



Estimation of Watershed Sustainability Index of University of Uyo Watershed Using UNESCO-IHP Help Tool

I. I. Ahuchaogu^{1*}, T. A. Ewemoje² and P. S. Isaiah¹

¹*Department of Agricultural and Food Engineering, University of Uyo, Nigeria.*

²*Department of Agricultural and Environmental Engineering, University of Ibadan, Nigeria.*

Authors' contributions

This work was carried out in collaboration among all authors. Author IIA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors TAE and PSI managed the analyses of the study. Author TAE read through the manuscripts severally and made valuable suggestions and inputs while author PSI managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The study employed the UNESCO-IHP (International Hydrology Programme) HELP (Hydrology Environment Life and Policy) tool for watershed sustainability index (WSI) to evaluate the sustainability of the study area, University of Uyo main Campus watershed, comprising of three communities namely: Use Offot, Nsukara Offot and Ekpri Nsukara. The populace living here is perpetually confronted with the challenge of having adequate water to meet their needs despite abundant rainfall. This is due to lack of appropriate extraction mechanism and government will to means of making water available and accessible to the people. This study was to determine how sustainable the zone is regarding availability of water resource using WSI, which information is lacking. Field investigations and questionnaire tools were adopted to extract quantitative data for evaluating the adopted WSI template between years 2013 - 2018. Result obtained for Use Offot, shows the pressure state scored 0.75 each with hydrology quality scoring zero and Environment scoring 0.50. These, when averaged gave the HELP indicator score of 0.55. The State and Response parameters maximum and minimum values recorded were 0.75 (for Policy and

*Corresponding author: Email: israelahuchaogu@uniuyo.edu.ng, israelahu2010@gmail.com;

Environment) and 1.0 for Hydrology quantity showing that these indicators are high within this region. The Community recorded a total average score of 0.59 of all the evaluated parameters, showing that the watershed was fairly sustainable. Nsukara Offot, recorded 0.60 on the final score, an indication that the watershed was sustainable since the value was above 0.50. However, Ekpri Nsukara recorded the highest sustainability value of 0.62 on the average after analysing all the indicators measured. This is because of the high values of the Hydrology (quantity and quality), Environment, and Life and Policy indicators when estimated. Summarily, the WSI of the studied area was of the order averagely: Use Offot = 0.59, Nsukara Offot = 0.60 and Ekpri Nsukara = 0.62 with an average total parameter score of 0.60 affirming that the watershed is sustainable.

Keywords: Watershed; sustainability-index; help-indicator; field investigations; questionnaire tools; template.

1. INTRODUCTION

The United Nations Conference on the Human Environment in 1972 sparked environmental awareness globally. The conference also inspired the publication of the Brundtland Report (also known as Our Common Future), where the notion of sustainable development was first introduced by the Brundtland Commission [1]. Since the publication of this report, studies and efforts to define sustainability and sustainable development have been extensively carried out by various institutions and organisations at all levels: local, national, regional and international. According to reference [2], sustainability is the ultimate goal of sustainable development. In the last few decades, there have been extensive efforts on measuring sustainability. One example is the development of assessment tools based on sustainability indicators, known as sustainability indices. These sustainability indices have common purposes: to measure the sustainability of resources.

Some authors have developed general sustainability indices, such as the Environmental Sustainability Index [3], Corporate Sustainability Indicators [4], the Barometer of Sustainability [5], Environmental Pressure Indices [6], Taking Sustainability Seriously [7], Sustainability Indicator Systems and Pressure-State-Response (PSR) based sustainability indicators [4]. Some sustainability indices are field-specific, such as indicators for environment [3], agriculture [8,9], fossil fuel [10] and water resources. Indices for water resource sustainability, for example, are the Water Poverty Index, WPI [11]; Water Poverty Index, WPI [12], Canadian Water Sustainability Index, CWSI [13], Watershed Sustainability Index, WSI [14,15] and West Java Water Sustainability Index, WJWSI [16]. All these indices have the same goal to measure sustainability, which can further be used to assist

decision makers and other stakeholders in achieving sustainability. Further, the indices can also be used to communicate the progress of sustainability to wider community. For example, the applications of a water sustainability index in one catchment for different years can be used to show the community how the catchment has progressed towards water sustainability.

The above-mentioned sustainability indices were developed based on existing definitions of sustainable development and sustainability principles, proposed by various individuals and institutions. These definitions re-affirm the definition of sustainable development in the Brundtland Report [1], which highlighted the concerns for future generations.

Watershed Sustainability Index (WSI) is an integrated indicator based on basin Hydrology, Environment, Life and Policy (HELP) state condition which include gathering, describing and assessing relevant socio-economic data, [17]. It is a quantitative, dynamic, and aggregated indicator, which uses a pressure-state-response function, developed by [15]. The WSI is suitable for application in a catchment area up to 2,500 km² and has been applied in UNESCO-IHP HELP River Basins since 2004 globally. The HELP index, developed by UNESCO and further consolidated into one single variable called the Watershed Sustainability Index (WSI), is a watershed specific index that takes into account cause-effect relationships and considers policy responses implemented in a given period as part of evaluating a basin sustainability [15]. The WSI integrates the Hydrology (H), Environment (E), Life (L) and Policy (P) aspects of a watershed under three parameters: Pressure, State and Response. Pressure addresses the human activities exerted on the watershed, State assesses the quality of the watershed in the base year of study, as well as the quality and quantity

of natural resources and response examines the society level of desire to address ecological problems in the watershed [18]. The Pressure-State-Response structure incorporates cause-effect relationships and thus provides a more comprehensive understanding of the watershed than an index that only examines the State.

The Ikpa River Basin (IRB), Uyo has been known to satisfy the water requirement needs of villagers of that rural area both for agriculture and domestic wise. But the community of the University of Uyo, a sub catchment of IRB has witnessed a steady increase in the entire population of the community due to the gradual relocation of the various faculties of the school to the main Campus and the attendant development of the adjoining Communities. Therefore, it becomes necessary to forecast the state of the Ikpa River Basin (IRB) watershed sustainability index (WSI) with respect to the University of Uyo, main Campus.

The result obtained will proffer a proper and exact solution to the water sustenance issue of the community in terms of adequate water supply for different use such as the domestic, agricultural, industrial, and entertainment uses, with particular emphasis on the University of Uyo and its adjoining communities of Use Offot, Ekpri Nsukara and Nsukara Offot. Reference [14] specifically applied watershed sustainability index (WSI) at the basin level with an attempt to integrate issues of hydrology, environment, life and policy into a single comparable number. Reviewed works of the developers of this index suggested that previous indices on water resources were not designed solely for use at the watershed scale and they never considered the cause-effect relationship of their indicators. The assessment of water resources sustainability at the basin scale is very vital and cannot be premised by jurisdictional boundary, [14]. The WSI ultimately utilised the Pressure-State-Response (PSR) to evaluate each of the HELP parameters in order to make up for the cause-effect relationships existing among indicators, [19]. Sustainability is the ultimate goal of any sustainable development, states [2]. The sustainability status of challenges/problems related to any project has to be evaluated if the project development in contest has sustainability as its goals. Harding further suggested that assessment should be completed during two important stages of a project, namely: planning and evaluation stages. The planning stage suggest that sustainability assessment makes

sure that project design follows stipulated sustainability guidelines while at the evaluation stage, the monitoring of sustainability progress of the project development is emphasized. The research work presented in this paper utilises the index in [14].

2. MATERIALS AND METHODS

The study area, a sub-watershed of Ikpa River Basin lies between longitude 7°5" E to 8°2" E east of the meridian, and latitude 5°2" N to 5°2" N of the equator with an average elevation of 52.705m above sea level as shown in Fig. 1. This lies within the equatorial rain forest belt, which is a tropical zone that use vegetation of green foliage of trees, shrubs and oil palm trees. A considerable area of the watershed is built-up and still under construction and expansion. The watershed climate is a tropical rainy type which experiences abundant rainfall with very high temperature. The mean annual temperature recorded lies between 20°C and 29°C and average sunshine accumulates to 1450 hours per year. Rainfall distribution pattern is seasonal, convectional and spatial. Uyo mean annual rainfall ranges from 1599 mm to 3855 mm. Maximum humidity is recorded in July while minimum humidity occurs in January. Thick cloud of cumulonimbus type, is commonly experienced in the months of March to November. Evaporation is high and annual values range from 1500 mm to 1800 mm, [20]. Major activities in the watershed are educational and farming.

The quantitative data required for the calculation of the WSI was available in census figures and atlases, and included information such as the district populations, HDI values, and the amount of natural vegetation areas for the study period (2013 - 2018). A research questionnaire was also formulated to collect some qualitative and quantitative data from respondents in the study area. A total of 150 structured questionnaires were distributed out of which 136 were recovered and used for the analysis. For the percentage values of the watershed forest coverage, GIS data was obtained from the Advanced Space Technology Application Laboratory (ASTAL) located in the study area (University of Uyo, main Campus), using ArcView, a GIS analysis software product, [21]. Finally, Water Availability information was obtained from the questionnaire and BOD₅ data was obtained from analysis of stream water sample in the study area through field investigation - measurement. BOD₅ was chosen as a parameter since it contains basic

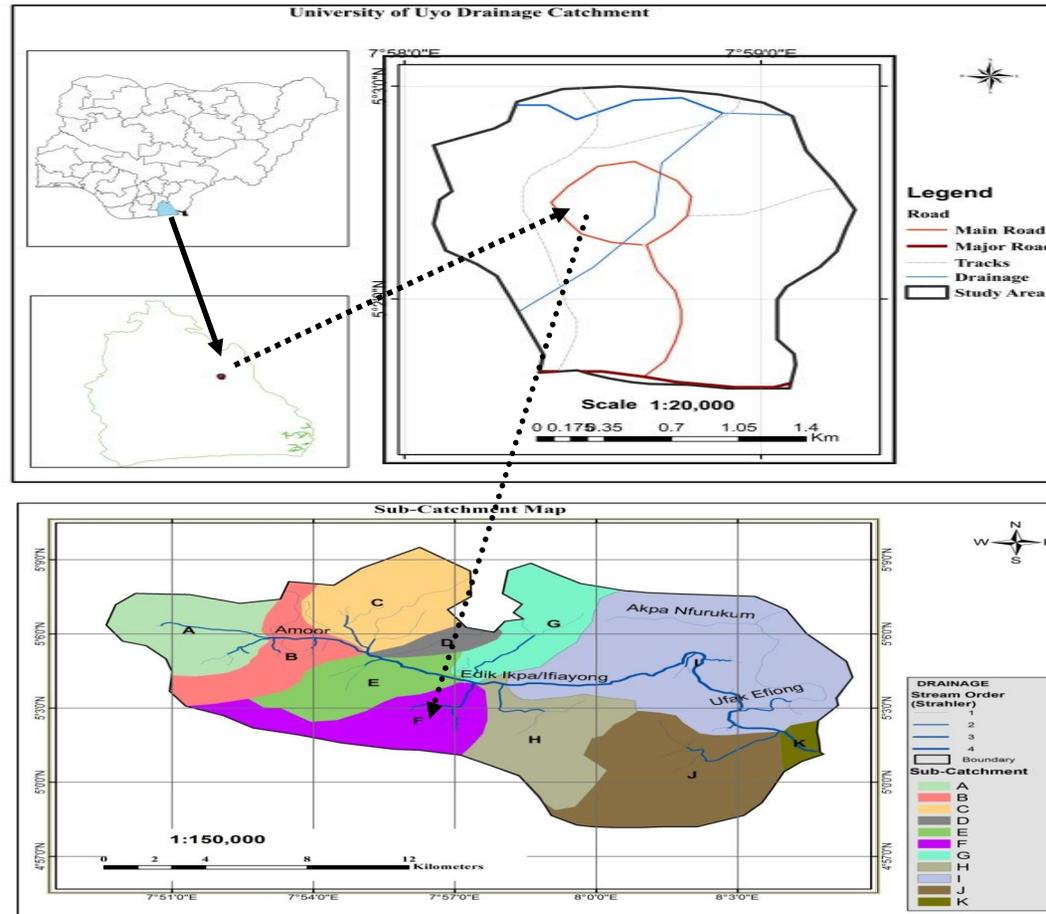


Fig. 1. Sub catchment of Ikpa drainage basin show the study area as sub catchment F

information of hydrological studies and readily available in watersheds. Furthermore, BOD₅ correlates with other important water quality parameters such as dissolved oxygen (DO), turbidity and pollution concentrations. A low BOD₅ represents less organic waste and more dissolved oxygen in the water body and thus is desired.

Water sustainability Index (WSI) developed by UNESCO-IHP is a watershed specific index that takes into account cause-effect relationships and considers policy responses implemented in a given period as part of the basin sustainability [15]. The WSI integrates the Hydrology (H), Environment (E), Life (L) and Policy (P) aspects of a basin under three parameters: Pressure, State and Response, the PSR-Model (Table 1).

The Pressure - State - Response structure incorporates cause-effect relationships and thus provides a more comprehensive understanding of the watershed than an index that only examines the State, for example.

Granting equal weight to each indicator, the simplest linear form of the WSI is:

$$WSI = \frac{H + E + L + P}{4} \quad (1)$$

Operating on a scale of 0 (very poor) to 1.00 (excellent), the WSI uses the most basic parameters that are generally available for all basins, such as the Human Development Index, the Biochemical Oxygen Demand over a five-day period (BOD₅) and the Environment Pressure

Table 1. Summary of the four indicators and three parameters of the watershed sustainability index

Indicators	Parameters			
	Pressure	State	Response	
Hydrology (H)	Quantity	Δ1- Variation in the basin per capita water availability in the period studied relative to the long term average (m ³ /person/year)	Basin per capita water availability (m ³ /person /year) considering both surface and ground water sources	Improvement in water use efficiency in the basin, in the period studied
	Quality	Δ2- Variation in the basin BOD ₅ in the period studied relative to the long term average	Basin average long term BOD ₅ (mg/l)	Improvement in adequate sewage treatment/disposal in the basin, in the period studied
Environment (E)		Basin EPI (rural and urban) in the period studied	Percent of basin area under natural vegetation (Av)	Evolution in basin conservation areas (Protected areas and BMPs) in the basin, in the period studied
Life (L)		Variation in the Basin per capita HDI- Income in the period studied, relative to the previous period	Basin HDI (Weighted by population)	Evolution in the basin HDI in the period studied
Policy (P)		Variation in the Basin per capita HDI- Education in the period studied, relative to the previous period	Basin institutional capacity in IWRM (Legal and Organizational)	Evolution in the basin's IWRM expenditures, in the period studied

Source: [22]

Index. In order to facilitate the estimation of the parameter levels by the users, both quantitative and qualitative parameters are divided into five scores (0, 0.25, 0.50, 0.75 and 1.00). The parameters can be easily assigned a score according to the full description of the levels and scores of all WSI parameters by Spangenberg and Bonniot [4].

After assigning a score to the aforementioned Pressure-State-Response parameters of each indicator, one averages the scores to obtain the indicator value [22]. Then, following the same averaging method, one is able to obtain the overall WSI value that represents the integration of Hydrology, Environment, Life and Policy aspects of the target basin in the period studied.

3. RESULTS AND DISCUSSION

The results of the calculation of the Watershed Sustainability Index (WSI) separated into the three communities making up the University of Uyo watershed [6] viz: Use Offot, Ekpri Nsukara and Nsukara Offot are shown in Table 2.

Applying equation 1 based on the information extracted from the administered questionnaire, field investigation and from appropriate organisations such as UNDP, National Bureau of Statistics (NBS), and National Population Commission (NPC), etc. To facilitate the presentation of the results, the compiled and systemised information is divided according to each indicator, namely: Hydrology, Environment, Life and Policy.

The overall WSI for University of Uyo watershed were computed as shown in the summary in Table 2.

Table 2 shows the average scores grouped by Community, as well as the average parameter scores for each Community and for the entire watershed. Subcatchments A – K (Fig. 1) represents a subcatchment of the entire Ikpa watershed. However, the subcatchment F, indicates the sub-subcatchment which covers the Communities of Use Offot, Ekpri Nsukara, Nsukara Offot (Fig. 1); which serves as

Table 2. Summary table of the watershed sustainability index

Region	Indicator	Pressure score	State score	Response score	Indicator score	Final region score	
Use Offot	Hydrology Quantity	0.75	0.25	1.00	} 0.46	0.59	
	Hydrology Quality	0.00	0.25	0.50			0.25
	Environment	0.50	0.75	0.50			0.58
	Life	0.75	0.50	0.50			0.58
	Policy	0.75	0.75	0.75			0.75
	Parameter Score	0.55	0.50	0.65			
	Score						
Ekpri Nsukara	Hydrology Quantity	1.00	0.00	1.00	} 0.46	0.62	
	Hydrology Quality	0.00	0.25	0.50			0.25
	Environment	0.75	0.75	0.50			0.67
	Life	0.75	0.50	0.50			0.58
	Policy	0.75	0.75	0.75			0.75
	Parameter Score	0.65	0.45	0.65			
	Score						
Nsukara Offot	Hydrology Quantity	0.75	0.25	1.00	} 0.46	0.60	
	Hydrology Quality	0.00	0.25	0.50			0.25
	Environment	0.75	0.75	0.50			0.67
	Life	0.75	0.25	0.50			0.50
	Policy	0.75	0.75	0.75			0.75
	Parameter Score	0.60	0.45	0.65			
	Score						
Total parameter score		0.60	0.47	0.65		0.60	

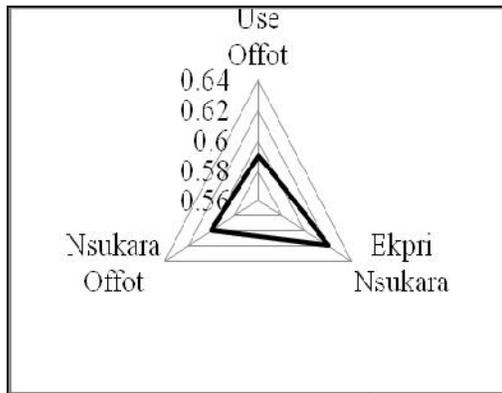


Fig. 2a. Radar comparing WSI for the sub-communities in the University of Uyo watershed

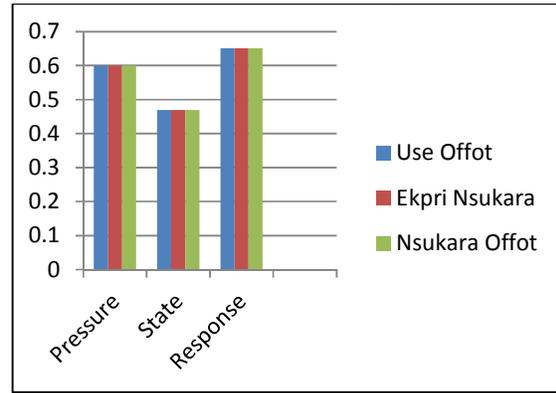


Fig. 2b. Comparison of final WSI values of pressure, state, response, score for the study communities

the study area. It can be seen that the final averages of each Community were close (0.59, 0.62 and 0.60 for Use Offot, Ekpri Nsukara and Nsukara Offot, respectively). However, the overall WSI score for the entire watershed was 0.60 denoting an intermediate (fair) sustainability. Across all of the indicators, the lowest relative score for this watershed was 0.46. As seen in Table 2, hydrology was the lowest scoring indicator. This result is presented graphically in Fig. 2a and 2b respectively.

4. CONCLUSION

The Chaves and Alipaz WSI computation process was followed for the computation of the four indicators (Hydrology, Environment, Life, and Policy) of the WSI for each of the three Communities of the University of Uyo, main Campus watershed. The results point to concerns in each Community/region and these concerns are validated by this research and observation. The general low scores of the hydrology indicator show the relatively poor quality of water and sanitation within the whole basin. This low value of the Hydrology quality Response parameter indicates a need to improve the sewage treatment and disposal plants in the basin. The result of the Hydrology Quantity Pressure parameter suggests that the lower region may need to, in the future, increase its water availability. The score of the Environment Pressure parameter implies that the middle region suffers from human agricultural activities. In sum, the University of Uyo watershed WSI overall result obtained can be said to be fairly sustainable and could benefit greatly from being a part of the UNESCO-HELP program since the

HELP program will provide resources that otherwise would not be available at this critical time to begin making significant and unprecedented efforts towards restoration of the watershed, as the results indicate not only the largest problem areas but those that show no future signs of improvement without intervention. It is therefore recommended that (I) HELP tool utilised in the University of Uyo, a sub-catchment of the Ikpa watershed should be replicated in different watersheds and sub-watersheds of the Local, State and Federal Government, hence a singular representative WSI for all the River basins and by extension the Country would be achieved. This is to have knowledge of their sustainability and their conformity to the sustainability development goals of the United Nations. (II) Water resources laboratories, gauge stations, observations stations that are effective, functional and accessible by researchers should be established by government and licensed individual and non governmental agency to bring about qualitative ways on which natural water planning could be based. (iii) Comprehensive, effective and functional water resources management system should be developed by the Government that will meet the international standards that can be implemented at all levels of Nigerian societies. And finally, this research should be accorded the necessary attention since the World is presently focusing on sustainable development goals (SDGs) of its natural resources and better still, government should expand this research so that it gains recognition on UNESCO – IHP sites located all over the World..It is hoped that for the future, should UNESCO take the recommendations seriously and that a positive change is brought

about in standardizing HELP basins and improving the condition of not just more than that of the University of Uyo watershed, but of similar watersheds all over the world. These UNESCO HELP sites could be used regularly in measuring and standardizing the responses of the population dependence on them and therefore make needful provisions that will make these watersheds to meet the needs of their dependent population, by so doing solve some objectives of the SDGs goals.

DISCLAIMER

This manuscript was presented in a Conference.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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