 2005). The majority of fisheries in the WIO region operate at an artisanal level and as such limited ecological and socioeconomic data regarding their activities exists (Osuka et al., 2020; Van der Elst et al., 2005). This often results in these artisanal fisheries being marginalized in policy-making processes (CGIAR: Research Program on Fish, 2020).

In an effort to address this shortage of data relating to small-scale fisheries, the collaborative study "Illuminating Hidden Harvests", which is to be released in 2021, has been initiated by the Food and Agriculture Organization (FAO) to investigate the current contributions, impacts and drivers of change of small-scale fisheries globally (CGIAR: Research Program on Fish, 2020). This study is a continuation of the 2012 Hidden Harvest study, which reported the following key findings:

- Millions of metric tons of fish from small-scale fisheries are unreported
- Of the 120 million people dependent upon capture fisheries, 116 million are in developing countries and of these more than 90% work in small-scale fisheries. 47% of the workforce are women.
- Small-scale fisheries produce more than half of the fish catch in developing countries, and 90-95% of this is consumed locally in rural settings
- Employment in small-scale fisheries is several times higher per ton of harvest than in large-scale fisheries (CGIAR: Research Program on Fish, 2020)

It is thus evident that small-scale fisheries play a crucial role in livelihoods across the world, especially rural livelihoods. In the WIO region specifically it is estimated that three million people are dependent upon artisanal fishing for their livelihoods (Levin et al., 2018). The estimated annual economic value of ocean-related activities (gross marine product) is approximately US$20.8 million and whilst in the global context this may not seem a significant sum, in a region that possesses some of the world's poorest countries (e.g. Mozambique and Madagascar), this contribution is crucial in helping alleviate poverty (Obura et al., 2017).

Meanwhile, the WIO region's rich biodiversity is under threat, largely due to direct and indirect pressures from over-exploitation and human-induced habitat degradation (Obura et al., 2017). This is of major concern as the ocean's ability to supply the ecosystem goods and services on which so many rely is dependent upon its health. Furthermore, climate change is exacerbating these pressures, further limiting the ocean's ability to supply resources and support livelihoods (Taylor et al., 2019).

**Text box 1. What is the blue economy?**

The blue economy refers to the marine-based economic development that contributes to improved human wellbeing and social equity, whilst maintaining a balance with ocean health, reducing environmental risks, and ensuring sustainability (Smith-Godfrey, 2016; Potgieter, 2017). Whilst there are various definitions of the blue economy, in the context of this study, and to put it into its simplest form, the blue economy is viewed as *the sustainable use of marine resources in such a way as to benefit coastal communities living in poverty.*

The richness of the WIO region's oceans means that its blue economy has great potential for growth, provided resources are managed in a sustainable manner and development and the installation of infrastructure does not further degrade the condition of marine habitats, biodiversity, or the physical assets that provide coastal protection (Obura et al., 2017).

The majority of the countries in the WIO region are relatively poor and face a host of severe socioeconomic challenges (Van der Elst et al., 2005). It is anticipated that these countries will soon enter a period of rapid economic growth, largely because of their current low baselines and rapidly increasing population size (Obura et al., 2017). Although this economic development is much-needed and will play an important role in uplifting many of these countries out of poverty, it will also pose numerous threats to ecosystems and species (Paula, 2016). It is thus essential that it occurs in an equitable and sustainable manner. In order to ensure a sustainable future, transformative change is required (Dasgupta, 2021).

Dasgupta (2021) proposes three broad transitions required to bring about a sustainable future, namely 1) ensure that our demands on nature do not exceed its supply, and that we increase nature's supply relative to its current level, 2) we change our measures of economic success to guide us on a more sustainable path, and 3) we transform our institutions and systems - in particular our finance and education systems - to enable these changes and sustain them for future generations.

## 2.3 The role of infrastructure in economic growth

**Text box 2. What is infrastructure?**

Infrastructure, or more specifically basic infrastructure, refers to the services that facilitate income-generating activities, such as housing, transportation, water, sanitation and solid waste disposal (Menendez, 1991). At its simplest definition, and as defined by the Oxford dictionary, infrastructure may be viewed as the "basic systems and services that are necessary for a country or organization to run smoothly, for example buildings, transport and water and power supplies". For the purposes of this study, infrastructure will be viewed as the facilities and installations that facilitate income-generating activities in rural coastal communities.

It is widely believed that infrastructure and investment in infrastructure are precursors for economic growth (Ansar et al., 2016; Cantú, 2017). Holmgren and Merkel (2017) note that investing in infrastructure is an important part of economic policy at regional, national, and international levels. Investing in infrastructure in areas with low economic activity can both assist in addressing issues of unemployment, and aid in fostering development (Holmgren & Merkel, 2017). As such, and theoretically at least, a connection should exist between GDP growth and investment in infrastructure (Holmgren & Merkel, 2017).

Although a number of studies have shown that basic infrastructure is a prerequisite for economic growth, this hypothesis has largely been unexplored in rural coastal communities in the WIO region. This is due to the fact that many of these communities lack basic infrastructure and as such the role this basic infrastructure plays in socio-economic development based on marine resources is unclear. Possessing an understanding of the role basic infrastructure plays in blue economic growth and socio-economic development is crucial for supporting and facilitating sustainable socio-economic development in the WIO region.

The role of basic infrastructure in facilitating blue economic/socioeconomic growth in rural coastal communities in the WIO region has largely been unexplored in the literature and as such there is a clear knowledge gap that exists. Given the need to improve livelihoods in these communities, and the clear potential of basic infrastructure to assist in doing so, it is crucial that this knowledge gap be addressed. This study sought to help address this gap.

## 2.4 Study Aim

The rich oceanic environment of the WIO region provides a plethora of natural resources that are likely to play a crucial role in facilitating the economic growth of the region. Identifying and supporting the connection between resource use and local development is key to supporting the goal of SwAM's international development programme, *SwAM Ocean*, which is to strengthen Sustainable Development Goal 14.7, i.e. by 2030 increase the economic benefits to Small Island Developing States (SIDS) and Least Developed Countries (LDCs) from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture, and tourism.

The prerequisites for linking access to marine and coastal resources with socio-economic development have been largely unexplored in the literature. SwAM Ocean have sought to address this gap in understanding through commissioning two studies addressing the question of what key institutional and infrastructure factors (except for the presence of marine resources and ecosystem services) need to be in place to enable local blue economic growth and/or social development in a development context. These two studies have provided valuable insights into the importance of institutional factors in local blue economic growth and socio-economic growth, such as importance of securing local co-management, sustainable resource use, access to credit, technical skills, presence of post-harvest value chains etc., but have not uncovered the importance of basic infrastructure, such as roads and access to water and sanitation.

The primary aim of this project is to undertake a quantitative study to assess whether the presence of basic infrastructure correlates with, and to what extent, socio-economic development in rural coastal communities in the WIO region. The study aims to answer the following question: **Does presence of basic infrastructure (e.g. roads, harbours, access to energy, sanitation and water) correlate with local blue economic growth and/or socio-economic development in rural coastal communities?**

# 3. METHODS

To address the aim of this study a number of case studies in the WIO region were selected. Through the collection and analysis of empirical data relating to basic infrastructure and socio-economic development associated with each of the case studies, relationships and correlations between infrastructure and socio-economic development were investigated. The methodology is presented in **Figure 3-1** and outlined in more detail below.

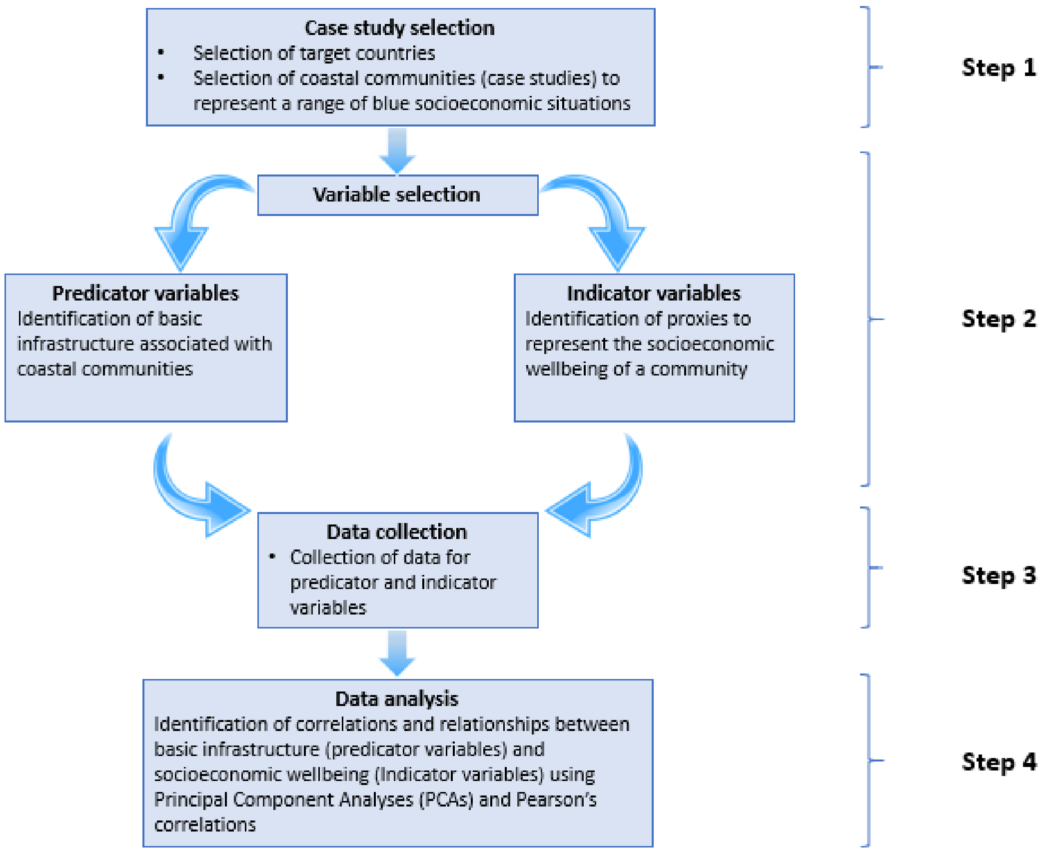



**Figure 3-1 Steps taken to assess relationship between basic infrastructure and socioeconomic development in coastal communities**

## 3.1 Case Study Selection

In order to assess whether a relationship exists between basic infrastructure and socioeconomic development in rural coastal communities in the WIO region, coastal communities were selected as case studies for which to collect data to interrogate this potential relationship. Six WIO region countries, namely Kenya, Madagascar, Mozambique, South Africa, Somalia, and Tanzania, were selected as target countries from which to select case studies. The decision to select these countries was based on SwAM's particular interest in obtaining information about them and the availability and ability to access relevant data. Although originally selected as a target country, Somalia was eventually excluded from the data collection process due to challenges in obtaining adequate socioeconomic data for the analysis.

An overview of each of the five selected countries was undertaken to identify coastal communities in which one (or multiple) of four key economic activities associated with the marine environment, namely 1) aquaculture, 2) conservation, 3) fishery and 4) coastal or marine tourism, was an important contributor to the local economy. In none of the case studies was conservation identified as the primary economic activity for the community. Rather, it was often present in conjunction with other activities, most commonly tourism.

**Text box 3. What are the key economic activities associated with the blue economy?**

For this study, key economic activities considered were those that have the potential to contribute to the socioeconomic development of rural coastal communities and which can be undertaken in a sustainable manner, ensuring that a balance between the use of marine resources and the health of the marine environment is maintained. Four key economic activities associated with the blue economy were selected:

1) **Aquaculture**: The farming of aquatic organisms
2) **Coastal/marine conservation**: The protection of coastal and marine ecosystems and species
3) **Small-scale fisheries:** Engagement in fishing to meet food and basic livelihood needs
4) **Coastal/marine tourism:** Tourism of the coastal and marine environment

In order to ensure that relationships between socioeconomic development and basic infrastructure could be statistically examined, case studies that represent a range of blue socioeconomic situations were selected. This range of blue socioeconomic situations may be represented on a spectrum from poor to good as in **Figure 3-2.** At the poor end of this spectrum exist case studies where little socioeconomic growth is being achieved through the use of marine/coastal resources, and/or the utilisation of these resources is being undertaken unsustainably and resulting in degradation of the resource base and natural environment. At the good end of this spectrum are case studies where socioeconomic development is being achieved without resulting in environmental degradation.

Additionally, case studies were selected to represent a range of intensities of the marine economic activity in question as the intensity, or scale, of the activity is often related to the economic success of the community. For example, case studies where fishing was being undertaken at an artisanal level were selected, as well as case studies where fishery was being undertaken on a larger, more commercial basis. The inclusion of more commercial level activities was deemed necessary to ensure that a full spectrum of blue economy situations was assessed and to determine which infrastructure is associated with these more economically successful communities.

The blue socioeconomic status of each case study was determined through a review of the available literature, with three key questions being investigated, namely:

1) Is there evidence that the use of marine or coastal resources is contributing to the economy of the area?
2) Is there evidence that the use of marine or coastal resources is contributing to social development?
3) Is there evidence that the use of marine or coastal resources is being undertaken sustainably, or is it resulting in environmental degradation?

A total of eleven case studies were selected, with many of these falling somewhere on the spectrum between the two extremes of a good blue socioeconomic situation and a poor blue socioeconomic situation. The spectrum of blue socioeconomic situations is presented in **Figure 3-2** below.

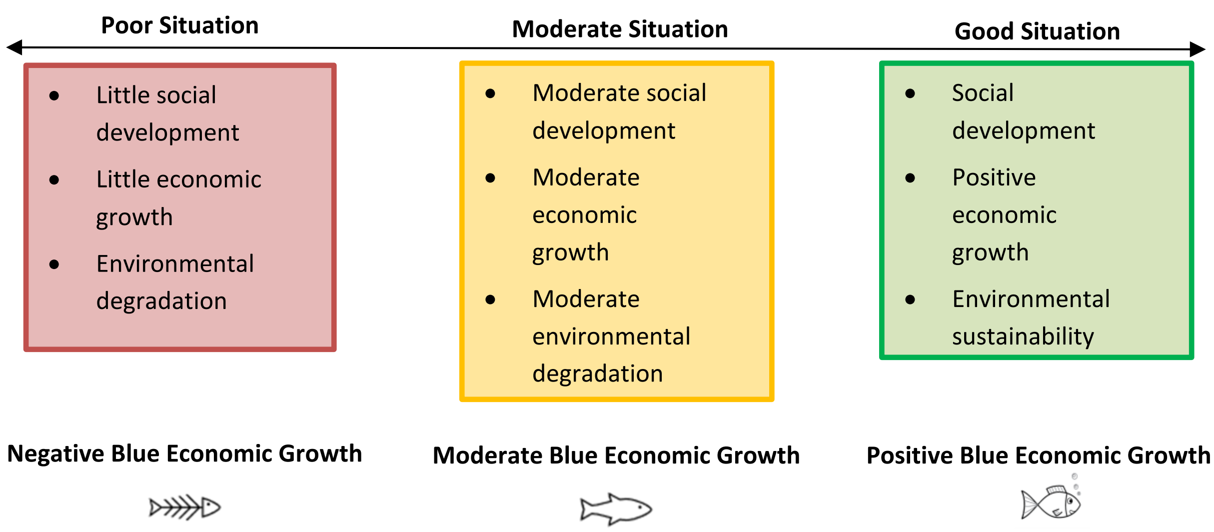



**Figure 3-2 Illustration of blue socioeconomic situations**

In order to identify specific case studies within each target country, a review of available literature was undertaken. Literature interrogated included inter alia reports and journal articles that reviewed projects implemented within rural coastal communities to strengthen aspects of the blue economy. In some cases, specific case studies were chosen based on GroundTruth's pre-existing knowledge of the site.

The selected case studies and their main marine economic activities are presented in **Table 3-1** and **Figure 3-3.** As per the Terms of Reference for the study, at least half of the case studies selected were from LDCs.

**Table 3-1 Major marine economic activities and perceived blue socioeconomic status associated with each case study. The colour of each village represents its perceived blue socioeconomic status, with red representing a poor situation, yellow a moderate situation, and green a good situation.**

| Country | Development status | Village/Town | Estimated Population (2019) | Economic activity |
|---|---|---|---|---|
| Kenya | Developing | Kibuyuni | 2 700 | Aquaculture |
| | | Watamu | 27 857 | Tourism |
| | | | | Conservation |
| | | | | Fishery |
| Madagascar | Least Developed Country | Andavadoaka | 1 700 | Fishery |
| | | | | Conservation |
| | | | | Aquaculture |
| | | Belo sur Mer | 13 290 | Fishery |
| | | | | Tourism |
| | | | | Conservation |
| Mozambique | Least Developed Country | Lalane | 1 150 | Fishery |
| | | Ponta Do Ouro | 3 300 | Tourism |
| | | | | Conservation |
| | | Vilanculos | 27 800 | Tourism |
| | | | | Conservation |
| South Africa | Developing | Haga Haga | 151 | Aquaculture |
| | | Saldanha | 31 700 | Fishery |
| | | | | Tourism |
| Tanzania | Least Developed Country | Matemwe | 5 319 | Aquaculture |
| | | | | Fishery |
| | | | | Tourism |
| | | Nungwi | 11 025 | Tourism |

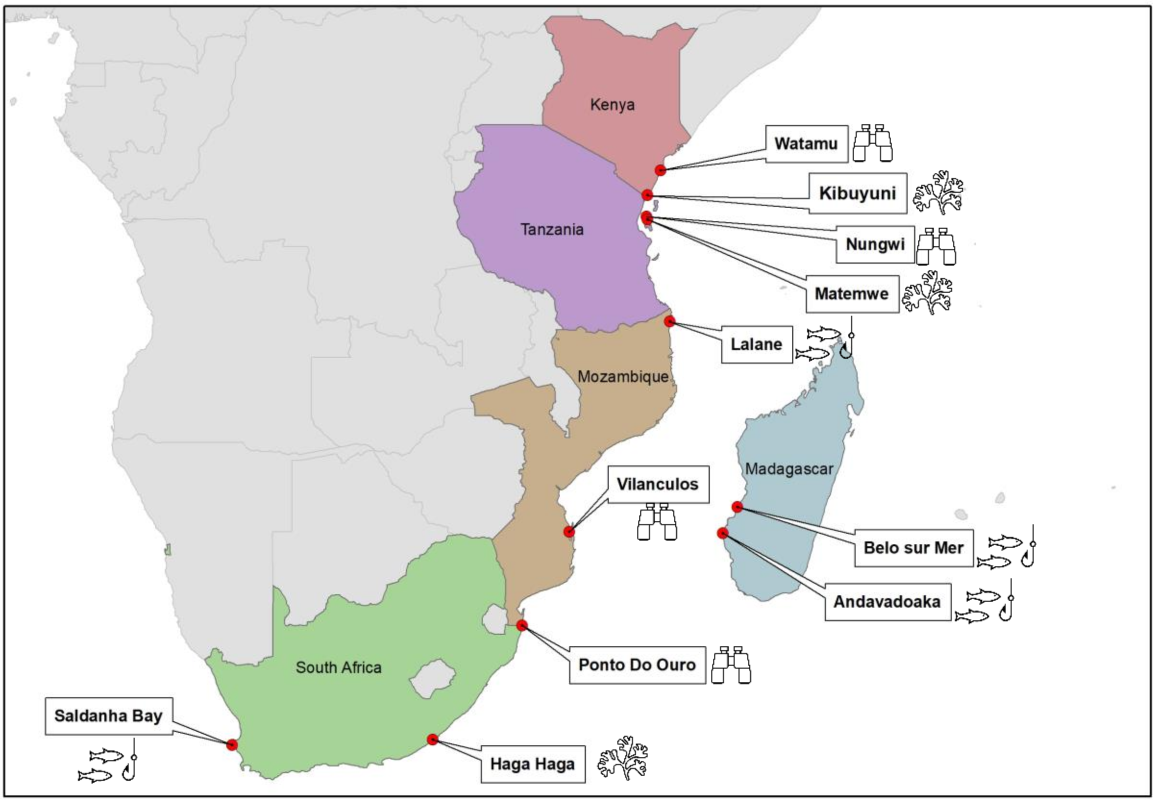



**Figure 3-3 Location of case studies. The symbols associated with each indicate the marine activity assessed as part of this study**

## 3.2 Variable Selection

### *3.2.1 Predicator Variables (Basic infrastructure)*

Infrastructure, or more specifically basic infrastructure, refers to the services that facilitate income-generating activities, such as housing, transportation, water, sanitation and solid waste disposal (Menendez, 1991). In order to identify a suite of basic infrastructure that is likely to facilitate blue socioeconomic development, and be relevant in rural coastal communities, the selected case studies were assessed using available literature and aerial imagery to develop an inventory of basic infrastructure present within each. This list of basic infrastructure was then reviewed and refined to include only that which is likely to be relevant in facilitating blue economic growth and socioeconomic development.

In addition to basic infrastructure, a number of other predicator variables may potentially correlate with socioeconomic development of rural coastal villages. For example, where villages are strongly dependent upon the use of natural resources, it is likely that the management and governance of these resources will influence the blue socioeconomic development of the village. Accordingly, we investigate whether a correlation exists between marine and coastal governance and socioeconomic status, and thus indicators representing these aspects were selected.

Additionally, the strategic planning of a village, in terms of whether it was a planned development and whether a government-level development plan exists to guide future development, provides an indication of the infrastructural development history of the village and potential future investment into the area. This in turn is likely to be correlated with its socioeconomic status. As such, indicators to represent strategic planning were also selected.

The historical context of a village, in terms of the local community's past traditional practices and relationships with the marine and coastal environment may potentially influence the village's socioeconomic development status and indicators to represent this were therefore selected. However, due to challenges associated with collecting this data, the potential correlation between historical context and socioeconomic development was not investigated in this study.

For this study, basic infrastructure, governance and strategic planning are viewed as first-tier predictor variables that are composed of a number of sub-variables, or second-tier variables, that together provide an overall representation of the first-tier variable's status. The final list of variables selected to represent each first-tier variable, namely basic infrastructure, marine and coastal governance (hereafter referred to as governance) and strategic planning, are presented in **Figure 3-4** and a description of each provided in **Appendix 1.** Each variable was graded, or scored, based on either its presence or absence, or abundance or condition. The grading process for each variable is discussed in more detail in **Section 3.3**.

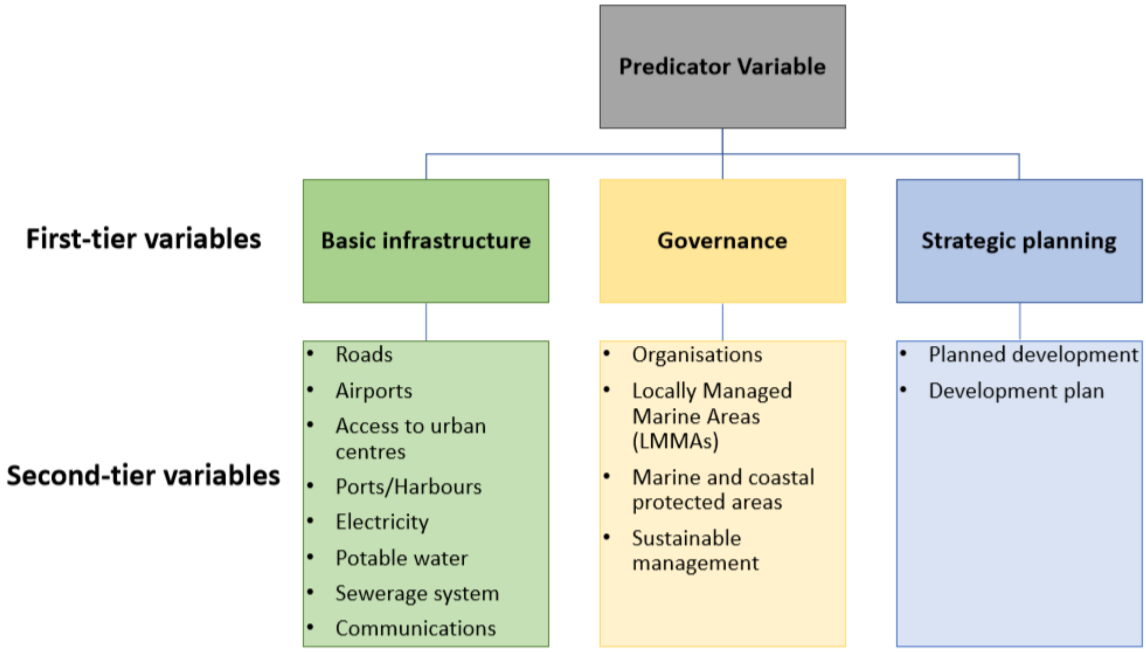



**Figure 3-4 First-and second-tier predicator variables likely to influence the blue economy**

For the purposes of this study the variable **organisations** was defined as the presence of community organisations that monitor or control the use of coastal/marine resources and/or engage in efforts to protect the coastal/marine environment. **Sustainable management** was considered in terms of whether evidence exists to suggest that coastal/marine degradation is occurring or whether evidence exists to suggest that efforts are being made to protect and conserve coastal/marine resources or utilise these in a sustainable manner.

### *3.2.2 Indicator variables*

The development of a country is a multidimensional process, comprising not only economic growth, but also the transformation and progress of the whole social system. As such, a number of components of socioeconomic development in rural settings exist, including natural capital, social wellbeing and economic wellbeing (United Nations, 2007). Additionally, institutional capital is also likely to be an important component of socioeconomic development. As such, four first-tier indicator variables that represent the socioeconomic development status of a community were selected, namely 1) natural capital, 2) social wellbeing, 3) economic wellbeing and 4) institutional capital. For the purposes of this study natural capital may be viewed as the natural assets that provide useful ecosystem services for rural coastal communities. Social wellbeing may be viewed as the health and education level of a community. Economic wellbeing may be viewed as the financial capital and security of a community, and institutional capital may be viewed as the availability and presence of institutional support and structures within a community.

As with predicator variables, each of the first tiers comprises a number of sub-variables, or second-tier variables, that when combined provide an overall representation of the first-tier. Indicators to represent each of the first tiers were selected based on a review of the available literature and through team workshops. Typically, social wellbeing is presented as a measure of life expectancy and literacy rate, and economic development as a measure of GDP. However, given the paucity of such information for rural communities, proxies were developed to provide an indication of these first-tier variables. Variables selected to represent each first-tier variable, namely natural capital, social wellbeing, economic wellbeing, and institutional capital, are presented in **Figure 3-5** and a description of each provided in **Appendix 1.** Each variable was graded, or scored, independently. Some variables, such as those representing natural capital, were graded only on a presence/absence basis, whilst others, such as those representing social wellbeing, were graded based on their abundance (number/1000 people). The grading and derivation process for variables is discussed in greater detail in **Section 3.3** and **Appendix 2**.

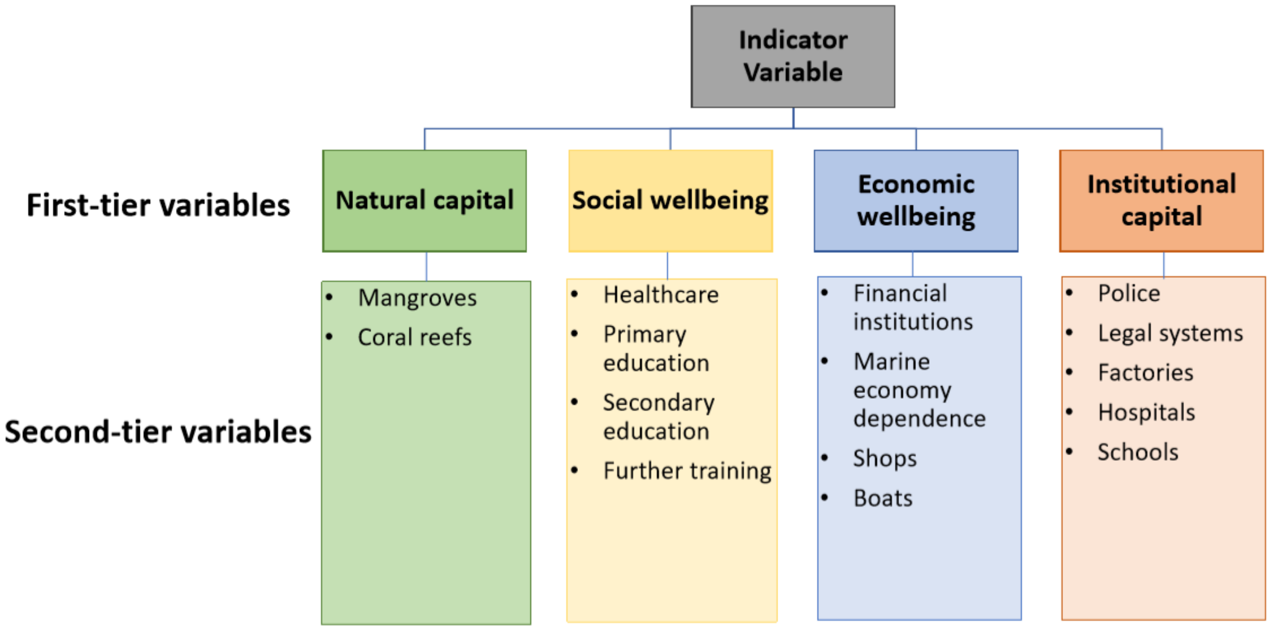



**Figure 3-5 First-and second-tier indicator variables likely to influence the blue economy**

## 3.3 Data Collection

Data for predicator and indicator variables were obtained through a review of available literature, as well as through spatial analyses of the selected sites. Literature interrogated included inter alia World Bank data, national and regional census data, journal and newspaper articles and internationally funded project reports. Where available, shapefiles were obtained in order to undertake spatial analyses for the collection of data pertaining to the selected variables. The majority of spatial analyses were undertaken using aerial imagery, namely Google Earth (https://www.google.com/earth/) and Satellites Pro (https://satellites.pro/). The use of aerial imagery involved conducting a "fly-over" of each case study site and manually identifying and recording the relevant physical features, such as roads and airports. Additionally, the search function in Google Earth was used to identify physical features that are generally recorded as part of its database, such as schools and shops. Examples of the types of data collected and how these were identified are illustrated in **Figures 3-6** to **3-9**.


**Figure 3-6 Example of spatial data collection in Saldanha, South Africa**


**Figure 3-7 Example of spatial data collection in Kibuyuni, Kenya**


**Figure 3-8 Example of spatial data collection in Andavadoaka, Madagascar**

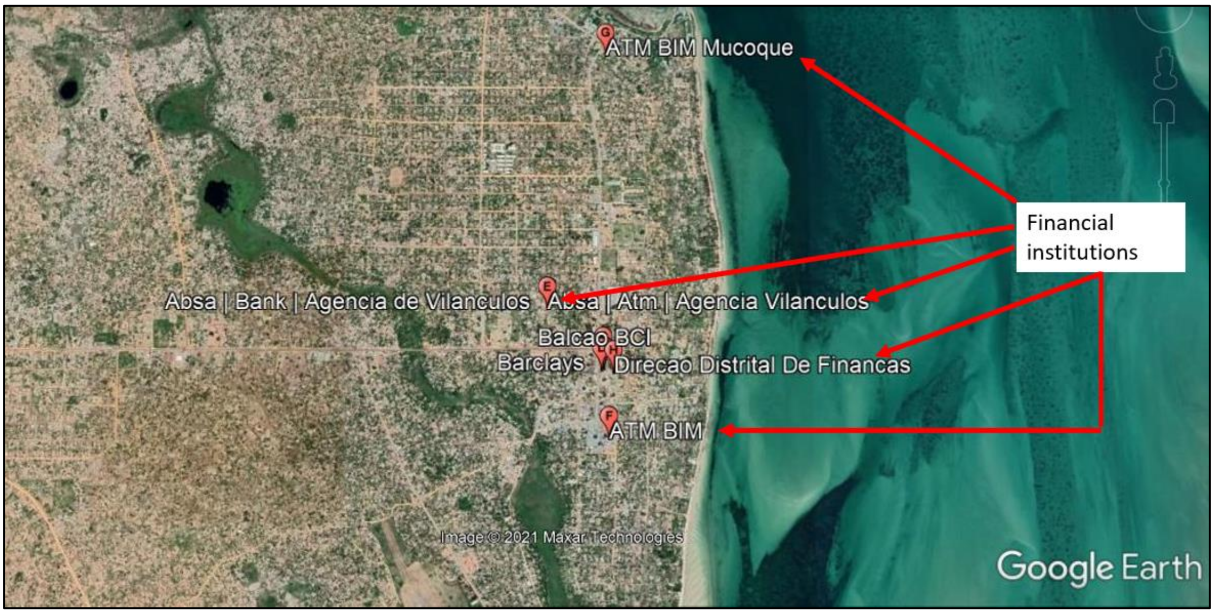



**Figure 3-9 Example of spatial data collection in Vilanculos, Mozambique**

The unit of measurement used to collect and record each variable differed. The decision to collect each variable in a particular unit of measurement was based on the granularity and level of detail available. The majority of variables were collected on a presence/absence basis, whilst some were assigned a score based on their abundance or condition and others were collected as count data and converted to a per capita basis. The reason for converting count data to per capita data is that count data does not account for the size of the population that that variable is servicing. For example, two different towns may each have only one primary school present but may have very different population sizes. One primary school for a population of 500 people is far better than one primary school for a population of 30 000 people. The scoring protocol for each variable is presented in **Appendix 2.**

In addition to collecting information regarding the variables, the population of each town was also recorded in order to allow for per capita measurements where necessary. Where some communities' population censuses may be dated, the population growth rate for each country was also obtained to allow for the current population of each case study site to be estimated.

## 3.4 Data Handling and Analysis

Where collected data were qualitative (e.g. presence/absence) they were translated into categorical variables in order to allow for numerical values to be assigned to them and thus allowing them to be statistically analysed. Because data were collected in different units of measurement, the data for each indicator were normalised to a scale of 0-1. Normalization allows for variables collected in multiple units of measurement to be reduced to a single standard scale and thus allows for variables to be comparable to each other. For example, one variable may be measured on a scale of 0 to 3 based on its condition where 0=not present, 1=poor condition, 2 =moderate condition and 3=good condition, whilst another variable may be measured based on a per capita basis. Typically, these two variables cannot easily be compared to one another as they are measured on different scales and in different units. As such, these two variables must be normalized to a single standard scale of 0-1 to allow comparisons to be made between them. The process for normalizing both categorical and continuous data is illustrated in **Text box 4** below.

Variables were then nested under the seven first-tier variables (predicator and indicator variables) and weighted to a cumulative weight score of one (1) for each first-tier variable. Weighting of variables was undertaken as it is unlikely that each variable plays an equally important role in contributing to the blue socioeconomic development of a settlement. Weightings were thus assigned to each second-tier variable to represent its relative importance to contributing to its first-tier variable. Variables that are more important in defining a specific variable get a higher, or heavier, weight. Assigning suitable weightings requires a prior knowledge of the importance of each variable if bias and skewing of the data are to be avoided. Given that prior knowledge regarding the importance of these variables was limited and would likely be biased, an objective and empirical approach for weight selection was used instead. Namely, a statistical analysis, specifically a Principal Component Analysis (PCA; see definition in **Text box 5**), was run on each of the seven first-tier groups of variables. This analysis provides correlation coefficients for each variable as part of its output which can then be used to develop a weight for each variable (Norlén, 2017). These weights were then checked to see if they appeared to be logical in the context of this study.

Scores for each variable for each case study were derived by multiplying the normalized values for each variable by its corresponding weight. The scores for each second-tier variable were then summed in order to obtain an overall score for each first-tier variable for each case study. The weights and scores for each variable are presented in **Appendix 3.**

PCAs were undertaken using the calculated scores for each variable in order to assess for correlations and relationships between first tier variables, the variables nested within each and between first-tier variables and sub variables. PCAs were run using Microsoft Excels' XLSTAT statistical add-in, as well as R statistical software. Additionally, Pearson's correlations were undertaken to assess for correlations between variables.

**Text box 4. Normalizing data**

**Categorical data**
Assuming we have 4 categories into which we have assigned variables:
0= absence
1= poor
2= moderate
3= good

The highest, or best, value gets assigned the highest value on the normalised scale (i.e., 1) while the lowest value gets the lowest value on your normalised scale (i.e., 0). In order to obtain the numbers for the other categories, 1 is divided by the number of categories (excluding that which is assigned 0). Therefor we obtain a value of 0.33. Categories thus increase in increments of 0.33, and so our new scale looks like this:
0= absence
0.33= poor
0.66= moderate
1= good

**Continuous data**
Continuous data is normalized using the following formula:

X'= (X'-xmin)/(xmax-xmin)

X'= value to be normalised
Xmin= the minimum value in the dataset
Xmax=the maximum value in the dataset

Lets say we have the following dataset:
Village A= 10
Village B= 3
Village C= 7
Village D= 1

Using the above formula, our dataset would look like this
Village A= 1
Village B= 0.22
Village C= 0.67
Village D= 0

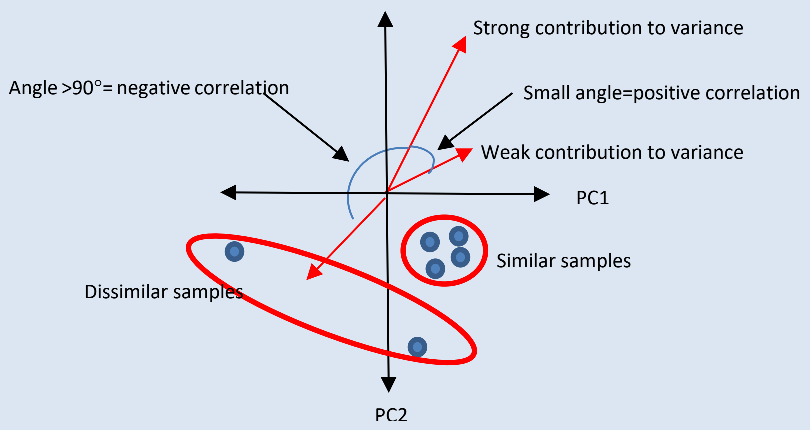
These two different datasets are now on the same scale and can be compared and analysed

**Text box 5. What is a Principal Component Analysis (PCA)?**

A Principal Component Analysis (PCA) is a tool used to reduce the dimensionality of the data when large datasets are present. A PCA reduces a large set of variables into a smaller one whilst ensuring that little information is lost. This reduces the "noise' in the dataset and ensures that the most important relationships in the data can be more easily identified and interpreted.

A PCA produces principal components which explain the variation in the dataset. Principal components are new variables that are created through combining the initial variables. The maximum possible information is assigned to the first component, and then the maximum remaining information into subsequent variables. Combining variables in this manner allows variables that contribute little information to be discarded and variables that account for the most variation in a dataset to be thoroughly explored. As such, the first principal component (PC1) can be viewed as the combination of variables that explain most of the variation in the dataset, the second principal component (PC2) the set of variables that account for the second most variation in the dataset and so on.

PCAs are graphically represented using a PCA biplot whereby the first principal component forms the horizontal or X axis, the second principal component the Y axis and subsequent principal components forming axes that fall on other dimensions within the graph space. Data points or samples are represented as dots and the distance between these samples and the way in which they cluster provides an indication of their similarity. PCA biplots also include vectors, arrows that begin at the origin of the graph and represent each variable in the dataset, which provides an indication of how strongly each indicator influences or contributes to its nearest principal component. The longer the vector, the stronger its influence on the principal component and the more it accounts for variation in the dataset. The angle between vectors also provides helpful insight when interpreting PCA biplots as this angle provides an indication of correlation between vectors. The smaller the angle, the more closely positively correlated the variables. When angles are greater than 90°, a negative correlation exists. An annotated example of a PCA is presented below.



# 4. RESULTS

The key results obtained from the PCAs and Pearson correlation analyses are presented below. Graphs presented have been annotated in order to assist in easier interpretation of the results. The statistical analyses outputs (i.e., data tables and unedited graphs) are provided in **Appendix 4.** A detailed discussion and interpretation of results is provided in **Section 5.**

## 4.1 Infrastructural and socioeconomic context of case study sites

A summary of the weighted scores for each of the first-tier variables for each village is presented in **Table 4-1.** Key findings are presented below:

- **Governance**: Villages located in Mozambique (Lalane, Ponta Do Ouro and Vilanculos) and Tanzania (Matemwe and Nungwi) had low governance scores whilst villages in Madagascar (Andavadoaka and Belo sur Mer) had the highest governance scores.
- **Strategic planning and social wellbeing** scores tended to be low within all villages, with the exception of Saldanha in South Africa and Watamu in Kenya.
- **Basic infrastructure and economic wellbeing** scores were highest in villages that possess a strong marine or coastal tourism industry (Vilanculos and Ponta Do Ouro in Mozambique, Saldanha in South Africa, Watamu in Kenya).
- **Institutional capital** scores were highest within larger towns (Saldanha in South Africa, Vilanculos in Mozambique and Watamu in Kenya), and lowest within small villages (Haga Haga in South Africa, Belo sur Mer in Madagascar, Matemwe in Tanzania and Ponta do Ouro and Lalane in Mozambique).

**Table 4-1 Weighted scores for each first-tier variable. Scores are colour ramped with green representing the highest scores and red the lowest for that variable**

| | | *Predicator Variables* | | | *Indicator Variables* | | | |
|---|---|---|---|---|---|---|---|---|
| **Country** | **Village** | **Governance** | **Strategic planning** | **Basic Infrastructure** | **Natural Capital** | **Social wellbeing** | **Economic wellbeing** | **Institutional capital** |
| Kenya | Kibuyuni | 0.61 | 0.00 | 0.33 | 1.00 | 0.12 | 0.11 | 0.31 |
| | Watamu | 0.71 | 0.75 | 0.74 | 1.00 | 0.52 | 1.00 | 0.70 |
| Madagascar | Andavadoaka | 1.00 | 0.00 | 0.49 | 1.00 | 0.41 | 0.11 | 0.54 |
| | Belo sur Mer | 0.87 | 0.00 | 0.33 | 1.00 | 0.20 | 0.25 | 0.21 |
| Mozambique | Lalane | 0.00 | 0.00 | 0.00 | 0.00 | 0.27 | 0.18 | 0.21 |
| | Ponto Do Ouro | 0.41 | 0.25 | 0.70 | 0.50 | 0.18 | 0.75 | 0.24 |
| | Vilanculos | 0.17 | 0.25 | 0.94 | 1.00 | 0.39 | 0.90 | 0.86 |
| South Africa | Haga Haga | 0.71 | 0.25 | 0.67 | 0.00 | 0.00 | 0.52 | 0.00 |
| | Saldanha | 0.71 | 1.00 | 0.99 | 0.00 | 0.73 | 1.00 | 0.80 |
| Tanzania | Matemwe | 0.17 | 0.00 | 0.61 | 0.50 | 0.31 | 0.32 | 0.21 |
| | Nungwi | 0.17 | 0.00 | 0.61 | 0.50 | 0.33 | 0.65 | 0.55 |

## 4.2 First-tier variable relationships

A PCA was undertaken to explore the relationships between first-tier variables and identify which of these variables are most important in explaining the differences between communities (variation in the dataset) (**Figure 4-1**). The variables most strongly correlated with Principal component 1 (PC1) are those that play the most important role in accounting for these differences. Out of the seven first-tier variables, five were found to be most important in terms of defining the difference between the assessed communities (most strongly positively correlated with PC1), namely economic wellbeing, institutional capital, strategic planning, social wellbeing, and basic infrastructure. These five variables were also found to covary i.e. if one increases, the remaining ones tend to increase as well. Because these five variables are strongly correlated with PC1, this principal component can be viewed largely as a measure of socioeconomic development. As such, communities that have a high value on the X axis (PC1), such as Saldanha in South Africa, Vilanculos in Mozambique, and Watamu in Kenya, tend to be those that have greater socioeconomic development (**Figure 4-1**). Conversely, those at the opposite, negative end of the X axis, such as Lalane in Mozambique, have poor socioeconomic development.

The second principal component (PC2) is strongly correlated with the first-tier variables that are slightly less important in explaining the variation between communities, namely natural capital and governance. These two variables also covary (**Figure 4-1**), indicating that as one increases the other tends to increase as well. Due to the strong correlation between natural capital and PC2, this principal component can largely be viewed as a measure of natural capital. As such, communities with a high score on the Y axis, such as Andavadoaka in Madagascar possess more natural capital than those on the opposite, negative side of the Y axis, such as Lalane in Mozambique (**Figure 4-1**).

The angle between each of the first-tier variables in **Figure 4-1** provides an indication of how closely these variables are correlated. The almost 90° between natural capital (PC2) and socioeconomic development (PC1) indicates that natural capital has little to no relationship or correlation with the first-tier variables that are strongly associated with PC1.

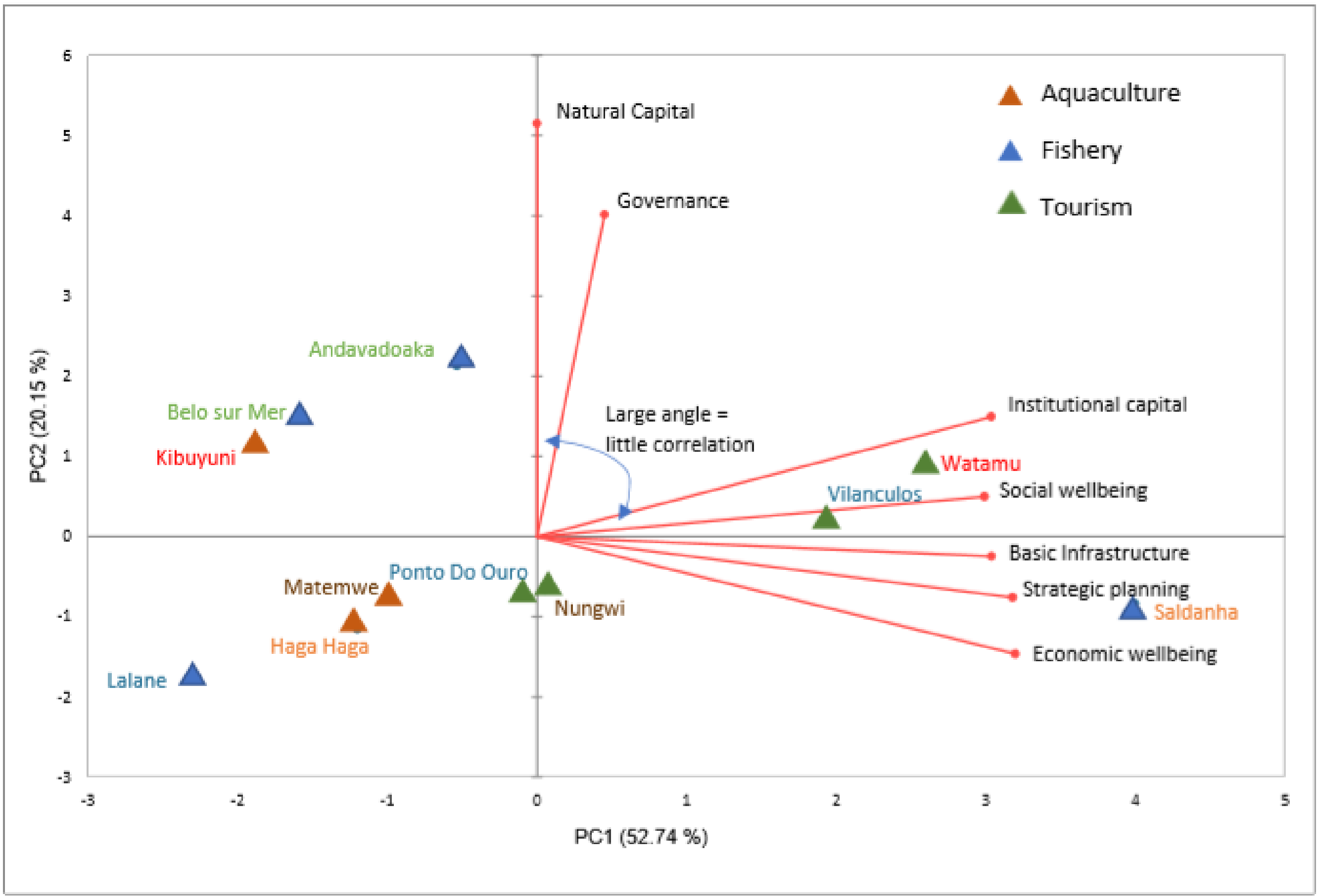



**Figure 4-1** **Principal Component Analysis biplot showing the first and second principal components of first-tier variables for the 11 case studies. The length of biplot lines approximates their variance whilst the angle between the lines indicates the correlation between variables. Community names written in blue are from Mozambique, communities in orange are from South Africa, communities in red are from Kenya, communities in green are from Madagascar and communities in brown are from Tanzania**

A Pearson correlation was undertaken to identify the relationships between each of the first-tier variables. The following relationships were identified:

1) A strong positive correlation between strategic planning and social wellbeing indicating that an increase in one tends to be associated with an increase in the other
2) A strong positive correlation between strategic planning and economic wellbeing indicating that an increase in one tends to be associated with an increase in the other
3) A strong positive correlation between basic infrastructure and economic wellbeing, indicating that an increase in one tends to be assocaited with an increase in the other
4) A strong positive correlation between instittuional capital and social wellbeing, indicating that an increase in one tends to be associated with an increase in the other.

## 4.3 Second-tier relationships

As stated above, the first-tier PCA and associated Pearson correlation matrix revealed strong relationships to exist between a number of the first-tier variables, namely, 1) strategic planning and social wellbeing, 2) strategic planning and economic wellbeing, 3) basic infrastructure and economic wellbeing and 4) institutional capital and social wellbeing. A PCA was undertaken for each set of variables in order to determine which specific predictor variables are responsible for contributing to the observed relationships. The relationship between institutional capital and social wellbeing was not interrogated as both variables in the pair are indicator variables.

### *4.3.1 Social wellbeing and strategic planning*

A PCA was undertaken to investigate the relationships between social wellbeing and the indicators of strategic planning and assess which indicators play an important role in accounting for the variation between communities. The results indicate that social wellbeing, the presence of a development plan and whether a development was planned were all strongly correlated with the first principal component (PC1) and thus all play an important role in defining the differences between communities (**Figure 4-2)**. These three variables were also covary. This indicates that as one increases, the others also tend to increase.

Given that development plan, planned development and social wellbeing all contribute strongly to PC1, as evidenced by the long length of each of their biplot lines, this principal component can be viewed as measure of strategic development and social wellbeing (**Figure 4-2**). As such, communities that score highly on this component (i.e. the X axis), namely Saldanha in South Africa, have good social wellbeing and strategic development. Conversely, communities that occur along the opposite, or negative side of this axis, such as Malagasy communities (Andavadoaka and Belo sur Mer), the Tanzanian communities (Nungwi and Matemwe), Ponta Do Ouro (Mozambique), Lalane (Mozambique), Kibuyuni (Kenya) and Haga Haga (South Africa) have poorer strategic planning and lower levels of social wellbeing (**Figure 4-2**).

A Pearson correlation between each of the three variables revealed the following relationship:

1. A strong positive correlation between social wellbeing and the existence of a development plan. This indicates that where a development plan is present, communities tend to have improved social wellbeing.

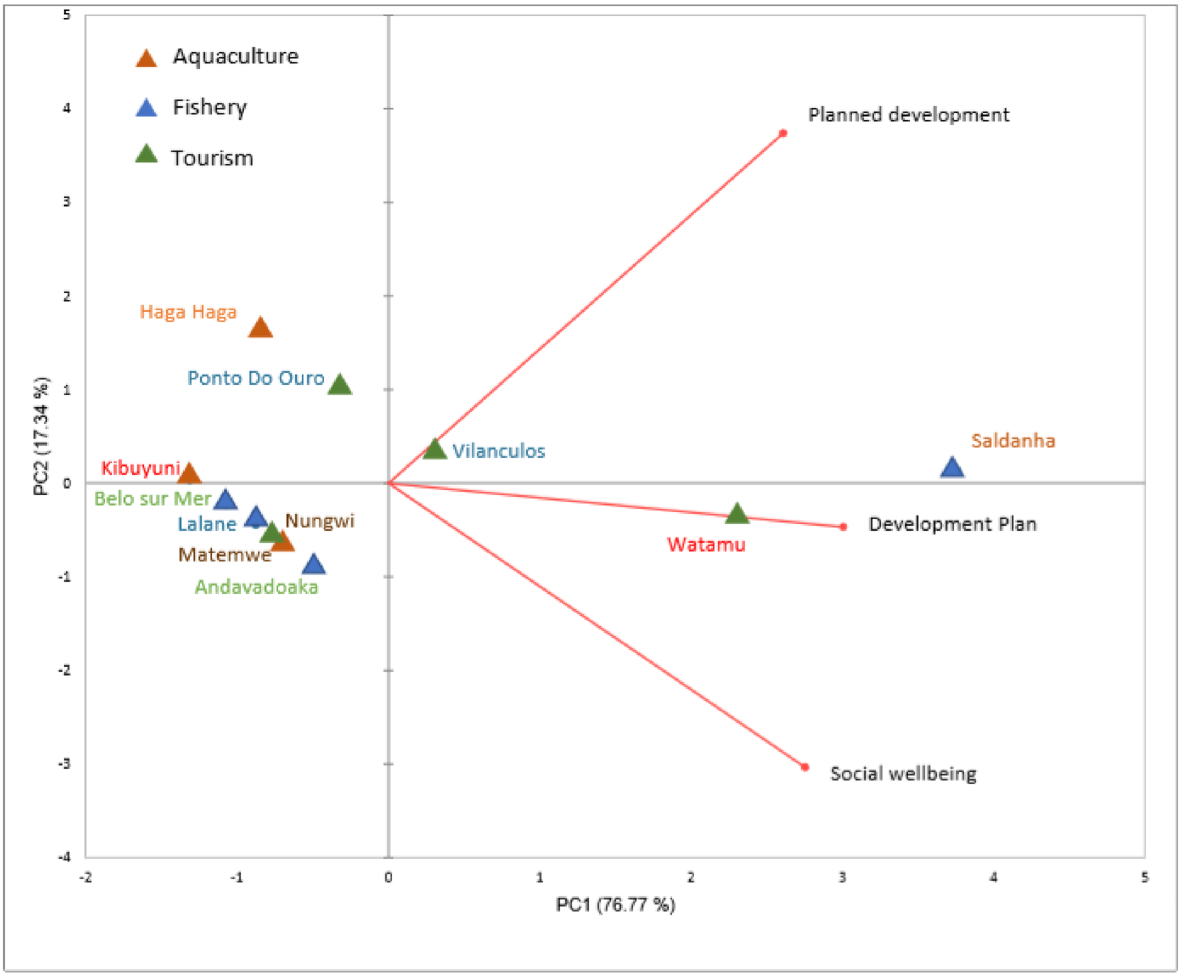



**Figure 4-2** **Principal Component Analysis biplot showing the first and second principal components of social wellbeing and strategic planning indicators for the 11 case studies. The length of biplot lines approximates their variance whilst the angle between the lines indicates the correlation between their corresponding variables. Community names written in blue are from Mozambique, communities in orange are from South Africa, communities in red are from Kenya, communities in green are from Madagascar and communities in brown are from Tanzania**

## *4.3.2 Economic wellbeing and strategic planning*

A PCA was undertaken to assess the relationships between economic wellbeing and indicators of strategic planning and to determine which variables play the most important role in accounting for variation between the communities. The results indicate that economic wellbeing, planned development and the presence of a development plan are all strongly positively correlated with PC1 and thus all play an important role in accounting for the variation between communities (**Figure 4-3**). These three variables were also found to be covariant, indicating that as one increases the others also tend to increase.

Given that all three variables are strongly correlated with PC1, this principal component can be seen as a measure of all three. As such, communities that score highly on this component (x-axis), namely Saldanha in South Africa and Watamu in Kenya, have high levels of economic wellbeing, show evidence of being planned developments and have a development plan in place (**Figure 4-3**). Conversely, communities that score poorly on this component, such as the Malagasy communities (Andavadoaka and Belo sur Mer), the Tanzanian communities (Matemwe and Nungwi), Lalane (Mozambique) and Kibuyuni (Kenya), have poor economic development, show little evidence of planning and do not have a development plan in place.

The second principal component (PC2) was found to be moderately positively correlated with the presence of a development plan. As such, communities that score poorly (i.e. on the negative side of the axis) on this component (the Y axis) generally do not possess a development plan. Specifically, whilst Haga Haga (South Africa), Ponta Do Ouro and Vilanculos (both Mozambique) show some evidence of planning and have moderate to good economic wellbeing, these communities lack a development plan (**Figure 4-3**).

A Pearson correlation between each of the three variables revealed the following relationships:

1) A strong positive correlation between economic wellbeing and planned development, indicating that communities that show evidence of having been planned tend to have greater economic wellbeing.

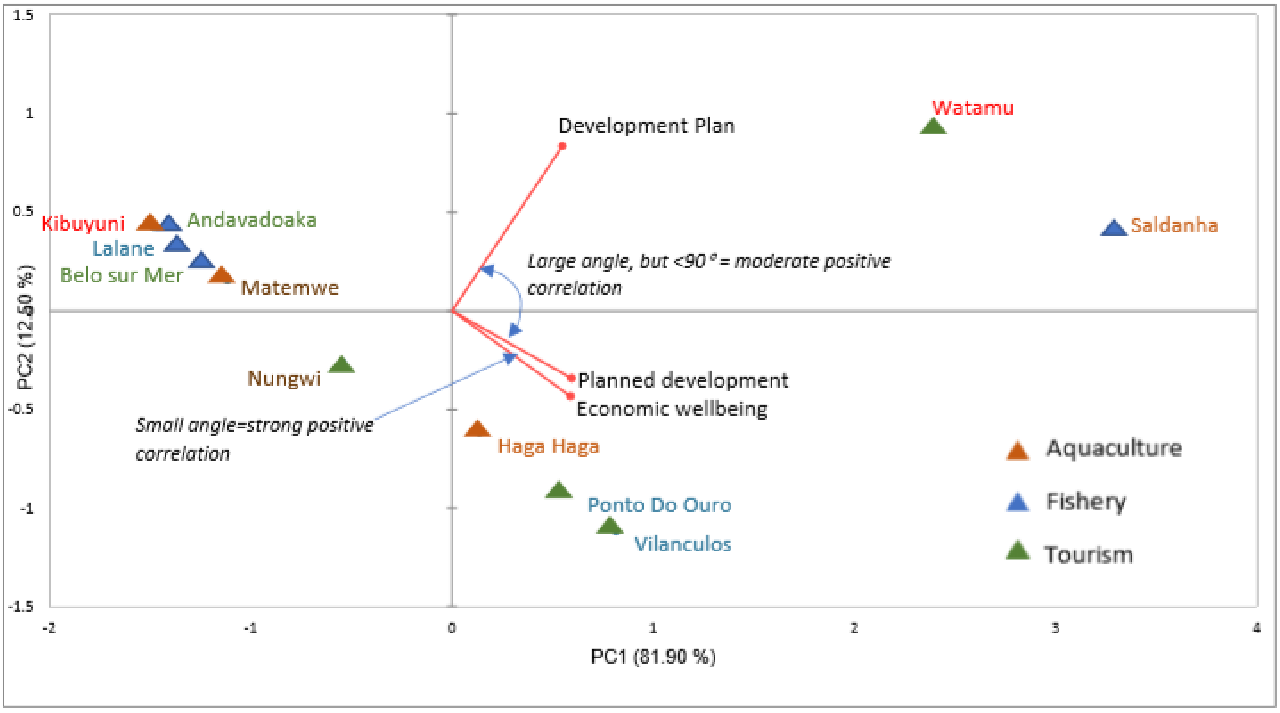



**Figure 4-3** **Principal Component Analysis biplot showing the first and second principal components of economic wellbeing and strategic planning indicators for the 11 case studies. The length of biplot lines approximates their variance whilst the angle between the lines indicates the correlation between their corresponding variables. Community names written in blue are from Mozambique, communities in orange are from South Africa, communities in red are from Kenya communities in green are from Madagascar and communities in brown are from Tanzania**

### *4.3.3 Economic wellbeing and basic infrastructure*

A PCA was undertaken to assess the relationships between economic wellbeing and basic infrastructure variables and determine which variables play the most important role in accounting for variation between the communities. The results indicate that economic wellbeing, roads, airports, access to urban centres, electricity, potable water, sewerage systems and communications are all strongly positively correlated with PC1 and thus all play an important role in accounting for the variation between communities (**Figure 4-4**). These eight variables were also found to be covariant, indicating that as one increases the others also tend to increase. Based on the fact that these eight variables are strongly correlated with PC1, this component can largely be viewed as being a measure of these, with electricity and roads proving to be the most important components of basic infrastructure as they contribute the most variation to PC1. As such, communities that have a high value on the X axis (PC1), namely Saldanha in South Africa and Watamu in Kenya, have good economic wellbeing and possess a suite of basic infrastructure (**Figure 4-4**). Conversely, communities that occur on the opposite, or negative, side of the X axis, such as Lalane (Mozambique), have poor economic development and lack this suite of basic infrastructure.

Harbours/ports were found to be strongly positively correlated with PC2, indicating that while this type of infrastructure is not as important as the suite of infrastructure associated with PC1, it does still play a role in defining the variation between communities.

Tourism communities, namely Watamu (Kenya), Vilanculos (Mozambique), and Ponta Do Oura (Mozambique), tended to be similar in that they have positive scores relating to PC1, indicating that these communities tend to have suite of basic infrastructure as well as good economic wellbeing (**Figure 4-4**). The slightly more negative PC1 score for Nungwi (Tanzania) was largely driven by the absence of an airport at the site, a feature the other tourism communities possessed, and a slightly lower economic wellbeing score than the other tourism communities.

With the exception of Saldanha (South Africa), fishing communities, namely Lalane (Mozambique), Belo sur Mer and Andavadoaka (both Madagascar), are similar in that they have negative scores in terms of basic infrastructure and have poor economic wellbeing (**Figure 4-4**).

The aquaculture villages of Kibuyuni (Kenya), Matemwe (Tanzania) and Haga Haga (South Africa) are closely clustered and thus similar in terms of their economic wellbeing, with all sites having moderate to low economic wellbeing scores (**Figure 4-4**). Haga Haga and Matemwe have slightly higher scores in terms of basic infrastructure than Kibuyuni. The higher infrastructure score at Haga Haga is largely being driven by the village's superior electricity supply and sewerage system. Kibuyuni on the other hand lacks infrastructure in terms of electricity and roads. All three sites have negative scores in terms of airport access.

A Pearson correlation between each of the variables revealed the following key relationships:

1) A strong positive correlation between roads and economic wellbeing, indicating that an increase in one tends to be associated with an increase in the other
2) A strong positive correlation between airports and economic wellbeing, indicating that an increase in one tends to be associated with an increase in the other
3) A strong positive correlation between electricity supply and economic wellbeing, indicating that an increase in one tends to be associated with an increase in the other.

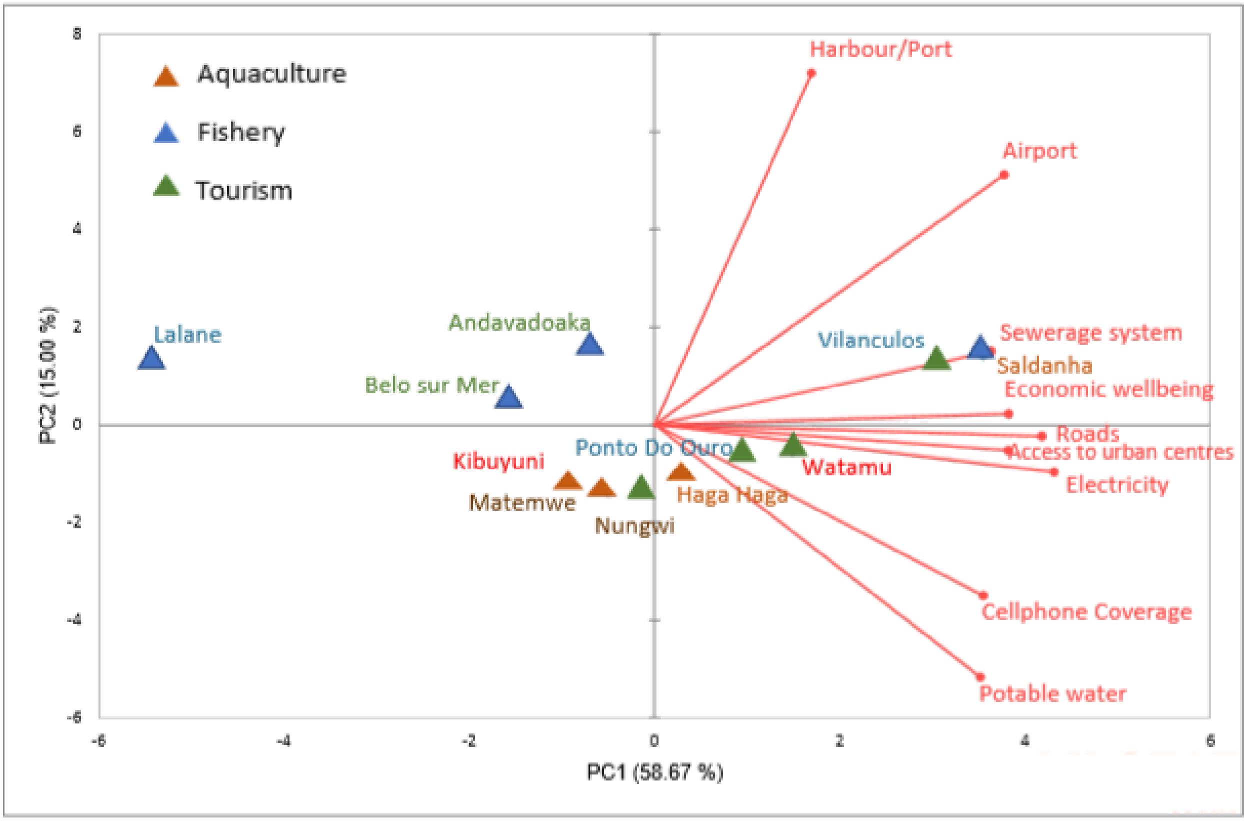



**Figure 4-4** **Principal Component Analysis biplot showing the first and second principal components of economic wellbeing and basic infrastructure indicators for the 11 case studies. The length of biplot lines approximates their variance whilst the angle between the lines indicates the correlation between their corresponding variables. Community names in blue are from Mozambique, communities in orange are from South Africa, communities in red are from Kenya, communities in green are from Madagascar and communities in brown are from Tanzania**

## 5. DISCUSSION

There is clear knowledge gap regarding the role of basic infrastructure in blue economic growth and/or socioeconomic development and as such the primary aim of this study was to address the question: Does the presence of basic infrastructure (e.g. roads, harbours, access to electricity, sanitation and water) correlate with local blue economic growth and/or socioeconomic development in rural coastal communities? The scope of the study was expanded to investigate whether strategic planning of a community, as well as governance relating to the use and management of natural resources, might also play a role in the socioeconomic development of a community.

Although the study sought to assess whether basic infrastructure correlates with local blue economic growth, assessing this requires an investigation of blue economic growth in each village over time. Obtaining the level of detail necessary to conduct such analyses proved challenging and as such only the relationship between basic infrastructure and a community's socioeconomic development was interrogated. A key assumption related to this is that in these small rural communities, socioeconomic development is facilitated by use of marine resources and as such communities with higher levels of socioeconomic development likely have a stronger blue economy.

To develop a deeper understanding and gain more meaningful insights into the impact of basic infrastructure, strategic planning and governance on socioeconomic development, the key components of socioeconomic development, namely natural capital, social wellbeing, economic wellbeing, and institutional capital, were interrogated in terms of their relationship with predictor variables (i.e. basic infrastructure, strategic planning and governance).

The study revealed the following key findings:

- The presence of a development plan for a community is strongly positively correlated with its social wellbeing
- Whether a community is a planned development is strongly positively correlated with its economic wellbeing
- Basic infrastructure, specifically roads, airports, and electricity supply, is strongly positively correlated with economic wellbeing
- Of the marine economic activities investigated, tourism is most closely associated with social and economic wellbeing
- Commercial fishery appears to be more closely associated with social and economic wellbeing than artisanal fisheries which largely lack basic infrastructure and possess relatively low social and economic wellbeing

Interestingly, the first-tier variables of governance, natural capital, social wellbeing, and institutional capital showed no strong relationships with any other variables, indicating that these variables do not play a significant role in the context of this study. However, it must be noted that a limited dataset was interrogated, and further research would be required to fully investigate the role these variables may play in rural coastal communities and the relationships that may exist between these variables.

The key findings of this study, sector-specific findings and observations relating to the first-tier variables where no strong relationships were identified are discussed below. Key considerations and limitations of the study are also outlined.

## 5.1 Strategic planning

### *5.1.1 The relationship between strategic planning and social and economic wellbeing*

The strategic planning context of a settlement proved to play an important role in both the economic and social wellbeing of the settlement. For the purposes of this study strategic planning considered two components, namely 1) did the settlement show evidence of having been a planned development, and 2) was a development plan that guides infrastructural development in place?

The first component, namely whether the settlement was a planned development, was found to be positively correlated with its economic wellbeing, indicating that the more planned a settlement, the better its economic wellbeing. Unplanned settlements tend to develop irregularly and lack basic planning or structure within their layout, and generally lack basic infrastructure (Kironde, 2006). This lack of planning within the design of a settlement creates a number of challenges for improving the status of the settlement and the livelihoods of its inhabitants, including difficulties in installing conventional infrastructure due to the haphazard nature of roads and dwellings within the settlement (Criqui, 2015). Conversely, planned settlements have basic infrastructure present and have typically received government input and support in their planning (Aditantri et al., 2019).

Infrastructure is recognised as an important driving force in economic growth (Srinivasu & Rao, 2013). Specifically, the presence of basic infrastructure within planned developments likely allows for important economic activities to occur. For example, roads likely allow for transport of goods and access to market whilst electricity allows for factories to operate and processing of goods to take place. Additionally, planned settlements have often received investment and support from government, with this investment most likely being in the form of supporting the installation and improvement of basic infrastructure. This perceived relationship between basic infrastructure and development is supported by the finding that these two variables are covariant, indicating an increase in one is related to the increase in another.

The second component, namely whether a development plan is in place to guide future development, was found to be positively correlated with social wellbeing, indicating that settlements for which a development plan exists, or which feature in a government-level development plan, have higher levels of social development. This relationship is not well documented in the literature. However, it may potentially be explainable in terms of investment into the development of communities. The mention of a community in a development plan provides an indication that investment, likely in terms of improving infrastructure, is planned, or already in progress, for the community in question. This investment is likely to improve social wellbeing within the community, either through job creation where infrastructure is being installed, or potentially through living standards where healthcare or education facilities are being supplied.

The findings relating to the relationships between development planning and socioeconomic development indicate that where new settlements are to be established, it is critical that these are well-planned in terms of their layout and basic infrastructure assemblage in order to facilitate their economic success. The relationship between the existence of a development plan and social wellbeing provides an indication that targeting rural coastal communities for investment and ensuring that a development plan is in place to guide their future development could play an important role in improving their social wellbeing.

### *5.1.2 General findings relating to strategic planning*

Saldanha (South Africa) and Watamu (Kenya) were found to have the highest scores in terms of strategic planning, as well as the highest scores in terms of social wellbeing and economic wellbeing. This is unsurprising as these were the two largest settlements assessed (28 142 and 27 857 people respectively) and were from the two most developed nations assessed, South Africa and Kenya respectively. Smaller, more rural communities namely Kibuyuni (Kenya), Andavadoaka (Madagascar), Belo sur Mer (Madagascar), Lalane (Mozambique), Matemwe (Tanzania) and Nungwi (Tanzania), showed no evidence of having been planned and all likely have their origins as small fishing villages. Ponta Do Ouro and Vilanculos (both Mozambique), however, showed some evidence of having been planned which has subsequently been followed by urban sprawl. Both these villages have become popular tourist destinations and it is likely that this has been a major contributing factor in urban sprawl as people migrate to these areas in search of work, as has been recorded in Ponta Do Ouro, Mozambique (Come, 2014). This urban migration likely exceeds the rate at which infrastructure and planned housing can be constructed, resulting in urban sprawl. Haga Haga also showed some evidence of planning, however due to the extremely small nature of the village (approximately 150 people) and lack of certain infrastructure, such as tarred roads it could not be defined as a highly planned settlement, thus accounting for its lower development score.

## 5.2 Basic infrastructure

### *5.2.1 The relationship between basic infrastructure and economic wellbeing*

A strong positive relationship was found to exist between basic infrastructure and economic wellbeing, indicating an increase in one is associated with an increase in the other. A number of studies have found a positive relationship to exist between basic infrastructure and the level of economic development of a community (Srinivasu & Rao, 2013). Although these studies were not conducted specifically in rural coastal communities, based on the results of this study, their findings are likely relevant and provide important insights into why a relationship between basic infrastructure and economic wellbeing may exist. Specifically, these studies reveal that improved basic infrastructure can allow for the expansion of local manufacturing industries, as well as enlarging markets and improving trade (Kodongo & Ojah, 2016; Srinivasu & Rao, 2013). This, in turn, will lead to job creation and improved economic circumstances, which often leads to improved social wellbeing of the community in question. Basic infrastructure provision thus has the potential to play an important role in alleviating poverty (Kodongo & Ojah, 2016). This study did note a positive correlation, albeit a moderate one, to exist between economic wellbeing and social wellbeing, indicating that where economic wellbeing improves, social wellbeing is also likely to improve.

Upon further interrogation it was found that the types of basic infrastructure which possess a strong positive relationship with economic development are roads, airports, and electricity. Road access is considered to be a critical component of both economic development and social wellbeing (Plessis-Fraissard, 2007). In the African context, where many rural communities lack adequate road networks, this lack of road infrastructure is believed to be inhibiting economic growth and socioeconomic development (Lombard & Coetzer, 2006). As such, investment in road infrastructure has been found to play an important role in alleviating poverty (Plessis-Fraissard, 2007). In particular, roads are crucial as they allow rural communities to access markets in which to sell goods and thus generate an income, as well as purchase goods that are needed (Lombard & Coetzer, 2006; Plessis-Fraissard, 2007). Additionally, roads are important to ensure that critical services, such as health care, can be supplied (Plessis-Fraissard, 2007). This is particularly important in communities, such as many of those assessed in this study, where access to healthcare is relatively limited and people likely have to travel to larger nearby communities for medical treatment. In fact, the importance of rural roads is so well recognised as being of great economic importance that between 2001 and 2006, the World Bank lent, on average, $1 030 million a year for rural road development (Plessis-Fraissard, 2007).

A strong positive relationship between airports and economic wellbeing was also found to exist. Specifically, towns with good economic wellbeing tended to have better airports. This link between airports and economic development is supported in the literature which shows that airport development is often linked with economic development (Green, 2014). It has been noted that airports likely play an important role in furthering the development of communities (Green, 2014). This is largely due to their role in transporting both people and goods and services (Baltaci et al., 2015). Although a relationship between airports and economic wellbeing is known to exist, establishing a cause- and- effect relationship is challenging and likely to be context-specific. For example, economic growth may create demand for airports, or generate the financial capital necessary to develop these airports

(Green, 2014). Conversely, the development of airports may raise productivity and/or demand of certain sectors of the economy, thus generating income and facilitating economic development (Green, 2014). Furthermore, airports may increase traffic to an area which may then encourage local investment within the area (Button et al., 2010).

This study also revealed a strong positive correlation to exist between access to electricity and economic wellbeing. This is unsurprising as a number of studies have found that access to electricity is a precondition for improving livelihoods in rural communities and that a lack of reliable access to electricity inhibits both people's opportunities and quality of life (Azimoh et al., 2016; Riva et al., 2018). The importance of electricity to socioeconomic development is emphasised by its inclusion as a Sustainable Development Goal (SDG), namely SDG 7: "ensure access to affordable, reliable, sustainable and modern energy for all" by 2030. The provision of access to rural communities has the ability to impact on economic growth in a number of ways. For example, it may allow the community to pursue new income generating activities that rely on electricity supply, such as the processing of goods and activities that require the use of tools (Kirubi et al., 2009; Riva et al., 2018). Additionally, the provision of electricity requires the installation of electrical infrastructure, the construction of which may potentially generate jobs for local community members (Riva et al., 2018). This job creation, and thus income generation, helps boost the economy of areas and drive economic development.

When looking to invest in the provision of basic infrastructure in rural communities in an effort to improve their economic wellbeing, the findings of this study suggest that investment in electricity supply and road infrastructure may be most beneficial, largely through improving access to markets and resources, and allowing for engagement in new activities. However, once-off investment in this infrastructure is unlikely to result in long-term, sustainable development. This infrastructure requires maintenance in order to remain effective and this is an important factor to consider in planning and design. Furthermore, the provision of this infrastructure is unlikely to be enough to realise economic development on its own. It is imperative that support and guidance accompany the provision of infrastructure to assist communities in sustainably reaching the full potential of the economic activities they engage in, as well as diversifying their economic activities. It is important to note that communities are complex and contextual. As such, each situation should be thoroughly investigated to determine their needs in terms infrastructure and economic growth, as well as to determine the feasibility and suitability of infrastructure provision.

### *5.2.2 General findings relating to basic infrastructure*

A wide range of infrastructure scores were recorded between the different villages. Towns, namely Saldanha (South Africa), Watamu (Kenya), Vilanculos, and Ponta Do Ouro (both in Mozambique) were found to have higher basic infrastructure scores than the smaller villages.

This is to be expected because as populations grow, the demand for basic infrastructure is likely to increase and become increasingly warranted and needed for the successful functioning of the community. The major findings relating to basic infrastructure related to the economic activity undertaken in the community. This is further discussed in **Section 5.6.**

## 5.3 General findings relating to governance

Although governance did not possess any strong correlations with socioeconomic development, it is possible to make some observations regarding the governance scores of each of the villages. The highest governance scores were noted in the two villages in Madagascar, namely Andavadoaka and Belo sur Mer. This is due to the fact that both villages fall within some sort of protected area (the Velondriake Marine Protected Area and the Belo-sur-Mer Kirindy-Mite Biosphere Reserve, respectively), with high levels of community involvement noted in Andavadoaka and evidence of both communities attempting to manage their resources in more sustainable manners.

The villages of Kibuyuni, Watamu (both in Kenya), Haga Haga and Saldanha (both in South Africa) also had moderate to high scores for governance which were largely attributable to the presence of protected areas and absence of notable degradation of marine resources at these sites. The higher governance scores recorded in the Kenyan and South African villages is to be expected as these countries are more developed and use of marine resources should, theoretically, be being closely monitored by relevant agencies.

Mozambican and Tanzanian villages possessed relatively low governance scores, which were largely attributable to the absence of protected areas and poor to moderate sustainable management of resources. Given the development status of these countries as LDCs, it is likely that limited support exists to enforce the sustainable management of resources in small, rural communities.

## 5.4 General findings relating to natural capital

Although natural capital was found to possess no strong correlations with any other variables, general observations relating to it can be made. Scores for natural capital were based on two natural capital components, namely coral reefs and mangroves. The scores for natural capital were based only on the presence of these two features, not on their condition or extent, as this level of detail proved difficult to obtain. Where natural capital scores were low, as in the cases of Lalane (Mozambique), Haga Haga and Saldanha (both in South Africa), this was attributable to an absence of mangroves and coral reefs at these areas rather than poor management of natural capital. Where natural capital scores were moderate, namely in Ponta

Do Ouro (Mozambique), Matemwe and Nungwi (both in Tanzania), this was attributable to these villages only possessing coral reefs or mangroves, and where natural capital scores were high, namely in Kibuyuni, Watamu (both Kenya), Andavadoaka, Belo sur Mer (both in Madagascar), and Vilanculos (Mozambique), this high score was attributable to these villages possessing both mangroves and coral reefs. It was noted that in villages where tourism is the main marine economic activity taking place, the natural capital score is moderate to high. This is unsurprising as both mangroves and coral reefs provide a basis for popular tourist activities, such as birding and snorkelling.

Natural capital likely plays an important role in blue socioeconomic development and thus warrants further investigation. Ideally, a larger suite of indicators to represent natural capital, such as the condition of coral reefs and mangroves, fish stocks, and ecosystem health, should be investigated. Due to the fact that indicators requiring this level of detail could not be detected spatially, and due to time constraints, these indicators were not collected as part of this study.

## 5.5 General findings relating to social wellbeing

Although social wellbeing possessed no strong correlations with any other variables, some observations regarding social wellbeing can be made. Social wellbeing tended to be low across all sites, with the exception of Saldanha (South Africa) and Watamu (Kenya). Social wellbeing was based only access to education and financial institutions and did not consider other factors that may contribute to it, such as quality of life.  The large populations in Saldanha (South Africa) and Watamu (Kenya) may warrant education and health care facilities, thus accounting for their higher scores. Furthermore, these two communities fall within the relatively developed countries, namely South Africa and Kenya where efforts are made to rollout education and health care to the population. The smaller population sizes, rurality, and proximity to other communities, of the other villages may account for their lower social wellbeing scores for a number of reasons. Firstly, smaller populations that can access health care and education in other communities may not feel installing these institutions in their communities is warranted and secondly, in small rural, communities where issues such as malnourishment are a concern, education may not be a priority.

## 5.6 Sector specific findings

### *5.6.1 Aquaculture*

All three villages in which aquaculture was the primary marine economic activity, namely Haga Haga (South Africa), Matemwe (Tanzania) and Kibuyuni (Kenya), had relatively low social and economic wellbeing and limited available institutional capital, despite the fact that two of these villages, namely Haga Haga (South Africa) and Matemwe (Tanzania), had moderate basic infrastructure in place. It must, however, be noted that all three villages have relatively small populations (>5 400) and the limited availability of social wellbeing indicators, namely healthcare and education, and economic wellbeing indicators, namely financial institutions and shops, is not warranted in towns with such small populations when these amenities can be accessed in nearby towns, as is the case for each of these villages. Due to the limited variation in villages with a strong aquaculture-based economy, in terms of basic infrastructure presence, social wellbeing, and economic wellbeing, and thus the inability to make comparisons between good and poor situations, drawing definitive conclusions on the importance of basic infrastructure in facilitating success in aquaculture was not possible.

However, the case of Kibuyuni in Kenya offers some insights into a possible relationship that exists between the economic success of aquaculture and the corresponding impacts on basic infrastructure and social wellbeing. Specifically, the community in Kibuyuni has had great success with seaweed farming. This success has facilitated the development of a good road network to other towns and an electrical power supply to the village, which has consequently improved education through allowing children to do schoolwork after school hours (Mirera et al., 2020). Furthermore, the economic success of aquaculture in Kibuyuni has allowed the village to build a modern fish handling facility to reduce loss of landed catches (Mirera et al., 2020). The village has also constructed infrastructure that will enhance the aquaculture industry, namely storage facilities to hold dry seaweeds and a small factory to process the seaweed and make products such as seaweed powder and soaps (Mirera et al., 2020). The presence of this infrastructure is likely to increase income from aquaculture and contribute to improved economic wellbeing of the community.

Seaweed aquaculture is considered to be a major source of livelihood in many rural coastal communities in developing countries (Mirera et al., 2020; Moh'd, 2015). Much of the appeal of seaweed aquaculture is rooted in the fact that it requires low investment costs, yields high returns, is believed to have limited environmental impacts and offers great potential for employment for women and youth (Mirera et al., 2020). Whilst the findings of this study could draw no definitive conclusions regarding the importance of seaweed aquaculture for the social and economic wellbeing of rural coastal communities, the literature suggests that investment in the sector in rural communities could yield great potential for improving livelihoods.

Although not part of the data collection or analyses of this study, observations regarding the role of gender in aquaculture case studies were made. Although no information regarding female employment in the aquaculture industry in Haga Haga was obtained, such information was available for Kibuyuni and Matemwe. In both villages seaweed farming was the type of aquaculture being undertaken and in both cases the industry was female-dominated. In

Kibuyuni 75% of the farmers are female whilst in Matemwe 99% are female (Mirera et al., 2020; The Revolutionary Government of Zanzibar, 2017). This employment in the aquaculture industry has reportedly resulted in numerous benefits for women, including providing them with the opportunity to earn their own income and participate more proactively in societal issues (Mirera et al., 2020). Although it is unclear exactly why more women than men participate in seaweed farming, evidence from Tanzania suggests that men prefer to engage in activities that generate income more quickly than seaweed aquaculture, which takes time before an income is derived (Msuya & Hurtado, 2017). The division in gender roles in aquaculture may also potentially be due to the fact that women traditionally engage in activities that are close to the shore and thus require no training in terms of swimming or steering a boat, whilst men tend to engage in activities that are perceived to be more physically challenging or dangerous that take them out to sea.

In the WIO region more women participate in seaweed aquaculture than men and this has been shown to yield a number of benefits these women, empowering them to become greater role players in their communities (Msuya & Hurtado, 2017). Investing in aquaculture in rural coastal communities thus has the potential for empowering women and improving their livelihoods and social status.

### *5.6.2 Fishery*

With the exception of Saldanha in South Africa, all fishery villages assessed, namely Lalane (Mozambique), Andavadoaka, Belo sur Mer (both in Madagascar), were unplanned settlements with no evidence of being on their respective government's radar for future development. These communities also largely lacked basic infrastructure and had poor social and economic wellbeing. Conversely, Saldanha was a highly planned settlement with high amounts of basic infrastructure, good social and economic wellbeing, and available institutional capital. It must be noted that in the three lesser developed, poorer fishing communities people largely participated in fishing for subsistence purposes and small-scale trade whilst in Saldanha fishing is undertaken at a commercial level with some export of goods occurring. The polarized socioeconomic situations in artisanal versus commercial fisheries suggests that in order to improve the economic status, and in turn the social situation, in rural fishing communities, a shift from fishing for subsistence purposes to trade of catches is likely to be necessary.

Within the context of Saldanha (South Africa), roads, electricity, and urban access appeared to be the most important features of basic infrastructure relating to economic wellbeing, respectively (**Figure 3-6**). Saldanha itself is an urban centre and thus has available markets within the town for the trade of catch. Roads likely play a number of important roles in the economy of the town, mainly through providing ease of transport for labour, equipment and materials, and fishery products. Electricity is likely to be an extremely important component of basic infrastructure within the town for a number of reasons. For example, electricity is essential for ensuring that cold storage of catches is possible and is needed for the running of factories where catches are processed for various different purposes. The case study of Saldanha suggests that if the growth of the fishery industry is to be supported such that it facilitates economic growth and a corresponding improvement in the social wellbeing of a community, investment should be aimed at providing road access and electricity. The provision of roads will ensure that materials and equipment needed for the industry can be more easily obtained, and, potentially more importantly, ensure that catches and associated products can be taken and sold to relevant available markets in nearby urban centres.

Attempting to grow the fisheries sector to commercial levels in rural communities must, however, be undertaken with great care and a holistic approach. Across the world, fisheries are under great pressure from overexploitation and ongoing stock depletion (Baust et al., 2015). Artisanal fisheries in rural coastal communities are poorly monitored and little is known about the available stocks in these areas and thus the potential to grow their fisheries economy (Samoilys et al., 2019). Trying to increase catches to support commercial activities is, however, likely to place increased pressure on an already vulnerable resource and in the long-term is likely to lead to a decline in the stocks, fewer catches and corresponding negative consequences for income and the economy. However, growing the fishing industry in rural communities is possible, provided it is done in a sustainable manner. For example, implementing catch quotas and gear restrictions, creating marine protected areas where fishing is prohibited and developing new management approaches are likely to be important tools for managing fish stocks (Baust et al., 2015). The case study of Andavadoaka provides an important example of sustainable management of marine resources for facilitating improved catches in the fishery sector. In response to declining local octopus populations, the village implemented octopus closures-periods of time when octopus hunting is banned-which has resulted in an increase in both the number and weight of octopuses caught and, in turn, increased revenue for fishers (United Nations Development Programme, 2012).

It must, however, be acknowledged that small scale fisheries are complex and show great variation due to a range of ecological, socio-cultural, economic and institutional factors and the findings of this study can thus not be used to draw definitive conclusions for all coastal rural communities (Osuka et al., 2020). When looking to enhance the socioeconomic situation of a particular community it is essential that the socioeconomic, ecological and cultural context of that community is investigated.

Little information regarding the role of gender in fishery in each of the case studies was obtained. However, evidence suggests that male and female roles in the commercial hake sector in Saldanha (South Africa) differ greatly. Specifically, whilst men are likely engaged in the actual catching of the fish, most of the processing of hake is done by women (Kupara, 2014). This has been attributed to the fact that women are more precise in their work, an important attribute in the processing of fish, and uncomfortable with going to sea, often perceived to be a dangerous activity (Kupara, 2014). The ability of women to engage in the processing of catches has generated female employment and empowered women to earn their own incomes

### *5.6.3 Tourism*

Villages in which tourism was the main marine economic activity, namely Nungwi (Tanzania), Watamu (Kenya), Ponta Do Ouro and Vilanculos (both in Mozambique), tended to have high levels of economic wellbeing. This is unsurprising as in African countries coastal tourism is recognised as one of the main driving sectors of the blue economy, playing an even more significant role than fisheries (Olale et al., 2020). In addition to having high levels of economic wellbeing, tourism villages had high scores in terms of basic infrastructure, with roads, airports and electricity being particularly important infrastructure in terms of accounting for their differences from other communities. Transport infrastructure, namely roads and airports, is considered to be an important component influencing the attractiveness of a destination for tourists (Khadaroo & Seetanah, 2007). This is due to the fact that this infrastructure determines the accessibility of these destinations for tourists (Khadaroo & Seetanah, 2007).

Although poorly documented in the literature, the importance of electricity in the tourism sector is likely due to the importance of electricity in the smooth functioning of resorts and the preference of tourists for having access to electricity to complete their daily tasks, such as charging their cellular devices. Most tourists visiting these coastal villages are international and will likely be accustomed to having access to electricity in their home countries and will most likely prefer to retain this access. The findings of this study thus indicate that in order to strengthen the tourism sector, investments should focus on improving/installing transport infrastructure and electricity supply. It must, however, be noted that the construction of such infrastructure can lead to land degradation, loss of habitat and deterioration of scenery (Sunlu, 2003).

Whilst it is evident that tourism has great potential to facilitate economic growth, it is associated with negative environmental impacts. For example, in Watamu (Kenya) tourism has been noted to result in negative impacts on marine ecosystems. Specifically, scuba divers and snorkelers often go close to corals, damaging these and disturbing sensitive marine life (Kajo, 2017). In addition to potentially having negative environmental impacts, tourism has also been observed to result in negative social impacts. For example, although tourism in Ponta Do Ouro (Mozambique) has provided employment and other economic benefits, it has also resulted in negative impacts on livelihoods, such as overcrowding, loss of access to public land and increased crime rates (Come, 2014). It is thus vital that the sector is closely monitored and adequately managed to avoid negative environmental and social impacts associated with the industry (Sotiriadis & Shen, 2020). When attempting to strengthen or grow the tourism industry in rural areas, a pro-poor approach should be adopted to ensure the benefits are fairly distributed and the needs of the local community are served (Come, 2014).

It was, in fact, noted that in all case studies where tourism was the main marine economic activity, conservation was also an important activity within the economy. This is likely attributable to the fact that conservation areas, namely marine protected areas and wildlife sanctuaries, are popular tourist destinations. This highlights that not only is conservation important for maintaining the biodiversity and ecological wellbeing of an area, but also for maintaining its appeal as a tourism destination and thus its economic wellbeing. For example, if an area such as Watamu in Kenya, which is famous for its marine national park and biodiversity, suffer severe environmental degradation it is likely there would be a decline in tourist visitation rates and the economy, and thus social wellbeing, of the area would suffer.

Tourism is often seen as a tool for development in rural areas for many reasons, one of which is that it is inclusive of women (Come, 2014). Whilst tourism may provide jobs for men and women, there are contrasts between the types of jobs that each may undertake. Evidence from Ponta Do Ouro, Mozambique, suggests that women are assigned the more “domestic” jobs, such as laundry staff, cleaners, housekeepers and receptionists, while men are assigned the more “manual” jobs, such as bartenders, maintenance technicians and guards (Come, 2014).

## 5.7 Important Considerations

When interpreting the results of this study or utilising the findings for any purposes, there are two key factors that are important to consider. The first is the concept of correlation vs causation, and the second is the risk of perverse outcomes.

### *5.7.1 Correlation vs Causation*

Although for the purposes of this study and the interpretation of results, predicator variables, most notably basic infrastructure, and development planning, were assumed to be the drivers of economic development, this cannot always be assumed and is not necessarily the case. Specifically, it cannot be assumed that economic success witnessed in a community is as a result of the community having access to basic infrastructure. The case of Kibuyuni in Kenya offers a perfect cautionary tale of assuming that the provision of basic infrastructure results in economic growth. In this village, economic success based on seaweed farming has allowed the community to generate the funds needed to afford the installation of roads and electricity infrastructure. This, in turn, has resulted in improved economic and social wellbeing and has further strengthened the economy, thus indicating that whilst basic infrastructure may not have driven the success of the marine economy, it has indeed strengthened it. This case study highlights an important reality: choosing which community to invest in in terms of basic infrastructure provision is an important decision for the assurance that this investment will result in successful economic growth. Specifically, targeting communities where some success, or some promise of success, relating to the use of marine resources is already prevalent is likely to yield the greatest benefit in terms of infrastructure provision for economic growth.

### *5.7.2 Perverse outcomes*

Although it may be tempting to view the provision of basic infrastructure as a panacea for the challenges facing rural communities, it is not without its pitfalls. Specifically, the installation of infrastructure may have a number of perverse outcomes, as alluded to earlier in this document. For example, the construction of roads into wilderness areas often creates a plethora of environmental problems, such as habitat fragmentation and loss, poaching and illegal mining (Laurance et al., 2015). The environmental problems arising in response to the installation of infrastructure often result in the degradation of the resource base upon which local communities rely and/or which initially made the area an appealing site for infrastructure expansion. This decline in the resource base has numerous adverse consequences, often creating economic hardship in the long-term (Obura et al., 2017). Thus, whilst the installation of infrastructure with the intention of creating economic growth may achieve its goal in the short-term, it may in fact have the opposite effect in the long-term. The long-term success of infrastructure installation requires that the concepts of environmental and social sustainability be incorporated, and institutional capital exists. When developing policy regarding infrastructure investment, it is vital that both the benefits and perverse outcomes that may arise from the installation of infrastructure be considered.

In addition to considering the perverse outcomes that may arise from the installation of basic infrastructure, it is also vital to consider that perverse outcomes will likely arise from efforts to strengthen and grow the marine economy. The ocean's ability to provide the goods and services that are the foundation for economic growth is dependent upon the health of its ecosystems. The areas still in good health in the WIO, and thus those prime for development, ironically owe their good health to their current low levels of population and economic development (Obura et al., 2017). The fishing industry, specifically the commercial fishing industry,  is recognized as one of the greatest drivers of ecological destruction (Monbiot, 2021). An expansion of the fishing industry is likely to place increased pressures on marine resources, a decline in ecosystem health and a corresponding decline in the goods and services these ecosystems can provide. This, in turn, reduces the benefits to users and a decline in economic and social circumstances. Thus, when looking to improve the socioeconomic situation in rural coastal communities through the use of marine resources it is vital that critical and careful consideration is given as to how best to achieve this improvement. Achieve too much growth and the ecosystem, and eventually those dependent upon it, will suffer. Diversified income streams, careful management and sustainable use of resources are of paramount importance to ensure a balance is maintained between achieving economic growth and the health of coastal and marine ecosystems.

### 5.8 Limitations

Although the findings of this study provide useful insights regarding the relationships between development predicators of socioeconomic development (i.e. governance, development and basic infrastructure) and socioeconomic development, there are some limitations to the study that need to be considered when interpreting and using the results of this work. Firstly, the sample size was relatively small and thus should not be used to make inferences for the entire WIO region. Secondly, there was limited variation in the range of some variables, such as potable water supply and communications, which prevented an accurate assessment of the impacts of this infrastructure on socioeconomic development from being made. Thirdly, causation has in some cases been assumed where there is correlation. It is important to understand that this is not always the case. In order to accurately state that socioeconomic development is as a result of basic infrastructure, one would need to examine this relationship over time. Gathering the necessary historical data is, however, extremely challenging. An additional limitation of this study is that data collection did not take quality or condition of variables into account. For example, the condition of natural capital or the quality of available education was not recorded. This is due to the fact that obtaining this level of details for rural communities at a desktop level is not possible. If one wanted to obtain this level of detail, it is likely that on the ground data collection would be necessary.

## 6. CONCLUSIONS

The aim of this study was to answer the following question:

1) Does the presence of basic infrastructure (e.g. roads, harbours, access to energy, sanitation and water) correlate with local blue economic growth and/or socio-economic development in rural coastal communities?

Additionally, this study also sought to investigate the following two questions, namely;

1) Does strategic planning of a community correlate with local blue economic growth and/or socioeconomic development in rural coastal communities?; and
2) Does governance relating to the use and management of coastal and marine resources correlate with local blue economic growth and/or socioeconomic development in rural coastal communities?

In the efforts to address these questions, the following key findings were revealed:

- Basic infrastructure **does** correlate with economic wellbeing in rural coastal communities
- Strategic planning of a community, specifically if a development plan is in place to guide future development **does** correlate with social wellbeing whilst whether a development of a community was planned correlates with its economic wellbeing.
- Governance **does not** appear to correlate with blue economic growth or socioeconomic development in rural coastal communities
- Roads, airports and electricity are the most important components of basic infrastructure relating to economic wellbeing. As such, investment in the provision of this basic infrastructure could potentially play an important role in improving the economic wellbeing of communities, in turn helping to alleviate poverty. It is critical that this investment be accompanied by guidance and support to ensure that communities explore ocean-based activities and reach their full economic development in a sustainable manner.
- Targeting rural communities for investment in basic infrastructure and ensuring that a development plan is in place to guide their future development will likely play an important role in improving their social wellbeing.
- Of all sectors investigated, namely tourism, fishery, aquaculture and conservation, tourism appears to have the greatest potential for driving blue economic growth in rural coastal communities. As such, this sector should potentially be targeted for investment. Specifically, the provision of road infrastructure and electricity supply may increase the tourism appeal of communities. This must, however, be done carefully as poor infrastructure planning and monitoring of tourism activities has the potential to result in environmental degradation.
- If shifted from occurring on a subsistence basis to occurring on a commercial basis, fishery has great potential for facilitating economic growth of communities. However, due to the fragile state of our marine resources, this shift would need to be carefully controlled and undertaken in a sustainable manner. This shift would likely require provision of roads and electricity to ensure goods can be stored, processed, and transported to market.

- When interpreting the results of this study it is important to note that communities are complex and show great variation due to a range of ecological, socio-cultural, economic, and institutional factors. The findings of this study can thus not be used to draw definitive conclusions for all coastal rural communities.
- When looking to enhance the socioeconomic situation of a particular coastal community it is essential that the socioeconomic, ecological, and cultural context of that community be investigated.

# 7. FURTHER STUDY

Although this study helped address the knowledge gap regarding the role of basic infrastructure in facilitating socioeconomic growth in rural coastal communities, it must be noted that this study focused only on a limited dataset and further studies would likely be warranted in order to gain deeper insights relating to development in rural coastal communities. It is proposed that further investigation into the relationships between natural capital, governance and social wellbeing be undertaken. It must also be noted that the correlations observed in the study do not necessarily imply causation. Ideally, to adequately investigate whether basic infrastructure drives blue economic growth and/or socioeconomic development, communities need to be examined over time.

Given that we now live in a COVID-19 world where travel is restricted, studies that investigate whether tourism still proves to be a good driver of economic growth could prove insightful. Additionally, restrictions placed on the import and export of goods due to COVID-19 are also likely to have consequences for the fisheries and aquaculture sectors. The impacts that this may have on the economic wellbeing communities warrants investigation.

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# 9. APPENDICES

## 9.1 Appendix 1: Description of variables

### 9.1.1 Description of predictor variables

| Variable | Tier | Description |
|---|---|---|
| **Basic infrastructure** | 1 | |
| Roads | 2 | The presence of roads within the village |
| Airports | 2 | The presence of airports within the village, or in close proximity to the village |
| Access to urban centres | 2 | The ability to access urban centres, either by road or boat |
| Harbours/Ports | 2 | The presence of harbours/ports within the village |
| Electricity | 2 | An electricity supply to the village |
| Potable water | 2 | A potable water supply to the village |
| Sewerage system | 2 | The manner in which sewage in the village is dealt with |
| Communication | 2 | The presence of cell phone coverage within the village |
| **Governance** | 1 | |
| Organisations | 2 | The presence of community organisations that protect, monitor or control the use of marine resources |
| Locally Managed Marine Areas (LMMAs) | 2 | Whether the village is part of a LMMA |
| Protected areas | 2 | Whether the village is part of a marine protected area or other protected area (coastal or marine) |
| Sustainable management | 2 | Is the marine environment being sustainably managed? or is there evidence of environmental degradation? |
| **Strategic planning** | 1 | |
| Planned development | 2 | If the village shows evidence of having been a planned development |
| Development plan | 2 | Whether a development plan of sorts exits for the village or if the village is mentioned in a government level development plan |

### *9.1.2 Description of indicator variables*

| Variable | Tier | Description |
|---|---|---|
| **Natural capital** | 1 | |
| Mangroves | 2 | The presence of mangroves in the vicinity of the village |
| Coral reefs | 2 | The presence of coral reefs in the vicinity of the village |
| **Social wellbeing** | 1 | |
| Healthcare | 2 | The type of healthcare facilities available in the village |
| Primary education | 2 | The number of primary schools present in the village |
| Secondary education | 2 | The number of secondary schools in the village |
| Further training | 2 | The number of further training institutions in the village |
| **Economic wellbeing** | 1 | |
| Financial institutions | 2 | The type of financial institutions present in the village |
| Marine economy dependence | 2 | The dependence of the village on the marine economy (low, moderate or high) |
| Shops | 2 | The presence of shops in the village |
| Boats | 2 | The type of boats present in the village |
| **Institutional capital** | 1 | |
| Police | 2 | The number of police stations in the village |
| Legal systems | 2 | The presence of legal institutions the village |
| Factories | 2 | The presence of factories in the village |
| Hospitals | 2 | The presence of hospitals in the village |
| Schools | 2 | The presence of schools in the village |

## 9.2 Appendix 2: Scoring protocol for variables

### *9.2.1 Scoring protocol for predictor variables*

| Variable | Tier | Scores |
|---|---|---|
| **Basic infrastructure** | 1 | |
| Roads | 2 | No=0; yes, only dirt roads=1; main roads tarred and rest dirt=2; mostly tarred roads=3 |
| Airports | 2 | No=0; small dirt/grass strip with no building=1; small with dirt runways=2; airport within 20km=3; airport with tarred runway=4 |
| Access to urban centres | 2 | poor access by road, accessible by boat =0, yes>100km=1; 2 more than 40km or by dirt road or more than 50km by tarred; less than 30km by tarred road=3; it is an urban centre=4 |
| Ports | 2 | No=0; yes=1 |
| Electricity | 2 | No=0; limited access or some solar power=1; connected to grid=2 |
| Potable water | 2 | Yes, but poor water quality=0; wells=1; piped water =2 |
| Sewerage system | 2 | No system=0; septic tanks and pit latrines=1; mostly septic tanks=2; waterborne sewerage system=3 |
| Communication | 2 | Yes, but limited=0; yes, good coverage=1 |
| **Governance** | 1 | |
| Organisations | 2 | No=0; yes=1 |
| Locally Managed Marine Areas (LMMAs) | 2 | No=0; yes=1 |
| Protected areas | 2 | No=0; yes=1 |
| Sustainable management | 2 | Poor=0; moderate=1; good=2 |
| **Development** | 1 | |
| Planned development | 2 | No=0; planned and some urban sprawl=1; highly planned=2 |
| Development plan | 2 | No=0; yes=1 |

### *9.2.2 Scoring protocol for indicator variables*

| Variable | Tier | Description |
|---|---|---|
| **Natural capital** | 1 | |
| Mangroves | 2 | No=0; yes=1 |
| Coral reefs | 2 | No=0; yes=1 |
| **Social wellbeing** | 1 | |
| Healthcare | 2 | No=0; 1=pharmacy only; 2=one primary health care unit/hospital; 3=pharmacies, clinics and 1 hospital; 4=multiple hospitals |
| Primary education | 2 | Primary schools/1 000 people |
| Secondary education | 2 | Secondary schools/1 000 people |
| Further training | 2 | Further training institutions/1 000 people |
| **Economic wellbeing** | 1 | |
| Financial institutions | 2 | No=0; ATMs =1; ATM and bureau de change=2; 1 bank and 1 ATM=3; Multiple banks and multiple ATMs=4 |
| Marine economy dependence | 2 | Moderate=0; High=1 |
| Shops | 2 | No=0; market only=1; one shop=2; few shops=3; multiple goods available=4 |
| Boats | 2 | Unmotorised=0; few motorised=1; many motorised=2; deep watercraft present=3 |
| **Institutional capital** | 1 | |
| Police | 2 | Police stations/1 000 people |
| Legal systems | 2 | No=0; Law firms=1; court houses=2 |
| Factories | 2 | No=0; yes=1 |
| Hospitals | 2 | No=0; yes=1 |
| Schools | 2 | No=0; yes=1 |

## 9.3 Appendix 3: Variable scores

### 9.3.1 Scores for predictor variables

| Variable | Weight | Kibuyuni | Watamu | Andavadoaka | Belo sur Mer | Lalane | Ponto Do Ouro | Vilanculos | Haga Haga | Saldanha | Matemwe | Nungwi |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Governance** | **1.00** | **0.61** | **0.71** | **1.01** | **0.87** | **0.00** | **0.41** | **0.17** | **0.71** | **0.71** | **0.17** | **0.17** |
| Organisations | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.00 | NA | NA | 0.30 | 0.30 | NA | NA |
| LMMA | 0.14 | 0.14 | 0.00 | 0.14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Protected areas | 0.24 | 0.00 | 0.24 | 0.24 | 0.24 | 0.00 | 0.24 | 0.00 | 0.24 | 0.24 | 0.00 | 0.00 |
| Sustainable management | 0.33 | 0.17 | 0.17 | 0.33 | 0.33 | 0.00 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 |
| **Development** | **1.00** | **0.00** | **0.75** | **0.00** | **0.00** | **0.00** | **0.25** | **0.25** | **0.25** | **1.00** | **0.00** | **0.00** |
| Planned development | 0.50 | 0.00 | 0.25 | 0.00 | 0.00 | 0.00 | 0.25 | 0.25 | 0.25 | 0.50 | 0.00 | 0.00 |
| Development plan | 0.50 | 0.00 | 0.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.50 | 0.00 | 0.00 |
| **Basic Infrastructure** | **1.00** | **0.33** | **0.74** | **0.49** | **0.33** | **0.00** | **0.70** | **0.94** | **0.67** | **0.92** | **0.66** | **0.66** |
| Roads | 0.15 | 0.05 | 0.10 | 0.05 | 0.00 | 0.00 | 0.10 | 0.15 | 0.05 | 0.15 | 0.10 | 0.10 |
| Airport | 0.07 | 0.00 | 0.05 | 0.04 | 0.02 | 0.00 | 0.04 | 0.07 | 0.02 | 0.00 | 0.00 | 0.00 |
| Urban access | 0.14 | 0.07 | 0.11 | 0.07 | 0.00 | 0.00 | 0.04 | 0.14 | 0.07 | 0.14 | 0.11 | 0.11 |
| Port | 0.05 | 0.00 | 0.00 | 0.05 | 0.05 | 0.00 | 0.00 | 0.05 | 0.00 | 0.05 | 0.00 | 0.00 |
| Electricity | 0.15 | 0.08 | 0.15 | 0.08 | 0.08 | 0.00 | 0.15 | 0.15 | 0.15 | 0.15 | 0.08 | 0.08 |
| Potable water supply | 0.14 | NA | 0.14 | 0.07 | NA | 0.00 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 |
| Sewerage system | 0.15 | NA | 0.05 | NA | 0.05 | 0.00 | 0.10 | 0.10 | 0.10 | 0.15 | 0.10 | 0.10 |
| Communication | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.00 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 |

### 9.3.2 *Scores for indicator variables*

| Variable | Weight | Kibuyuni | Watamu | Andavadoaka | Belo sur Mer | Lalane | Ponto Do Ouro | Vilanculos | Haga Haga | Saldanha | Matemwe | Nungwi |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Natural Capital** | **1** | **1** | **1** | **1** | **1** | **0** | **0.5** | **1** | **0** | **0** | **0.5** | **0.5** |
| Mangroves | 0.5 | 0.50 | 0.50 | 0.50 | 0.50 | 0.00 | 0.00 | 0.50 | 0.00 | 0.00 | 0.00 | 0.00 |
| Coral reefs | 0.5 | 0.50 | 0.50 | 0.50 | 0.50 | 0.00 | 0.50 | 0.50 | 0.00 | 0.00 | 0.50 | 0.50 |
| **Social wellbeing** | **1** | **0.1161** | **0.5248** | **0.4086** | **0.2063** | **0.27** | **0.1793** | **0.399** | **0** | **0.733** | **0.2936** | **0.3267** |
| Healthcare | 0.35 | 0 | 0.26 | 0.18 | 0.18 | 0.00 | 0.09 | 0.26 | 0.00 | 0.35 | 0.18 | 0.26 |
| Primary education | 0.27 | 0.1161 | 0.0702 | 0.1836 | 0.0243 | 0.27 | 0.0918 | 0.0216 | 0 | 0.0405 | 0.1026 | 0.0567 |
| Secondary education | 0.05 | 0 | 0.0085 | 0.05 | 0.007 | 0 | 0 | 0.0095 | 0 | 0.0025 | 0.016 | 0.0075 |
| Further education | 0.34 | 0 | 0.1836 | 0 | 0 | 0 | 0 | 0.1054 | 0 | 0.34 | 0 | 0 |
| **Economic wellbeing** | **1** | **0.11** | **1** | **0.11** | **0.2548** | **0.18** | **0.7475** | **0.9** | **0.3325** | **0.9** | **0.32** | **0.6474** |
| Financial institutions | 0.33 | 0.00 | 0.33 | 0.00 | 0.00 | 0.00 | 0.25 | 0.33 | 0.08 | 0.33 | 0.00 | 0.17 |
| Marine economy dependence | 0.11 | 0.11 | 0.11 | 0.11 | 0.00 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 |
| Shops | 0.28 | 0.00 | 0.28 | NA | 0.07 | 0.07 | 0.21 | 0.28 | 0.14 | 0.28 | 0.21 | 0.28 |
| Boats | 0.28 | 0.00 | 0.28 | 0.00 | 0.18 | 0.00 | 0.18 | 0.18 | 0.00 | 0.18 | 0.00 | 0.09 |
| **Institutional capital** | **1** | **0.31** | **0.70** | **0.54** | **0.21** | **0.21** | **0.24** | **0.86** | **0.00** | **0.80** | **0.21** | **0.55** |
| Police | 0.03 | 0 | 0.003 | 0 | 0 | 0 | 0.03 | 0.00399 | 0 | 0.003 | 0 | 0.009 |
| Legal systems | 0.32 | 0.00 | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.32 | 0.00 | 0.16 | 0.00 | 0.00 |
| Factories | 0.10 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 |
| Hospitals | 0.33 | 0.00 | 0.33 | 0.33 | 0.00 | 0.00 | 0.00 | 0.33 | 0.00 | 0.33 | 0.00 | 0.33 |
| Schools | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.00 | 0.21 | 0.21 | 0.21 |

## 9.4 Appendix 4: Statistical analyses output

### 9.4.1 First-tier analysis

**Table 1. Correlations between variables and Principal Components. Correlations >0.7 are considered to be strong and are presented in bold**

| | PC1 | PC2 |
|---|---|---|
| Governance | 0.125 | 0.689 |
| Development | **0.882** | -0.130 |
| Basic Infrastructure | **0.843** | -0.042 |
| Natural Capital | 0.000 | **0.884** |
| Social wellbeing | **0.830** | 0.085 |
| Economic wellbeing | **0.888** | -0.251 |
| Institutional capital | **0.843** | 0.256 |

**Table 2. Correlations between variables. Correlations >0.7 are considered to be strong and are presented in bold**

| Variables | Governance | Development | Basic Infrastructure | Natural Capital | Social wellbeing | Economic wellbeing | Institutional capital |
|---|---|---|---|---|---|---|---|
| Governance | **1** | 0.26 | 0.11 | 0.32 | 0.09 | -0.09 | 0.02 |
| Development | 0.26 | **1** | 0.68 | -0.23 | **0.70** | **0.81** | 0.57 |
| Basic Infrastructure | 0.11 | 0.68 | **1** | 0.00 | 0.49 | **0.83** | 0.61 |
| Natural Capital | 0.32 | -0.23 | 0.00 | **1** | 0.01 | -0.12 | 0.31 |
| Social wellbeing | 0.09 | **0.70** | 0.49 | 0.01 | **1** | 0.55 | **0.84** |
| Economic wellbeing | -0.09 | **0.81** | **0.83** | -0.12 | 0.55 | **1** | 0.63 |
| Institutional capital | 0.02 | 0.57 | 0.61 | 0.31 | 0.84 | 0.63 | **1** |

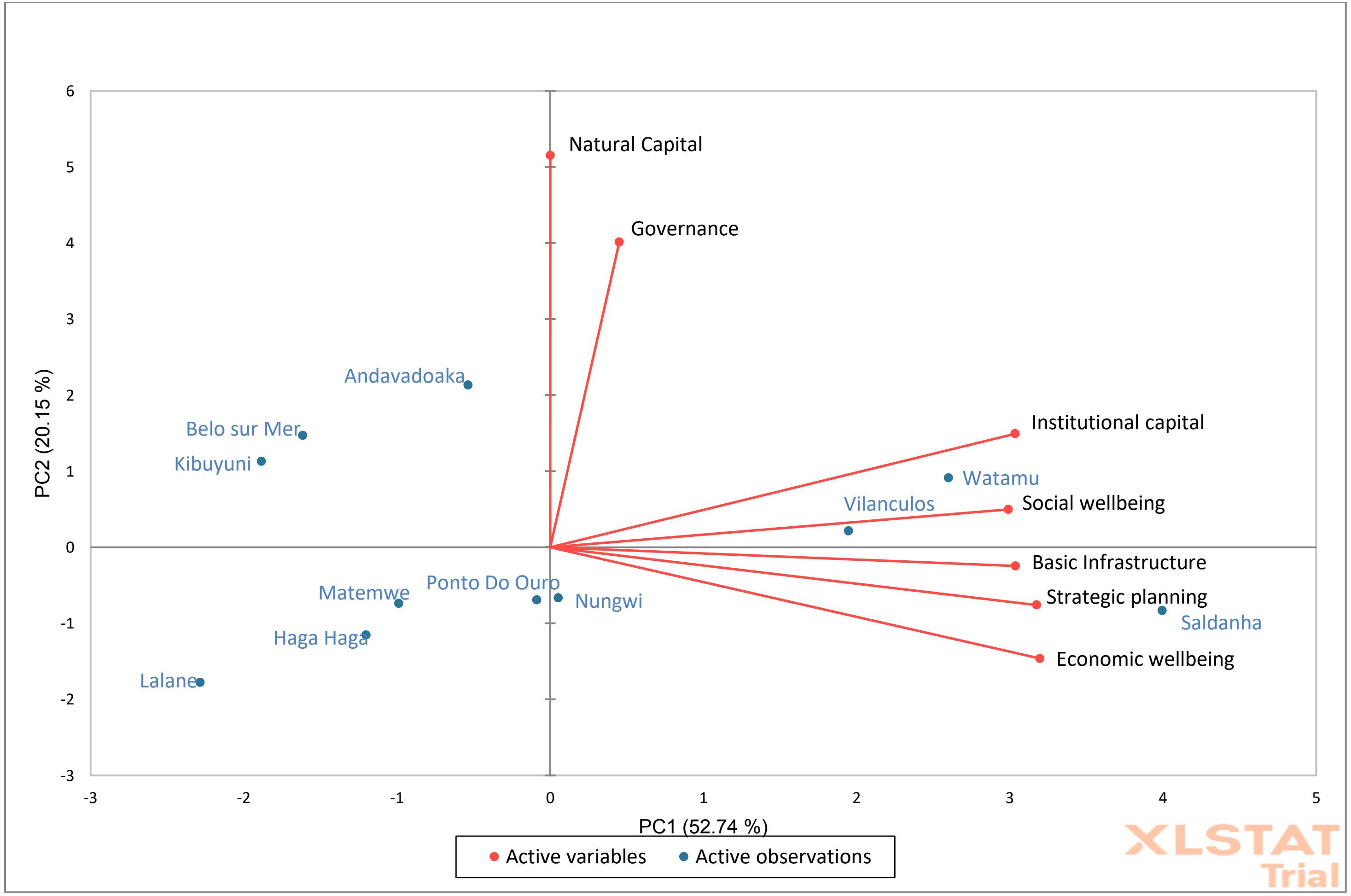


**Figure 1. Principal Component Analysis biplot showing the first and second principal components of first-tier variables for the 11 case studies.**

### *9.4.2 The relationship between strategic planning and social wellbeing*

**Table 3. Correlations between variables and Principal Components. Correlations >0.7 are considered to be strong and are presented in bold**

| | PC1 | PC2 |
|---|---|---|
| Social wellbeing | **0.863** | -0.452 |
| Planned development | **0.818** | 0.558 |
| Development Plan | **0.943** | -0.070 |

**Table 4. Correlations between variables. Correlations >0.7 are considered to be strong and are presented in bold**

| Variables | Social wellbeing | Planned development | Development Plan |
|---|---|---|---|
| Social wellbeing | **1** | 0.486 | **0.772** |
| Planned development | 0.486 | **1** | 0.686 |
| Development Plan | **0.772** | 0.686 | **1** |

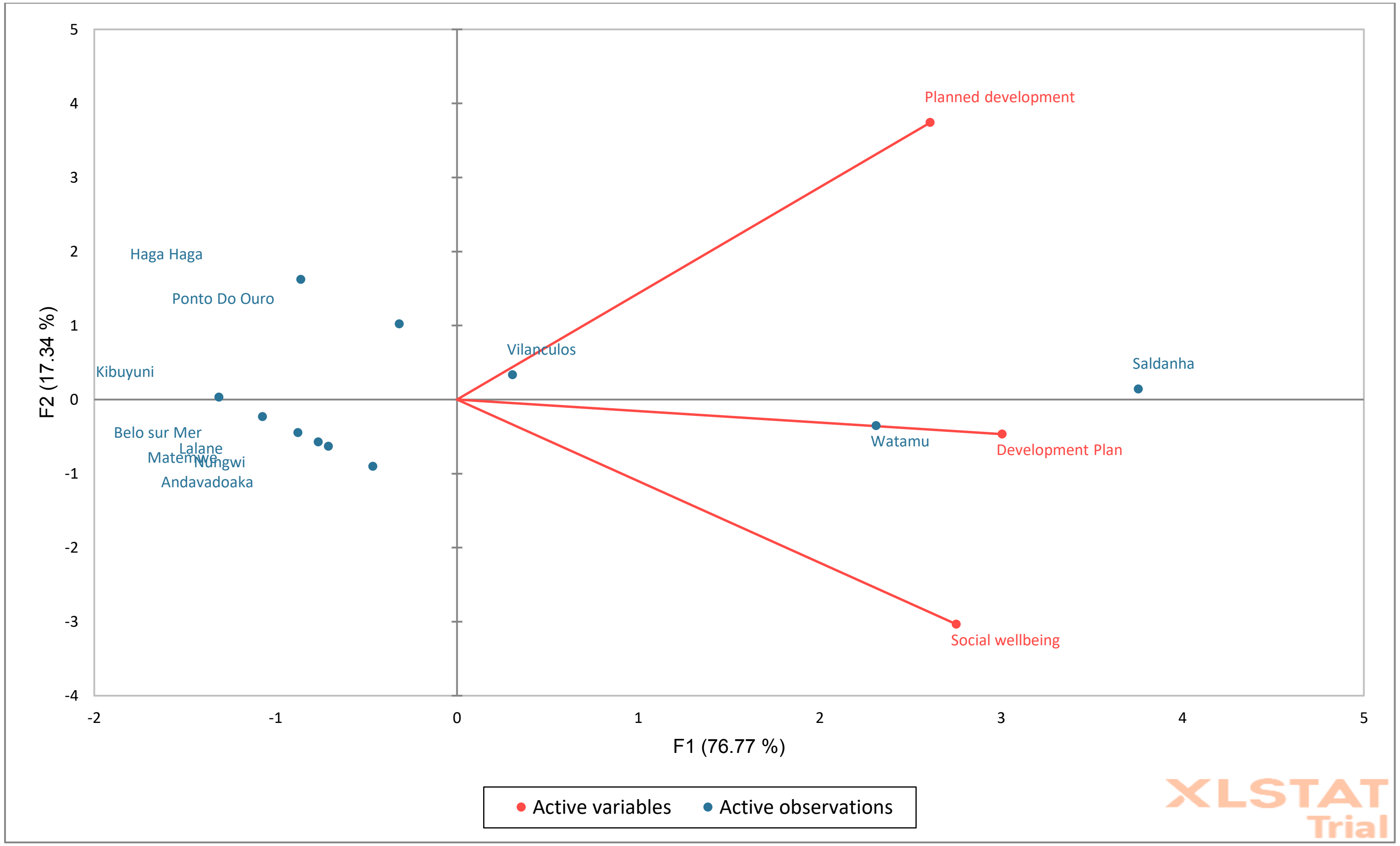


**Figure 2. Principal Component Analysis biplot showing the first and second principal components of strategic development and social wellbeing variables for the 11 case studies.**

### *9.4.3 The relationship between strategic planning and economic wellbeing*

**Table 5. Correlations between variables and Principal Components. Correlations >0.7 are considered to be strong and are presented in bold**

| | PC1 | PC2 |
|---|---|---|
| Economic wellbeing | **0.923** | -0.265 |
| Planned development | **0.931** | -0.209 |
| Development Plan | **0.859** | 0.511 |

**Table 6. Correlations between variables. Correlations >0.7 are considered to be strong and are presented in bold**

| Variables | Economic wellbeing | Planned development | Development Plan |
|---|---|---|---|
| Economic wellbeing | **1** | 0.831 | 0.664 |
| Planned development | 0.831 | **1** | 0.686 |
| Development Plan | 0.664 | 0.686 | **1** |

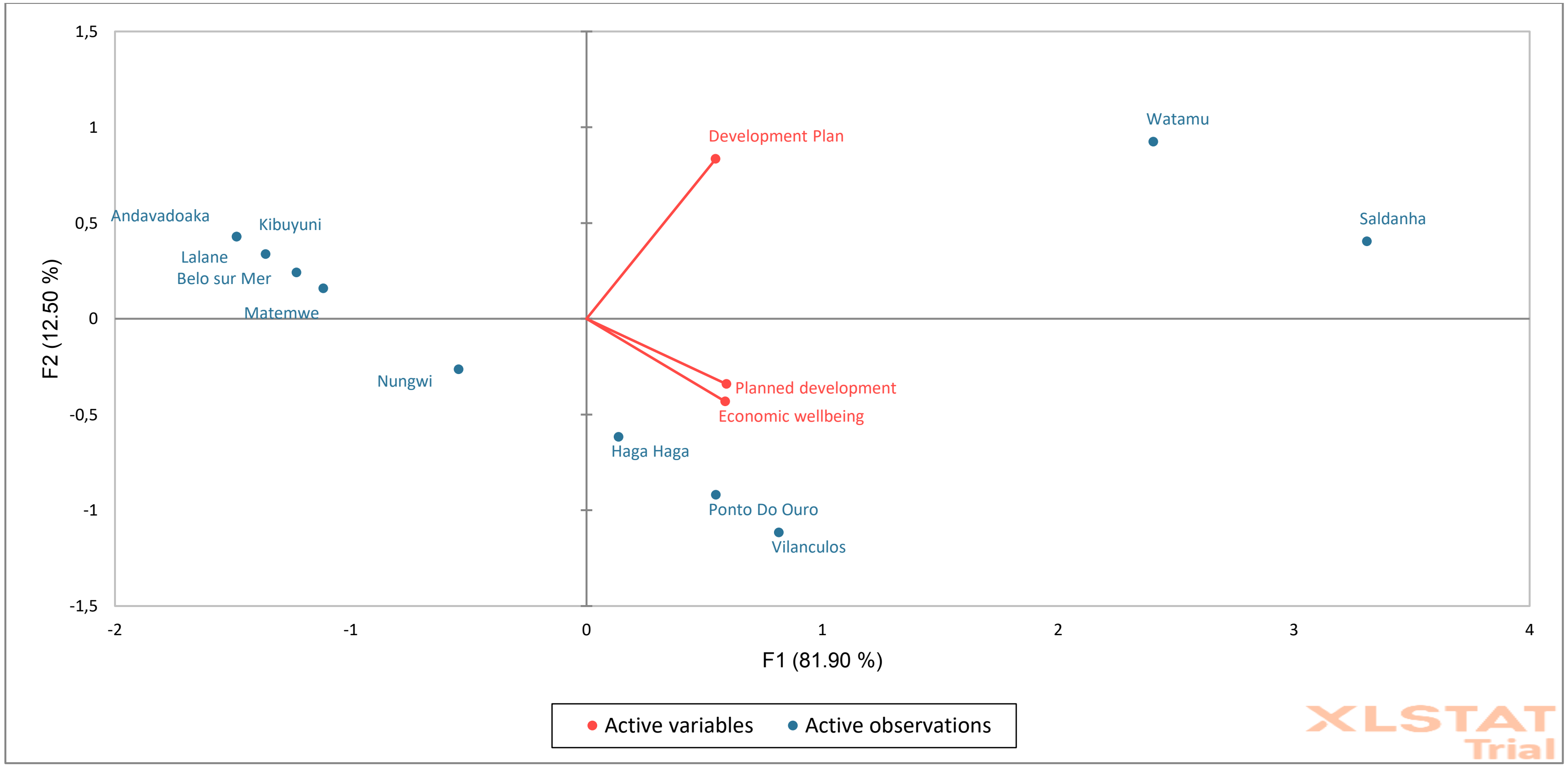


**Figure 3. Principal Component Analysis biplot showing the first and second principal components of strategic development and economic wellbeing variables for the 11 case studies.**

### 9.4.4 *The relationship between basic infrastructure and economic wellbeing*

**Table 7. Correlations between variables and Principal Components. Correlations >0.7 are considered to be strong and are presented in bold**

| | PC1 | PC2 |
|---|---|---|
| Economic wellbeing | **0.800** | 0.023 |
| Roads | **0.875** | -0.026 |
| Airport | **0.790** | 0.542 |
| Access to urban centres | **0.799** | -0.056 |
| Harbour/Port | 0.354 | **0.762** |
| Electricity | **0.903** | -0.103 |
| Potable water | **0.736** | -0.547 |
| Sewerage system | **0.761** | 0.159 |
| Cell phone Coverage | **0.742** | -0.370 |

**Table 8. Correlations between variables. Correlations >0.7 are considered to be strong and are presented in bold**

| Variables | Economic wellbeing | Roads | Airport | Access to urban centres | Harbour/ Port | Electricity | Potable water | Sewerage system | Cell phone Coverage |
|---|---|---|---|---|---|---|---|---|---|
| Economic wellbeing | **1** | **0.804** | **0.751** | 0.628 | 0.091 | **0.794** | 0.488 | 0.360 | 0.327 |
| Roads | **0.804** | **1** | 0.662 | **0.890** | 0.163 | 0.690 | 0.541 | 0.556 | 0.493 |
| Airport | **0.751** | 0.662 | **1** | 0.540 | 0.607 | **0.737** | 0.259 | 0.598 | 0.326 |
| Access to urban centres | 0.628 | **0.890** | 0.540 | **1** | 0.180 | 0.558 | 0.502 | 0.513 | 0.516 |
| Harbour/Port | 0.091 | 0.163 | 0.607 | 0.180 | **1** | 0.160 | 0.028 | 0.441 | 0.239 |
| Electricity | **0.794** | 0.690 | **0.737** | 0.558 | 0.160 | **1** | **0.709** | 0.685 | 0.671 |
| Potable water | 0.488 | 0.541 | 0.259 | 0.502 | 0.028 | **0.709** | **1** | 0.492 | **0.886** |
| Sewerage system | 0.360 | 0.556 | 0.598 | 0.513 | 0.441 | 0.685 | 0.492 | **1** | 0.622 |
| Cellphone Coverage | 0.327 | 0.493 | 0.326 | 0.516 | 0.239 | 0.671 | **0.886** | 0.622 | **1** |

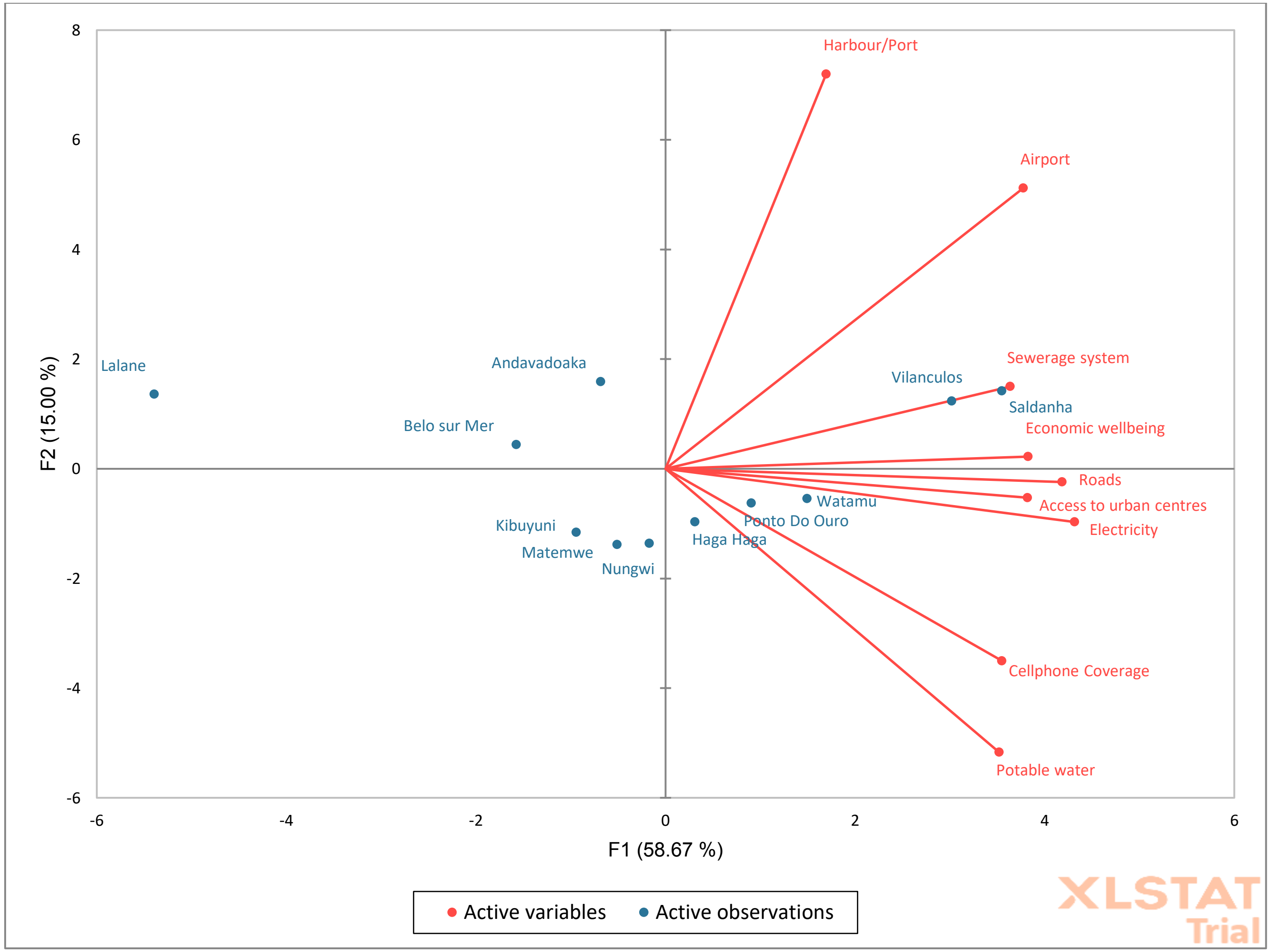


**Figure 7. Principal Component Analysis biplot showing the first and second principal components of basic infrastructure and economic wellbeing variables for the 11 case studies.**