Warawa Living Lab Water Project:Using Sensor based Data Models to solve Multi Poverty Index through access to water for enhanced social outcomes

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Abstract

The Living Lab Project aims to understudy the correlation between the availability of clean potable water with some social indices in Northern Nigeria. The project aims to collect real-time data through a sensor-based mechanism that tracks the effect of the availability of clean and safe water to other social variables such as; travel time to accessing water at the lab; social behavioural patterns as results of the project, health indices and sanitation conditions; and migration patterns as a results of new point of clean and accessible water from an equidistance between other sources of water and population dynamics in relation to access to clean and accessible water system within the community. The project moves from the traditional water supply system to an innovative, cost-effective and technologically inclined model that provides clean water to the community at a minimal cost.

The prototype is a solar-powered water facility equipped with water meters and cameras for sensor-based data collection of the quantity of water collected by each household and prediction of the estimated age and gender of persons accessing water from the facility. Satellite Imaging using Google Earth Pro was used to estimate the population dynamics through image density mapping and cadastral analysis to determine development rate within the community.

Key words: *Social Outcomes, Sensor based data, geospatial analytics, living lab, Water, Multi Poverty Index, big data, prediction algorithms, satellite imagery*

1. Background & Introduction

In 2015, world leaders agreed to addressing social and development challenges around inclusiveness and poverty reduction through the 17 SDG goals; access to water and sanitation were identified as one of the key global concerns with a rippling effect to health, education, climate change etc. especially in developing countries. *Slaymaker and Bain* (2017) reported one in every ten people do not have access to clean drinking water and almost half of these people lived in Sub-Saharan Africa, with 80% of these population in the rural communities. WHO and UNICEF (2017) estimates the SDG baseline as 2.1 billion people out of the world's population; 3 in every 10 people consume unprotected, contaminated water. These numbers are projected to increase with the adverse effects of climate change, and other key factors.

While this has an implicative effect on the multi poverty dimensions of living in developing societies, especially those with higher concentration of rural communities, understanding the causative enablers to some of these issues, especially as it relates to maternal mortality, migration, poverty and access to basic education requires understanding the functional flow of data and its relationship to social outcomes as it relates to achieving the SDGs.

In this paper, we introduce the concept of using Living Lab as a solution through the use of pervasive computing using sensor based data to track migration patterns to critical social infrastructure like water points and its effect on social outcomes like health, education and agriculture.

2. Living Lab

The living lab concept having been used since the 1990s gives a user-experience and a people-centric approach to design, deploy and test ideas within a real environment (IST Africa, 2017). In Africa, the living lab approach has the potential to address Africa's essential socio-economic and developmental needs (Coetzee et al., 2012) as it has the potential of solving social issues especially around public health due to the dearth of data. The use of Geographic Information System in monitoring the outcomes of Living labs has been an emerging area, gaining recognition as a more qualitative and cost effective way to monitor health investments. More recently, the use of Remote Sensing and Geographic Information System have come to play in disease surveillance and vaccine tracking.

The Warawa Living Lab Project aims to use a Blended Model (Data - Model Fusion); combining the use of Sensor Based Models; Time Series Analysis Method, Gender and Age Estimation Model and Statistical Model (United Nations, 2017) to estimate the effect of the availability of clean and potable water on some social indices across Health, Education, Community Behavioral Patterns and Environmental Development.

The lab is primarily co-created to understudy individual social behaviours and the effect of network decision making in solving social issues that deal with access to safe and clean drinking water. The lab focuses on a problem domain of poverty in a rural setting and tries to explore how social behaviour is affected with the introduction of social amenities and its potential as multiplier effect as it relates to multidimensional poverty.

Through the living lab, we intend to use the concept of "Reality Mining" (Eagle and Petland, 2017) to understudy the time series of social behaviour for rural poor communities around access to social infrastructure like water and how this impact their decisional flows for education and health choices they make as a result of availability of infrastructure or lack thereof.

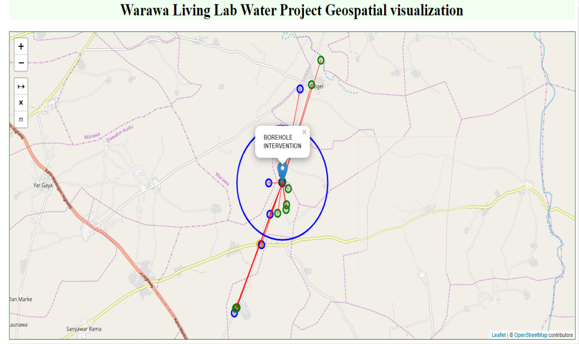
3. Geospatial Analysis

In the paper, we further layout the use of geospatial analytics to connect migration flows to areas of critical infrastructure as a hypothesis on the social behavioural patterns and the decisional flows as it relates to social outcomes in health, livelihood and productive economic activities. Through the study, we have mapped points of interest (POIs) as it relates to infrastructure points, social services points and other related service points.

To track migration patterns, we understudy satellite imagery from a baseline point before the intervention to estimate population size while collecting future satellite imagery on new settlements and POIs that have developed along regular intervals.

Below you can visualize the point interest in community understudy , the blue circle represents 2000 meter radius as approximation of the community boundary understudy.

Warawa Living Lab Water Project Geospatial visualization



https://gislivinglab-dot-datacollection-224020.appspot.com/

4. Project Design and Facility Architecture

Project Design

The living lab is designed through retro-fitting sensor based technology across households through a smart water access card for accessing water. The water meters are further fitted with accelerometers to track water consumption while a motion based image capturing device is integrated into the solar facility to detect the gender of households fetching water at the pumps. The technology is designed as a people-centered approach to engage community members and key stakeholders as it relates to collecting high resolution data across a time bound series.

1. **Process:** The facility provides an interface between the households and a sensor based data collection system, while population density and environmental development changes are estimated using time series analysis model and statistical models (United Nations, 2017).

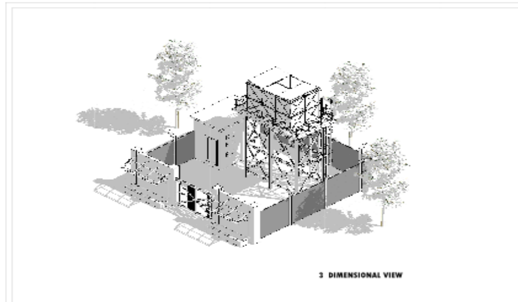
2. **People:** The Human Centered Approach puts the people at the core of the research, as they contribute to the design and implementation of the research, while monitoring facility functionality for ownership and sustainability.

3. **Data:** Data collections is sensor driven while analysis is carried out at the backend and a data visualization tool provides near real time data on consumption and other metadata analysis by providing insights through a decision tree analysis.

Facility Architecture

The solar-powered facility has eight water points, with each point integrated with a smart card-system water meter to measure the amount of water collected per card at any given time.

Each point also has a camera for prediction of age and gender estimates of persons collecting water and a date and timestamp.



Labels

a. Solar Panels
b. 20,000 Liter Storage Tank
c. Control room/ power house
d. General Water meter
e. Card system water points
f. Gate
g. Wire mesh fence
h. Solar powered lights

5. Methodology

The research used a Blended Model (Data - Model Fusion); combining the use of Time Series Analysis Method and Statistical Model (United Nations, 2017) in estimating population increase as a behavioural pattern attributable to the availability of clean water and other infrastructural development within the community.

A household survey baseline study was conducted using National Bureau of statistics household survey design (National Bureau of

Statistics, 2007) to estimate the total number of households and average number of persons within the community. This was further validated using the National Population Commission 2018 estimated population of Warawa Local Government Area and the population disaggregates in Nigeria.

Infrastructural mapping using GPS, and the identification of functional and non functional water points and other POI was conducted during the survey.

A baseline Satellite Imagery of the community was collected using Google Earth Pro and the GPS locations of interest points overlaid on the map, to visually monitor population density and identify environmental changes within the community.

The time series analysis on environmental development using Google Earth Pro is expected to be conducted every year over a period of 5 years to determine the relationship between social behaviours accessing the water facility and other social outcome indicators like education, livelihood, population migration dynamics and productive economic activities..

6. Results

While the research is at an early stage, we have seen some promising results as it relates to drawing a decisional process flow map for data.

Enumeration of Households: Early results from our household survey provided early baseline results on the social connections to social outcomes. For example, out of a total 124 households enumerated, only 30% had access to either formal or informal education due to the absence of critical social infrastructure which limits time to engage in social improvement activities in the community. 49% of dependents in the households were female with high barriers to accessing basic social facilities due to non-existence facility. Access to water in the community is through (1) ponds, (2) boreholes and (3) wells which takes an average combined time of **1-2 hours** with adverse effect on education, health and their productive hours

Accelerometers: As a prelude to data collection and analysis, we were able to build an integrated smart card water metering system that measures the level of consumption in a time series model detailing peak period around water usage and the connection to social behavioural patterns. The accelerometers provide a glimpse on the usage level and its connection to other variables like gender, household characteristics around usage etc.

Accuracy of Gender Prediction Model: Early test use case on the gender prediction model using conventional neural networks (Levi & Hassncer, 2015) shows 65% gender accuracy. While this does not represent the most effective state for prediction algorithms, we are working fine tuning the gender prediction algorithm by training the "train dataset model" with local, native pictures of the community. We estimate to hit the 75% once we complete our training datasets.

Migration patterns and geospatial analysis.

Through geospatial technology, we have been able to map points of interest (POIs) and estimate population samples through geo-fencing across the Warawa general area. In addition, we have also assessed satellite imagery with the aim of tracking the development of new settlements to estimate population growth across the social infrastructure.

The goal is to track migration patterns to the living lab and track development and its associated social outcomes as a result of improved living conditions as it relates to access to clean and safe drinking water.

Early results show a direct correlation between infrastructure investment and social outcomes. For example, the siting of the living lab had attracted social mobility and enhanced level of improvement across multiple social indices

Below is the satellite imagery of the community understudy as at 29 , January 2019.

7. Future Work & Conclusion

Having reached significant milestones around the (1) use of Internet of Things (IoT) integration of smart card water meters, (2) tested our age and gender prediction model with some level of success, (3) develop a data model for transmission of near real time data to a central repository for visualization and modelling and (4) implemented a geospatial analytics framework to track migration flows and relationships between water and other social outcomes. We look forward to progressing to the active study around collecting sensor based data over a period of 2 years as part of our decisional flows of mapping social behaviours to functional infrastructure.

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