FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 6 No. 6, December, 2022, pp 241 - 250
DOI: https://doi.org/10.33003/fjs-2022-0606-1164

MULTI-CRITERIA INDICATORS FOR IRRIGATION SCHEMES SUSTAINABILITY PERFORMANCE ASSESSMENT

***Shanono, N. J., M. S. Abubakar, M. M. Maina, M. L. Attanda, M. M. Bello, M. D. Zakari, N. M. Nasidi and N. Y. Usman**

Department of Agricultural and Environmental Engineering, Bayero University Kano, Nigeria

*Corresponding authors' email: njshanono.age@buk.edu.ng Phone: +2348038443863

ABSTRACT

Assessing the sustainability performance of an irrigation scheme requires a multi-criteria approach that holistically incorporates factors from all the sustainability pillars. To achieve this, a framework of indicators for irrigation schemes sustainability assessment that identify multi-dimensional challenges affecting the sustainability performance of irrigation scheme was developed. The framework entails the identification, selection and screening of criteria (primary and secondary) that cut across 5 sustainability pillars (economic, social, environmental, technological and institutional). Moreover, the framework was developed based on the experts' opinions using a 5-level Likert scale (not important, least important, moderately important, important and very important) and out of 212 administered questionnaires, 153 were returned (72%). The experts' higher ratings of very important for institution, environment, technical, economic and social were 56, 50, 41, 40 and 37% respectively. Hence, irrigation experts rated institutional and environmental aspects as the most important for a sustainable irrigation scheme. The Cronbach's alpha (Cα) values interpretation was used to evaluate the internal consistency of the criteria and all the criteria have Cα values of greater than 0.5, thus, all the criteria were considered reliable for further analysis. Out of the 17 primary criteria, 3 (17.6%), 6 (35.3%), and 8 (47.1%) were rated as excellent, good and satisfactory respectively. At the initial stage, the framework comprises 17 primary and 70 secondary criteria and after the screening, the framework comprises 17 primary and 64 secondary criteria for measuring the sustainability performance of irrigation schemes in northern Nigeria.

Keywords: Indicators, Irrigation schemes, Multi-dimensional, Sustainability performance

INTRODUCTION

The rate at which the human population increases in Nigeria is alarming. This instigated the need to manage the country's irrigation schemes effectively, thereby improving agricultural production to meet the population's needs (Mohammed & Ali, 2021). To achieve this, there is a need to develop a monitoring tool that can holistically assess the state of irrigation schemes from a multi-dimensional perspective (Shanono and Ndiritu, 2019). A method that can be used to fulfil some of these multi-dimensional tasks is through the development and use of a sustainability approach using suitable indicators (Fiksel et al., 2012; Xiaoyu et. al., 2017; Shanono and Ndiritu, 2020). The sustainability approach of system assessment has the power of providing means of assessing and communicating information about the state of systems in a simplified manner (Kuscu and Demir, 2015; Borsato et. al., 2020).

In assessing the sustainable development of strategies, processes or systems like irrigation schemes, criteria and indicators with different dimensions can be used to trace changes (if any) in the pillars of sustainability. This approach can help assess how human activities (management, operations, maintenance, policies etc.) affected the performance of a given system over time (Chun and Chung, 2013; Shanono, 2014). This method involves the identification, screening and development of performance assessment criteria from all pillars of sustainability. The assessment criteria are the set of measurable factors that can be used to make a judgment about the relative sustainability of a set of options and indicators as measures of past and current values of specific criteria. Such screened criteria are commonly used as baseline indicators for future performance assessments (Marzbal and Mohammad 2014; Bell & Morse, 2018). The Organization for Economic Co-operation and Development (OECD), United Nations (UN), the United States Environmental Protection Agency (USEPA), and the European Environment Agency (EEA) have developed templates of different sets of measurable criteria and indicators for the performance assessment of systems or processes (Spangenberg, 2016; OECD, 2008). The template can assess different aspects of the given system including environment, society, economy, institution and technology thereby, monitoring the system's progress temporally and/or spatially.

The OECD identified five main targets for sustainable development, operation and maintenance of any given system as stated by Wang and Fang (2014). The five main targets are; resource efficiency, energy efficiency, pollution prevention, harmonization with the environment and integrated and systemic approaches. It is important to note that a set of core criteria and indicators are developed concerning the system under consideration. Criteria and indicators must, therefore, provide appropriate and reasonable information to enable the goals and objectives of the measurement and assessment of sustainable development for a given system under consideration. Furthermore, many studies reported that a set of core criteria and indicators should be validated and accepted by decision-makers and stakeholders of any assessment process (Cloquell-Ballestera et al., 2009; Azevedo et. al., 2017; Lawal et al., 2022). One major function of an indicator is to reduce the complexity and volume of information that is required by stakeholders and decision-makers.

A significant number of studies have been reported to utilize such a set of core criteria and indicators to assess the performance of various systems including water-related sectors in different regions across the world (Singh et. al., 2007; Azevedo et al., 2017). For example, studies on Sustainable Development (SD) and Integrated Water

Resource Management (IWRM) have used approaches such as social surveys in form of research questionnaires, workshops, seminars, expert panels, oral interviews, formal meetings and site visits to identify, select, screen and develop criteria and associated methods of measurement (Song and Moon, 2018). Gallego-ayala et al., (2014) used an expert panel comprising technicians from the Water Regulatory Council of Mozambique and the main water supply institutions in Mozambique to debate and harmonize aspects such as selecting baseline indicators, indicator weights and indicator boundaries involved in the construction of a Water Utility Performance Index (WUPI). This was achieved using an interactive approach by the means of a round table meeting to agree on the criteria and indicators constituting the WUPI. Carden and Armitage, (2013) developed a set of indicators (Sustainability Index) to assess urban water management in South Africa. A comprehensive list of indicators to assess the sustainability of urban water management in South Africa was developed using participatory processes which involve the use of oral interviews with municipal officials, local authorities and other stakeholders. Other methods used include data availability and credibility assessment and review of existing indices to identify suitable indicators (Plessis & Bam, 2018).

In northern Nigeria, there are limited tools that can be used to assess the sustainability of irrigation schemes, although irrigation is an important aspect of food security in the region and the country (Nasidi et al., 2015; Zakari et al., 2015; Ismail et al. 2021; Shanono and Abba, 2022). It is, therefore, essential to study and develop a framework of a set of core criteria and indicators for the assessment of the sustainability performance of irrigation schemes. This paper, therefore, presents the outcome of an extensive review (desktop study), questionnaire and consultation with irrigation and water resource management experts to develop a framework of sustainability-based indicators for a holistic assessment of irrigation scheme sustainability in northern Nigeria.

METHODOLOGY

Development of Irrigation schemes sustainability assessment indicators

Irrigation schemes' sustainability criteria and indicators (primary and secondary) were initially generated through an extensive review (desktop study) of the irrigation management-related reports, journals, books, questionnaires and site visits. The review covered major irrigation schemes within the northern part of Nigeria. Indicators selection was based on the measurability, analytical soundness and relevance to irrigation scheme sustainability assessment. The criteria were selected to reflect a variety of sustainability issues associated with irrigation schemes. The framework was developed using the first two steps procedure for the development of composite indicators (CI) as explained in the OECD report (OECD, 2008; Kondyli, 2010).

Theoretical framework for irrigation schemes sustainability assessment indicators

The theoretical framework was developed based on the criteria for the selection of indicators from all the sustainability pillars and the combination of these indicators into a meaningful Composite Indicator (CI). Moreover, the theoretical framework was set to accurately describe the phenomena to be measured and the elements that shape them. The predominant factors affecting irrigation schemes in Nigeria, especially the northern part of the country were considered. Some of the factors include stakeholders, water allocation or sharing methods, irrigation efficiency, irrigation schemes operation, management and maintenance. Other factors considered include sustainable irrigation and impediments to irrigation as well as legislation and regulatory requirements were also studied. To understand the concept of sustainability in terms of irrigation schemes management, an extensive literature review on the irrigation schemes design, operation and maintenance was conducted. Several related journal articles, conference papers, reports and thesis were reviewed (Mohammed and Ali, 2021; Aiyedun, 2020; Borsato et al., 2020; Marinello, 2019; Bervar and Bertoncelj, 2016; Wang and Fang, 2014; Cakmak et al., 2010; Savva and Frenken, 2002). In addition, sustainability criteria and indicators were reviewed using five key considerations as follows; irrigation water and soil management, cost-related implications, social and cultural inclinations, environmental considerations and technological advances in irrigation management (Xiaoyu et al., 2017; OECD, 2008; Singh et al., 2007).

Selection and screening of irrigation schemes sustainability assessment indicators

The multi-criteria sustainability indicators were selected based on their analytical soundness, measurability, spatial coverage, relevance to the phenomenon being measured (irrigation schemes performance) and their relationship to each other. The multi-criteria sustainability indicators were categorized under the five irrigation sustainability pillars. The pillars include Social well-being (SW), Economic Benefit (EB), Environmental Health (EH), Technological Advances (TA) and Institutional Arrangement (IA). The criteria and associated methods of measurement developed were subjected to the 3S validation process (Cloquell-Ballestera et al. 2009). Cloquell-Ballestera et al. (2009) suggested 3 forms of validation which are (i) self-validation; (ii) scientific validation; and (iii) social validation. The irrigation and water management experts validated the selected criteria and their methods of measurement (self-validation). Scientific validation was conducted to assess the selected criteria and their methods of measurement from case studies and expert opinions. The social validation was ensured by participation of different stakeholders with knowledge of irrigation across the entire water management and irrigation institute in northern Nigeria.

A social survey in the form of a questionnaire was developed, administered and analyzed to extract expert opinions and insight for the development of criteria and indicators framework for assessing the sustainability of irrigation schemes in northern Nigeria. The targeted respondents are irrigation management experts from various irrigation schemes, water management researchers and practitioners located in northern Nigeria. The criteria were divided into primary and secondary criteria, the primary criterion serves as the construct being measured with multiple secondary criteria. The structure of the questionnaires was broadly divided into the following 4 sections; Section 1 provides an introduction, the aim of the study and simple definitions of keywords used in the questionnaire such as irrigation scheme, criteria and types of irrigation water allocation for potable use. Section 2 requests the respondent to fill in the water management or irrigation sector he/she is currently active in, (respondent may tick more than one) and requests the respondent to revise/modify criteria supplied in the questionnaire and to suggest additional criteria and units of measurement. Section 3 requests the participants to rate the importance of the indicators in the sustainability assessment of irrigation schemes. Section 4 requests the participants to rate the importance of the secondary criteria under each primary criterion for assessing the sustainability of irrigation schemes and revise/modify the criteria supplied in the questionnaire and suggest additional criteria and units of measurement if any.

The experts were required to rate the degree of the importance of each secondary criterion ranging from not important (NI), least important (LI), moderately important (MI), important (I) and very important (VI). Cronbach's alpha coefficient was used to evaluate the degree to which a set of criteria measures a single latent construct. Alpha coefficient (Cα) ranges from a value of 0 to 1, where a higher value indicates greater internal consistency and a lower value indicates lower consistency (Doloi et. al., 2012; Vaske ea. al., 2017). There are quite a number of rules for deciding on the range of Cα values, however, there is a rule of thumb for the interpretation: $C\alpha > 0.8$ implies excellent, $0.8 > C\alpha > 0.7$ implies good, $0.7 > C\alpha > 0.5$ implies satisfactory and $C\alpha < 0.5$ implies poor (Albogamy et al. 2013). In this study, several secondary criteria were used to measure how well a primary criterion is performing in relation to an indicator category. The data collected were analyzed using the Statistical Package for Social Sciences (SPSS) software. A two-step approach was used to evaluate the experts' opinions with regard to the importance of the criteria to the sustainability irrigation scheme assessment process. The first step involved the use of the Cα value to determine if the secondary criteria measure the same construct (primary criterion). The second step involves the use of frequency of occurrence of "very important" to develop the list of criteria imperative to the sustainability irrigation scheme assessment process. Thus, the framework consisted of a list of screened indicators which were categorized under 5 sustainability pillars. The procedure for the development of irrigation scheme sustainability assessment indicators are summarized in Figure 1.

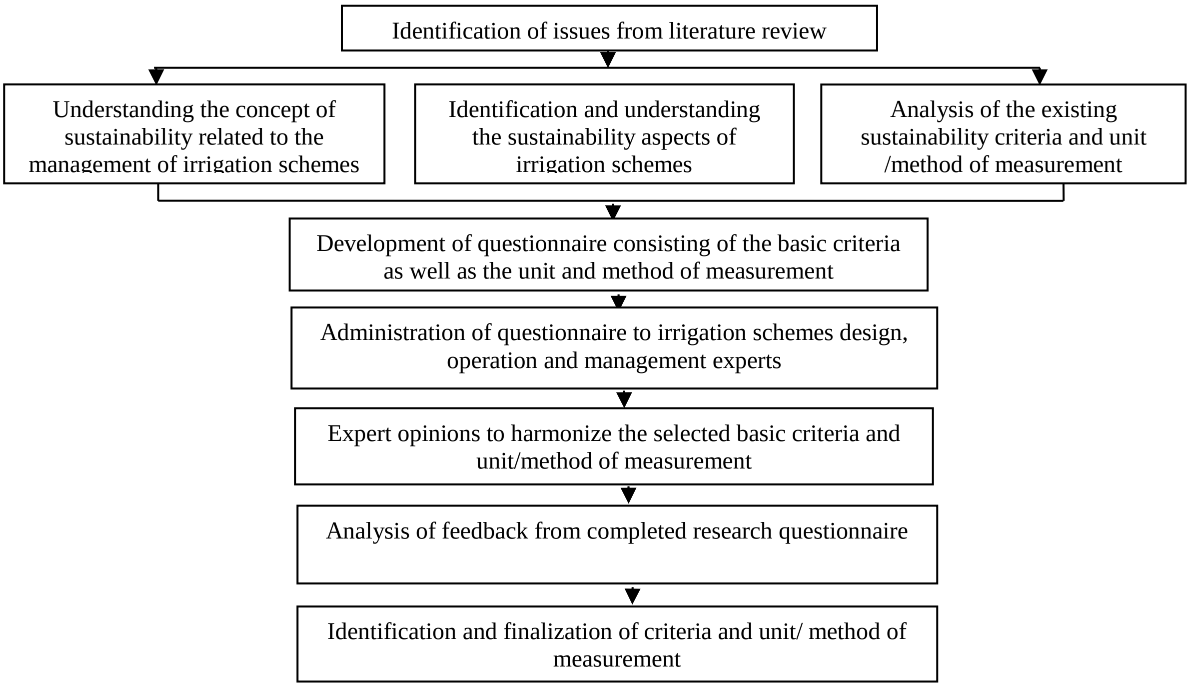

Figure 1: Framework for the development of irrigation scheme sustainability assessment indicators

RESULTS AND DISCUSSIONS

Irrigation and Water Management Experts' Responses

A total of 212 questionnaires were administered to the irrigation and water management experts across northern Nigeria out of which 153 questionnaires were returned. Thus, the corresponding response of 72 % was achieved which is on average acceptable for the analysis of survey research as suggested by Sunjka and Jacob (2013). Though the sample size is relatively small, the quality of the responses was considered to be highly reliable for this study due to relevant irrigation and water management experiences and a clear understanding of the subject matter among the selected respondents. In addition, the questionnaires were distributed across the northern part of the country which was considered to have a wider coverage of different respondents with different cultures and work ethics. All responses were selected for further analysis based on the measurability, analytical soundness, relevance to irrigation scheme sustainability assessment and validity of the information provided. A summary of participating experts is summarised in Table 1.

Table 1: Responses of the participating irrigation and water management experts

Respondents Sectors	Questionnaires administered	Questionnaires returned	Proportion returned (%)
Federal Academic institutions	34	25	73.50
State Academic institutions	20	16	80.00
Federal ministry of water resource	30	22	73.30
State ministry of water resource	36	23	63.90

Federal ministry of agriculture	25	18	72.00
State ministry of agriculture	28	19	67.90
Engineers and consultants	7	6	85.70
Non-governmental organizations	15	11	73.30
Other water regulatory authorities	17	13	76.50
Total	**212**	**153**	**72.20**

Table 2 shows the analysis of the 153 returned questionnaires rating the 5 sustainability pillars (environmental, technical, economic, social and institutional) using the 5-level Likert scale (not important, least important, moderately important, important and very important). For the very important option, the institution was rated as the highest with 86 out of the 153 respondents (56.2%) and social was rated the least with 57 out of 153 (37.3%). Meanwhile, the environmental, technical and economic were rated as 77 out of 153 (50.3%), 63 out of 153 (41.2%) and 62 out of 153 (40.5%) respectively. The results indicated that institutional arrangement and environmental health were rated as the most important aspects of sustainable irrigation scheme operation followed by technological advances, economic gain and social well-being respectively.
Based on the results, irrigation and water experts considers institution arrangement should carry higher weight as explained in the concept of ethics which involves methodizing the concept of right and wrong conduct. Hence, irrigation scheme management institutions should set following the moral standpoint as a code of conduct governing stakeholders' activities reflected in their actions. Through sound institutions, irrigation stakeholders' activities can be limited by advocating virtuousness thereby, taking care of all other sustainability aspects including technical, environmental, social, and economic (Groenfeldt & Schmidt, 2013; Shanono, 2020). When an irrigation scheme attains these values, the ethical climate is said to have prevailed which is the overall view of the moral atmosphere and positive responses are always expected from the irrigation stakeholders (Treviño *et al.*, 2006; Shanono, 2019). It is, therefore, desirable that such a moral atmosphere is created in all irrigation schemes of northern Nigeria by developing a sound institution that can take care of all other sustainability dimensions. Four response measures were proposed and should be incorporated in any irrigation management institutions to serve as a response to some undesirable activities by irrigation stakeholders; i) sensitivity and awareness-raising campaigns, ii) law enforcement and legal actions, iii) participation and sharing of responsibilities and iv) engagement and policy dialogues.

Table 2: Frequency of rated indicators by respondents irrigation and water management experts

Sustainability Pillars	**Not Important*(%)***	**Least Important*(%)***	**Moderately Important*(%)***	**Important *(%)***	**Very Important*(%)***	**Total *(%)***
Environmental	2*(1.3)*	6*(3.9)*	20*(13.1)*	48*(31.4)*	*77(50.3)*	**153*(100%)***
Technical	1*(0.7)*	3*(2.0)*	18*(11.8)*	68*(44.4)*	63*(41.2)*	**153*(100%)***
Economic	2*(1.3)*	3*(2.0)*	16*(10.5)*	70*(45.8)*	62*(40.5)*	**153*(100%)***
Social	1*(0.7)*	6*(3.9)*	21*(13.7)*	68*(44.4)*	57*(37.3)*	**153*(100%)***
Institutional	6*(3.9)*	4*(2.6)*	16*(10.5)*	41*(26.8)*	86*(56.2)*	**153*(100%)***
Total	**12*(1.6%)***	**22*(2.9%)***	**91*(11.9%)***	**295*(38.6%)***	**345*(45.1%)***	***(100%)***

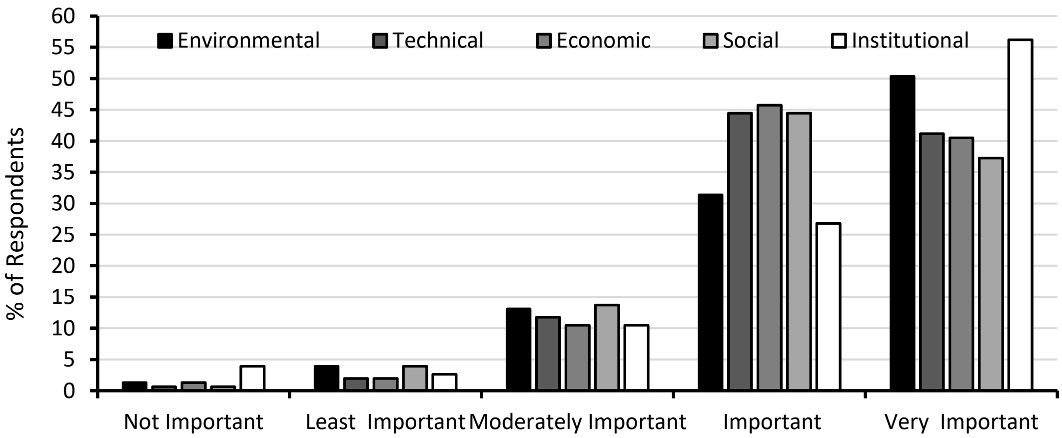

Figure 2: Frequency of rated indicators by irrigation and water management experts

Data Analysis of Participating Experts' Opinions

Internal consistency of primary criteria for assessing irrigation scheme sustainability

The Cronbach's alpha (Cα) values interpretation by Albogamy et al. (2013) was used in this study; Cα > 0.8 implies excellent, 0.8 > Cα > 0.7 implies good, 0.7 > Cα > 0.5 implies satisfactory and Cα < 0.5 implies poor. Table 3 below shows the primary and secondary criteria and Cronbach's alpha value for the measured criteria. All the criteria used to measure the sustainability of the irrigation scheme have Cα values greater than 0.5. For that reason, all the criteria were considered reliable for further analysis. Internal consistency (reliability) test was conducted for the 17 constructs (primary criteria). Out of the 17 primary criteria, 3 (17.6%), 6 (35.3%), and 8 (47.1%) were rated as excellent, good and satisfactory respectively. The results of the internal consistency of criteria for assessing irrigation scheme sustainability are presented in Table 3.

Table 3: Internal consistency of 17 primary criteria for assessing irrigation scheme sustainability

Performance rating	Frequency	Percentage (%)
Excellent	3	17.6
Good	6	35.3
Satisfactory	8	47.1
Poor	0	0.0
Total	17	100

Experts' rating of secondary criteria for assessing irrigation scheme sustainability

Table 4 shows the frequency of experts' ratings ranging from 1 (not important), 2 (least important), 3 (moderately important), 4 (important) to 5 (very important) for the various indicators used for sustainability assessment of irrigation schemes was analyzed. The ratings reflect the importance of the secondary criteria for assessing the sustainability of irrigation schemes in northern Nigeria. The experts' rating of the importance of secondary criteria associated with the institutional aspect, out of the 19 secondary criteria, the experts rated 9 (47.4%) as very important, 8 (42.1%) as important and 2 (10.5%) as moderately important for institutional assessment of irrigation scheme sustainability in northern Nigeria. Whereas none (0%) of the criteria were rated as least or not important. The experts' rating of the importance of secondary criteria associated with the social aspect, out of the 19 secondary criteria, the experts rated 3 (15.8%) as very important, 15 (78.9%) as important and 1 (5.3%) as moderately important for social assessment of irrigation scheme sustainability in northern Nigeria. While none (0%) of the criteria were rated as least and not important. For the environmental aspect, out of the 9 secondary criteria, the experts rated 6 (66.7%) as important and 3 (33.3%) as moderately important. While none (0%) of the criteria were rated as very, least and not important. For the economic aspect, out of the 7 secondary criteria, the experts rated 1 (14.3%) as very important and 6 (85.7%) as important. While none (0%) of the criteria were rated as moderately, least and not important. For the technological aspect, out of the 17 secondary criteria, the experts rated 16 (94.1%) as important and 1 (5.9%) as moderately important. While none (0%) of the criteria were rated as very, least and not important.

Table 4: Experts' rating of secondary criteria associated with the sustainability of irrigation schemes

Performance rating	Institutional		Social		Environmental		Economic		Technological	
	Score	%	Score	%	Score	%	Score	%	Score	%
Very important	9	47.4	3	15.8	0	0.0	1	14.3	0	0.0
Important	8	42.1	15	78.9	6	66.7	6	85.7	16	94.1
Moderately Important	2	10.5	1	5.3	3	33.3	0	0.0	1	5.9
Least Important	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Not Important	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total	**19**	**100**	**19**	**100**	**9**	**100**	**7**	**100**	**17**	**100**

Table 5 provides a summary of the screened criteria. Initially, 17 primary criteria and 70 secondary criteria were identified and selected. After rigorous screening by the experts, although the experts acknowledged the fact that all the identified criteria are important, however, the finally screened criteria comprise 17 primary criteria and 64 secondary criteria as summarised in Table 5.

Table 5: Finally screened primary and secondary criteria

Irrigation Scheme Sustainability Pillars	Initial criteria (primary and secondary)		Screened criteria (primary and secondary)	
	Primary	Secondary	Primary	Secondary
Institutional	4	19	4	18
Social	4	18	4	17
Environmental	2	9	2	6
Economic	3	7	3	7
Technical	4	17	4	16
Total	**17**	**70**	**17**	**64**

The final and comprehensive list of the screened criteria (primary and secondary) for the assessment of the sustainability performance of irrigation schemes in northern Nigeria is shown in Table 6. These criteria can be used as a baseline tool by irrigation managers, operators, engineers and other people that have knowledge of irrigation schemes to evaluate the sustainability of the existing schemes.

Table 6: Final list of criteria (primary and secondary) rated "important" and "very important".

Sustainability Pillars	Primary Criteria	Secondary Criteria	Unit/(MoM)
INSTITUTIONAL	Water allocation performance (efficiency)	Adequacy of water to be supplied to farmers	Ratio of water delivered to required (%)
		Reliability of the water supply systems	Temporal variability of adequacy (%)
		Equity in sharing the water among farmers (fair share of water to users)	Spatial variability of adequacy (%)
		Resilience of the overall water allocation system	Ratio (%)
		Vulnerability of the overall water allocation system	Ratio (%)
	The state of irrigation scheme infrastructures due to maintenance of the management	Condition of the water source (e.g storage active capacity, embankment, spillway etc.)	Ration (%)
		Primary canals (e.g siltation, weeds, cracks etc.)	Ration (%)
		Secondary canals (e.g siltation, weds, cracks etc.)	Ration (%)
		Tertiary canals (e.g siltation, weeds, cracks etc.)	Ration (%)
		Control structures (e.g gates, turnover etc.)	Ration (%)
	Suitability and adherence to Rule and Regulations by irrigation stakeholders	Suitability of water allocation method	Ratio as rated by the experts and managers (%)
		Farmers' adherence to water allocation rules	Ratio as rated by the experts and managers (%)
		Managers' adherence to water allocation rules	Ratio as rated by the experts and managers (%)
		Role of WUAs in rules enforcement	Ratio as rated by the experts and managers (%)
		Role of traditional leaders in rules enforcement	Ratio as rated by the experts and managers (%)
	Farmers participation in the management and maintenance activities	Participation in decision making	Ratio as rated by the experts, managers and farmers (%)
		Farmers' participation in maintenance activities	Ratio as rated by the experts, managers and farmers (%)
		Formation and participation in associations (WUAs)	Ratio as rated by the experts, managers and farmers (%)
SOCIAL	Farmers' trust, risk perception and willingness to behave ethically	Trust in irrigation management staff	% of farmers having trust in management staff
		Perceived risk associated with water allocation method	% of farmers with concerns about water allocation method
		Perceived risk associated with water shortage	% of farmers with concerns about water availability
		Willingness to obey rules	% of farmers willing to abide by the rules
	Irrigation scheme managers' social wellbeing	Irrigation managers' job satisfaction	% of the managers satisfied
		Satisfaction with the condition of the workplace	% of the managers satisfied
		Satisfaction with the salary and other allowances	% of the managers satisfied
		Satisfaction with the security in the area	% of the managers satisfied
		Access to, and satisfaction with the social amenities	
	Farmers	Farmers' satisfaction with the irrigation scheme staff	% of the farmers satisfied

	satisfaction and social wellbeing	Farmers' satisfaction with the WUAs activities Farmers'	% of the farmers satisfied
		Farmers' satisfaction with the governmental intervention	% of the farmers satisfied
		Farmers' satisfaction with the non-governmental intervention	% of the farmers satisfied
		Farmers' satisfaction with the market	% of the farmers satisfied
	Community responsibility, resilience, public education and awareness	Individual action to encourage effective irrigation scheme	% of people willing to change behaviour
		Public education and awareness programmes	% of awareness in the neighbouring community
		Social inclusion	% of the population with access to information
		Community response to unexpected calamities	% of the population to withstand unexpected disaster
ENVIRONMENTAL	Major water quality constituents affecting agricultural production	Water salinity (EC)	dS/m
		% of Na out of Ca, Mg, Na and K in irrigation water	% of Na out of the cations
		Major heavy metal in the irrigation	Mg/L
	Impact of irrigation activities on irrigated soils	Salinity level of the soil (EC)	dS/m
		% of Na out of Ca, Mg, Na and K in the irrigated soil (%ESP)	% of Na out of the cations
		Over application of chemicals by farmer	% of farmers using chemical farm input
ECONOMIC	Estimated seasonal cost of operating of 1 hector (ha) of land	Average cost of renting of irrigation land (ha)	Naira/season/ha
		Average cost of farm operations (land preparation - harvesting) (ha)	Naira/season/ha
		Revenue collected from farmers per ha	Naira/season/ha
		Cost of water collected from farmers per ha	Naira/season/ha
	Estimated seasonal benefit generated from 1 ha of land	Average benefit generated from 1 hector (ha) of land	Naira/season/ha
	Benefit-Cost ration	Average payback period (length of time to recover the cost of investing in farming)	Year as rated by the experts and managers (%)
		Ratio of the average of benefit generated to the average cost of investment	Ratio as rated by the farmers and managers (%)
TECHNICAL	Design-to-operational capacity of the irrigation scheme	Ratio of design to the current capacity of Dam	Ratio (%)
		Ratio of design to the operational capacity of the main canal	Ratio (%)
		Ratio of design to the operational capacity of distributaries canal	Ratio (%)
		Ratio of design irrigable area to the current irrigable area	Ratio (%)
	Condition of the irrigation scheme infrastructures	Proportion of canals silted	Ratio (%)
		Proportion of canals infested with weeds	Ratio (%)
		Number of cracks per unit length of the canal	Ratio (%)
		Proportion of irrigation scheme equipment working effectively (e.g. gates, turn over etc.)	Ratio (%)

	Proportion of the capacity of the night storage reservoir (if any)	Ratio (%)
Robustness and reliability of water allocation system	Flexibility for proper control of water allocation method when the need arises	Ratio as rated by the experts and managers (%)
	Proportion of farmers received required amount of water	Ratio as rated by the experts and managers (%)
Methods of farm operations	Proportion of land preparation using mechanized and other technologically improved methods	Ratio as rated by the experts and managers (%)
	Proportion of crop management using mechanized and other technologically improved methods	Ratio as rated by the experts and managers (%)
	Proportion of crop harvest using mechanized and other technologically improved methods	Ratio as rated by the experts and managers (%)
	Proportion of post-harvest using mechanized and other technologically improved methods	Ratio as rated by the experts and managers (%)
	Proportion of marketing the farm produce using technologically improved methods	Ratio as rated by the experts and managers (%)

CONCLUSION

Assessing the sustainability of irrigation schemes requires a multi-criteria approach that integrates multi-dimensional factors. With the aim to contribute toward achieving this, a framework of irrigation schemes sustainability assessment indicators that identify challenges affecting irrigation scheme sustainability was developed and reported herein. The framework identified, selected and screened the criteria (primary and secondary) that cut across 5 sustainability pillars (economic, social, environmental, technological and institutional). Moreover, the framework was developed based on the experts' opinions using the 5-level Likert scale (not important, least important, moderately important, important and very important) and out of 212 administered questionnaires, 153 were returned (72%). The experts' higher ratings of very important for institution, environment, technical, economic and social were 56, 50, 41, 40 and 37% respectively. Thus, irrigation experts rated institutional arrangement and environmental health as the most important aspect of a sustainable irrigation scheme. The Cronbach's alpha (Cα) values interpretation was used to evaluate the internal consistency of criteria and all the criteria have Cα values of greater than 0.5, thus, all the criteria were considered reliable for further analysis. Out of the 16 primary criteria, 3 (17.6%), 6 (35.3%), and 8 (47.1%) were rated as excellent, good and satisfactory respectively. Initially, the framework comprises 17 primary and 70 secondary criteria and after the screening, the framework comprises 17 primary and 64 secondary criteria that can be used to measure the sustainability performance of irrigation schemes in northern Nigeria.

ACKNOWLEDGEMENTS

On behalf of the entire authors, our appreciation is extended to the management of Bayero University Kano, Nigeria for the opportunity to conduct this study through the Directorate of Research, Innovation and Partnerships (DRIP), Institution Based Research (IBR), a component of the Tertiary Education Trust Fund (TETFund).

REFERENCES

Aiyedun, E. A. (2020). Irrigated Agriculture In Nigeria : Problems And Prospects. *African Journal of Agricultural Science*, *18*(April).

Albogamy A., Scott D., Dawood N. and Bekr G. (2013). Addressing crucial risk factors in the Middle East construction industries: A comparative study of Saudi Arabia and Jordan. Sustainable Building Conf. Coventry University, West Midlands, UK, pp. 118 – 128.

Azevedo, S. G., Carvalho, H., Ferreira, L. M., & Matias, J. C. O. (2017). A proposed framework to assess upstream supply chain sustainability. *Environment, Development and Sustainability*, *19*(6), 2253–2273. https://doi.org/10.1007/s10668-016-9853-0

Bell, S. and, & Morse, S. (2018). Sustainability Indicators Past and Present : What Next ? *Sustainability MDPI*, *10*(1688), 1–15. https://doi.org/10.3390/su10051688

Bervar, M., & Bertoncelj, A. (2016). The Five Pillars of Sustainability : Economic, Social, Environmental, Cultural and Security Aspects. *Management International Conference*, 243–244. Pula, Croatia.

Borsato, E., Rosa, L., Marinello, F., & Tarolli, P. (2020). Weak and Strong Sustainability of Irrigation : A Framework for Irrigation Practices Under Limited Water Availability. *Frontiers in Sustainable Food Systems*, *4*(February), 1–16. https://doi.org/10.3389/fsufs.2020.00017

Cakmak, B., Kibaroglu, A., Kendirli, B., & Gokalp, Z. (2010). Assessment of the irrigation performance of transferred schemes in Turkey: A case study analysis. *Irrigation and Drainage*, *59*(2), 138–149. https://doi.org/10.1002/ird.452

Carden, K., & Armitage, N. (2013). Assessing urban water sustainability in South Africa - Not just performance Assessing urban water sustainability in South Africa – not just performance measurement. *Water Institute of Southern Africa (WISA) Biennial Conference, Cape Town, 6–10*, *39*(3), 345–350. https://doi.org/10.4314/wsa.v39i3.1

Chun, S. G., & Chung, D. (2013). A critical review of popular multi-criteria decision making a critical review of popular multi-criteria decision making. *Issues in Information Systems*, *14*(1), 358–365. Retrieved from https://www.researchgate.net/publication/271526736%0AA

Cloquell-Ballestera, V., Ana del Carmen Torres Sibillea, V.-A. C.-B. and R. D. (2009). Development and validation of a multicriteria indicator for the assessment of the objective aesthetic impact of wind farms. *Renewable and Sustainable*

Energy Reviews (ScienceDirect), *13*, 40–66. https://doi.org/10.1016/j.rser.2007.05.002

Fiksel, Joseph, T. E., & Frederickson, H. (2012). *A Framework for Sustainability Indicators at EPA A Framework for Sustainability Indicators at EPA Authors*. Retrieved from www.epa.gov/ord

Gallego-ayala, J., Dimene, S., Munhequete, A., & Amos, R. (2014). Assessing the performance of urban water utilities in Mozambique using a water utility performance index. *Water South Africa*, *40*(757), 665–676. https://doi.org/10.4314/wsa.v40i4.12

Groenfeldt, D., & Schmidt, J. J. (2013). Ethics and Water Governance. *Ecology and Society*, *18*(1), 1–10.

Ismail H., Rowshon M.K., Shanono N.J., Nasidi N.M. and Umar D.A. (2021). Hydrological Modelling for Evaluating Climate Change Impacts on Streamflow Regime in the Bernam River Basin Malaysia. *FUDMA Journal of Sciences.* 5(3), pp 219 – 230. https://doi.org/10.33003/fjs-2021-0503-707

Kondyli, J. (2010). Measurement and evaluation of sustainable development A composite indicator for the islands of the North Aegean region, Greece. *Environmental Impact Assessment Review*, *30*(6), 347–356. https://doi.org/10.1016/j.eiar.2009.08.006

Kuscu, H. and, & Demir, A. O. (2015). Performance assessment for irrigation water management : A case study in the Karacabey irrigation scheme in Turkey. *African Journal of Agricultural Research*, *4*(2), 124–132. Retrieved from http://www.academicjournals.org/AJAR

Lawal, A., N.J. Shanono, and Nasidi, N.M. (2022). Toward Adoption of Drip Irrigation and Soil-moisture Sensors by Small-Scale Farmers. *FUDMA Journal of Sciences* Vol. 6 (3), pp 259 - 270 https://doi.org/10.33003/fjs-2022-0603-961

Marzbali, M. J. M. T. and M. H. (2014). Developing a Criteria Framework for Evaluation of the Urban Development Plans in Iran: Bridging the Gap Between Knowledge and Action. *Journal of Urban and Environmental Engineering*, *8*(2), 232–241. https://doi.org/10.4090/juee.2014.v8n2.232242

Mohammed, U., & Ali, and M. S. (2021). Socio-economic Challenges of Irrigation Farming Along River Yobe (A case study of Yobe State). *Journal of Environmental Science, Toxicology and Food Technology*, *15*(4), 1–7. https://doi.org/10.9790/2402-1504010107

Nasidi, N. M. et al. (2015). Reclaiming Salt-affected Soil for the Production of Tomato at Barwa-Minjibir Irrigation Scheme, Kano. in International Conference on Green Engineering for Sustainable Development, IC-GESD 2015. Held at Bayero University, Kano Nigeria.

OECD. (2008). *Handbook on Constructing Composite Indicators METHODOLOGY AND USER GUIDE*. Retrieved from www.oecd.org/publishing/corrigenda.

Padikkal, S., Sumam, K. S., & Sajikumar, N. (2018). Sustainability indicators of water sharing compacts. *Environment, Development and Sustainability*, *20*(5), 2027–2042. https://doi.org/10.1007/s10668-017-9975-z

Plessis, J., & Bam, W. (2018). Comparing the Sustainable Development Potential of Industries : A Role for Sustainability Disclosures ? *Sustainability MDPI*, *10*(878). https://doi.org/10.3390/su10030878

Savva, A. P., & Frenken, K. (2002). *Irrigation Manual Module 13. Construction of Irrigation Schemes*. Harare.

Shanono, N. J. et al. (2014). Assessment of Field Channels Performance at Watari Irrigation Project Kano, Nigeria. in 1st International Conference on Dryland, Center for Dryland Agriculture, Bayero University Kano, Nigeria. 8th – 12th December 2014.

Shanono, N. J. and Ndiritu, J. (2020). A conceptual framework for assessing the impact of human behaviour on water resource systems performance. Algerian Journal of Engineering and Technology. 3: 9–16.

Shanono, N.J. (2019). Assessing the Impact of Human Behaviour on Reservoir System Performance Using Dynamic Co-evolution – A PhD Thesis Submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, Johannesburg. 2019. http://wiredspace.wits.ac.za/handle/10539/29043

Shanono, N. J., & Ndiritu, J. (2019). Development of reservoir operation socio-hydrological simulation model to assess the impact of human behaviour on reservoir performance. 10th NAHS International Conference on 21st – 24th October 2019 at UDU, Sokoto, State, Nigeria. *at UDU, Sokoto, State, Nigeria* (pp. 124–133).

Shanono, N.J. (2020). Applying the concept of socio-hydrology to assess the impact of human behaviour on water management sectors: A review. Bayero J. of Eng & Tech, 15(2), 105–116.

Shanono, N.J. (2021). Co-evolutionary Dynamics of Human Behaviour and Water Resource Systems Performance: A Socio-Hydrological Framework. *Academia Letters*, Article 1191. https://doi.org/10.20935/AL1191

Shanono, N.J. and B.S. Abba (2022). Modelling the Onion Yield Response to Deficit Irrigation and Mulch using Multiple Regression Model in Semi-Arid Nigeria. *FUDMA Journal of Sciences (FJS) Vol. 6 No. 3*. https://doi.org/10.33003/fjs-2022-0603-977

Singh, R. K., Murty, H. R., Gupta, S. K., & Dikshit, A. K. (2007). Development of composite sustainability performance index for the steel industry. *Ecological Indicators*, *7*(3), 565–588. https://doi.org/10.1016/j.ecolind.2006.06.004

Song, Z., & and Moon, Y. (2018). Sustainability metrics for assessing manufacturing systems: a distance-to-target methodology. *Environment, Development and Sustainability*, 1–24. https://doi.org/10.1007/s10668-018-0162-7

Spangenberg, J. H. (2016). Institutions for sustainable development : indicators for performance assessment. *Sustainable Europe Research Institute SERI Germany*, (December), 133–162. Retrieved from www.researchgate.net/publication/281528866%0AThe

Sunjka, J. B. P. and. (2013). significant causes and effects of project delays in the niger delta region, nigeria. *Stellenbosch, South Africa © 2013 SAIIE T*, (July), 9–11. https://doi.org/10.1.1.882.9428

Treviño, L. K., Weaver, G. R., & Reynolds, S. J. (2006). Behavioral Ethics in Organizations: A Review. *Journal of Management*, *32*(6), 951–990. https://doi.org/10.1177/0149206306294258

Vaske, J. J., Beaman, J., & Sponarski, C. C. (2017). Rethinking Internal Consistency in Cronbach â€™ s Alpha. *Leisure Sciences an Interdisciplinary Journal*, *400*(February), 163–173. https://doi.org/10.1080/01490400.2015.1127189

Wang, Y., Yi, H., & Fang, M. (2014). Developing a Sustainability Performance Assessment Tool for Public Funded Projects According to Policies and Stakeholders ' Perceptions. *The Open Construction and Building Technology Journal*, *8*, 52–62.

Xiaoyu G, I. C. Fernandezb, J. Guoc, M. Wilsond, Y. Zhaoe, B. Z. and J. W. (2017). When to use what : Methods for weighting and aggregating sustainability indicators. *Ecological Indicators(ScienceDirect)*, *81*(February), 491–502. https://doi.org/10.1016/j.ecolind.2017.05.068

Zakari, M. D. et al. (2015). Sensitivity analysis of crop water requirement simulation model (CROPWAT (8.0) at Kano River Irrigation Project, Kano Nigeria. in Proceedings for international interdisciplinary conference on global initiatives for integrated development (IICGIID 2015 Chukwuemka Odumegwu University, Igbariam campus Nigeria).