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Deployment of performance indicators toward bridging monitoring gaps in Africa's Great Green Wall

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Abstract

Background: The health and productivity of the land across the Sahel are in declension due to desertification. This has lowered the quality of ecosystem services and has led to a vicious cycle of drought, famine, poverty, and insecurity in the region. As one of the flagship interventions of the UN's decade (2020-2030) of ecosystem restoration to tackle desertification and respond to climate change, there are mixed reactions to the successes of the Great Green Wall (GGW) in Nigeria due to the failure of the Sustainability of Policy Instrument.

Methods: A two-round Delphi reached consensus on 42 sub-indicators under 14 indicators as indicated by Kendell's ($W = 0.509$, $P = 0.001$) and high correlation between rounds ($rho = 0.959$, $P = 0.001$). The indicators were then deployed to assess the GGW in a questionnaire ($n = 401$) via a multi-stage sampling, and their performance was weighted using principal component analysis (PCA).

Results: "Proportion of land reclaimed" was recorded as the highest-performing indicator due to the multifaceted afforestation program covering fodder and wood lot areas, while "dune fixation" has the least performance due to the lack of employment of ecological engineering tools. The findings showed that the presence of local jobs is not significant in raising the livelihood status above the poverty line.

Conclusion: To meet the 2030 timeline, there is a need to scale up the implementation of the GGW and support the desert frontline states (DFS) with alternative energy to reduce the rate of deforestation.

Keywords: Ecosystem, Climate change, Conservation of natural resources, Consensus, Poverty

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Introduction

The increase in desertification across many parts of the world has continued to impair the ecosystems' health and quality of life for many species. Desertification has been recognized as a stumbling block to attaining sustainable development goals (SDGs), thereby attracting attention from the global scientific and policy spheres (1,2). Although scientists have various opinions, especially on the concept of desertification, the perceptible social and economic impacts on the affected regions compelled policymakers to act (3). The past three decades have seen the emergence of several national, regional, and global efforts to tackle desertification. These intervention efforts achieved little in addressing the problem due to the lack of consensus amongst scientists on the extent of degradation, the absence of clear goals, and poor funding (4). With the degradation of the environment persisting, there are renewed interventions to repeal the failed efforts in many countries in the world (5).

In Africa's Sahel, one of the world's poorest regions ravaged by desertification, the resurgence of the idea of a Great Green Wall (GGW) in 2007 has raised hope for environmental restoration and economic growth. The Pan-African initiative, which was initially nurtured by 11 countries, now has 22 states participating either directly or indirectly. As a pack of adaptation and mitigation measures to climate change, the GGW for the Sahara and Sahel aims to strengthen the resilience of the people (in the region with the highest rise in temperature) and build the capacity of the communities living along the shelterbelt that is 8000 km (in length) by 15 km (in breadth), which spreads from Senegal (to the west) to Djibouti (to the east) of the continent via ecosystem management, sustainable land resources development, and protection of rural/

cultural heritage. The intervention is to affect over 300 million people via its targets to restore 100 million hectares of the currently known degraded land, sequester about 250 million tons of carbon, create over 10 million green jobs to stem youth migration, employ engineering techniques to fix (sand) dunes, and grow food security in the Sahel (6,7).

The ambitious intervention aligns with some international policy frameworks like the Convention on Biodiversity (CBD), the United Nations Convention to Combat Desertification (UNCCD), the United Nations Framework Convention on Climate Change (UNFCCC), and the SDGs in addressing many of the global problems such as climate change, inequality, poverty, injustice, and environmental degradation, etc. Importantly, the GGW indirectly confronts 15 out of the 17 SDGs, while it directly goes in tandem with eight of the goals as shown in Figure 1 (8,9). Similar to the SDGs which have recorded some successes, but enormous challenges are raising obvious fear that the goals are not achievable by 2030, the GGW has equally recorded progress in many participating countries since its take-off in 2008. Out of the over 4 million hectares (representing only 15-18%) of the degraded land restored, Ethiopia, the Niger Republic, and Eritrea are at the forefront of the success with a record of 57%, 20%, and 15%, respectively. While Senegal achieved 3% success, the other countries combined (Burkina Faso, Chad, Djibouti, Mali, Mauritania, and Sudan) only recorded 5% (9).

The slow phase of success has been attributed to many various challenges facing the implementation of GGW across the member nations. Four categories of challenges ranging from those of governance, funding, technical, and reporting were identified (10). Moreover, a common challenge to all the 11 initial countries is that of monitoring and evaluation (M&E), which is more pronounced in Nigeria where the intervention is to cover 1,392 km (representing 17.4%). The monitoring gap has resulted in

Figure 1. The GGW coverage of the sustainable development goals

poor community ownership, lack of grass root structure, and participation in the Desert Frontline States (DFS), and has contributed to the failure of the sustainability of the policy instrument (the long-term benefits of the intervention after the projects are executed) in Nigeria (11,12). The gap has been linked to the absence of key performance indicators (KPI) to track the progress and evaluate the performance of the GGW (13,14).

Therefore, this work aimed to bridge the monitoring gap by deploying KPIs to assess the GGW. Specifically, the study develops the KPI for appraising the intervention. It then proceeds to deploy the KPI to assess the performance of the GGW in Nigeria's DFS toward scaling up the GGW to achieve the 2030 timeline of the SDGs and the UN decade for ecosystem restoration.

Materials and Methods

The Study Area

The study covers the rural households in Bauchi (landmass: 49, 119 km^2) and Jigawa (23, 154 km^2) States of the 11 most affected states formally regarded as Nigeria's DFS. The two states were chosen for three reasons including the good representation of the Northeast and Northwest geopolitical division (15,16), the presence of all the GGW intervention phases, and the peaceful atmosphere (17,18). Figure 2 shows the details of the study area.

Data collection

Data for the study were collected via two steps: a Delphi technique for expert consensus and a research instrument for households in the study area. A two-round Delphi survey was employed to reach a consensus on developing performance indicators for assessing the GGW. As a technique widely used for environmental, health, and natural resources studies, the Delphi procedure here began with the searching of literature for relevant indicators (19). Forty-three sub-indicators under 14 indicators were identified and presented to the panelists for the first round. The panel comprises a dozen experts each from academia, the federal and the states' civil service, while relevant research institutions and NGOs have 10 experts each. Out of the 56 experts invited, 53 and 36 of them consented/participated in the first and second iterations, respectively, after sending at least two reminders (20). The Delphi questionnaire was issued and the responses were analyzed using SPSS version 20. The questionnaire was modified as suggested by the panelists, and then, re-issued for the second round so that saturation (a Kendell's coefficient of concordance of ≥ 0.5 and a rho of ≥ 0.9, $P = 0.01$) be reached (21,22).

Validity of instrument

Upon reaching consensus in the Delphi, a well-structured questionnaire was designed to acquire data on the indicators (latent variables) through the sub-indicators (constructs). Using Martuza's 1977 improved approach, the validity index for individual items (I-CVI) and the whole Section (S-CVI) involving nine experts (n = 9) was

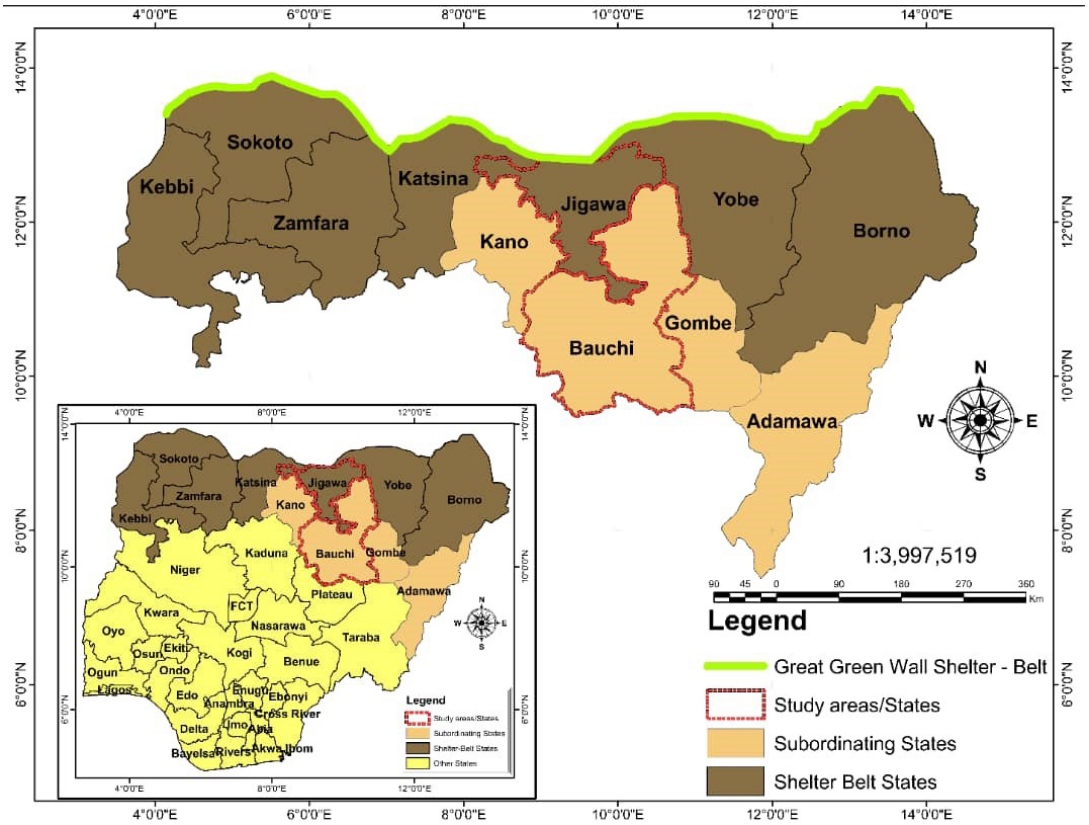

Figure 2. Map of Nigeria's Desert Frontline States

computed. A very good I-CVI of 0.9 and an S-CVI of 0.92 were recorded (23,24).

Reliability of instrument

Using Taylor's alpha range classification, the internal consistency (using SPSS version 20) was found to be 0.706, which is satisfactory.

Sample size

The total population of rural households in Bauchi (430 594) and Jigawa (416 499) states as obtained from the National Population Commission (NPC, 2021) formed the sample frame (847 093). The sample size was determined using Scheaffer and Mandenhall's (1990) formula:

$$n = \frac{N}{(N-1)\times e^2} + 1$$

Where n is the sample size, N is the total number of rural households, and e is the sampling error.

Based on the computation of the cumulative total rural household of 847 093 in the study area and with a sampling error of 5%, a total of 401 was achieved as the estimated sample size for this study.

Sampling technique

A multistage sampling technique was adopted for the study due to the availability of information on the communities and phases of the GGW intervention. In the first stage, a state was selected from each geopolitical zone: Bauchi from the Northeast and Jigawa from the Northwest. In the second stage, the three phases of GGW interventions were considered. Local Governments covering the phases were selected in the two states. Therefore, Katagum, Gamawa, and Darazo were selected from Bauchi, while Sule Tankarkar, Gumel, and Kaugama were from Jigawa. For the third stage, the questionnaire was rationed based on the population of the LGAs. Bulkachuwa (received 93 questionnaires), Alagarno (96), and Malori (84) in Bauchi, while Jake (36), Zuke (48), and Girbobo (44) were the communities selected from the LGAs of Jigawa state. The cluster sampling was combined with systematic random sampling at the fourth stage to pick the first house at random, and then the subsequent houses after skipping five houses. The questionnaire was finally administered to the household representative by the enumerator trained to handle the KoboCollect software.

Data analysis

The Delphi analysis and the principal component analysis (PCA) were conducted using SPSS version 20. The PCA employed to analyze the data from the research instrument was on the criteria that only sub-indicators with an eigenvalue of 1 and above, and that have scored the highest percentage of variance are considered significant. Those values below 0.49 are not considered; while those below 0.3 are removed by the software (25).

Results

At the end of the first round of the Delphi survey, the result revealed the level of expert consensus on the inclusion of 14 proposed KPIs for tracking the GGW intervention based on the set criteria of [1] Percentage score of items that is ≥ 75%, and an expert's response on items ≤ 1 on the (descending) scale; [2] a median score; [3] an interquartile range (IQR) ≤ 1, and a standard deviation that is below 1.0. Thirteen representing 92.8% of indicators and 39 (92.8%) sub-indicators (out of 42) had reached expert consensus. However, 1 (7.2%) of the indicators and 3 (7.2%) sub-indicators did not gain consensus.

The indicator and sub-indicators that did not achieve consensus are PA3 Availability of Green Jobs/Indigenous Knowledge, and its sub-indicators PA3–1 Types of Indigenous Knowledge incorporated, PA3–2 Available Green Agricultural Jobs, and PA3–3 Available Renewable Energy options involved were dropped by the panelists. Other categories of expert judgment on the indicators are those the panelists suggested their modification. These categories include the LR3 number of lost biodiversity that has reappeared, which has been modified to "Change in Phenology". The second category of modification by the panelist involved all indicators and sub-indicators that begin with 'Number of …' – except two sub-indicators: The number of rivers that got recharged and the Number of Renewable Energy options involved. The panelist suggested the replacement of the initial (Number of …) with "Proportion of …". Appraising the level of experts' agreement, a moderate Kendall's Coefficient of Concordance ($W = 0.405$, $P = 0.001$) was recorded. It implies that a significant value not satisfactory for the survey was achieved, thereby indicating the need for taking the second round.

The results in Table 1 show the outcome of the second iteration. Fourteen (93.3%) of the potential indicators and 41 (93.2%) sub-indicators achieved consensus and were retained as KPIs. Whereas 1 (6.7%) of the indicators and 3 (6.8%) of the sub-indicators which could not attain consensus were, therefore, removed. The indicator removed is the "Availability of Green Jobs/Indigenous Knowledge". Similarly, the sub-indicators removed are Types of Indigenous Knowledge incorporated, Available Green Agricultural Jobs, and Available Renewable Energy options involved. For the second round, Kendall's W for the group's agreement indicated a higher and satisfactory value ($W = 0.509$, $P = 0.001$). Also, Spearman's rank correlation coefficient computation revealed the stability of experts' ratings between the rounds with a strong positive correlation at a 0.01 level of significance ($Rho = 0.959$, $P = 0.001$). This indicated a high level of stability was recorded among experts' rating opinions in the study. Thus, the Delphi survey stopped as 14 indicators

Table 1. Summary of Delphi second-round results (n = 36)

Indicators/Sub-indicators		Median	Min	Max	IQR	SD
Land restoration/afforestation						
LR1	Proportion of land reclaimed over total degraded land	1.0	1.0	2.0	0.0	0.35
LR1–1	Area covered by afforestation program	1.0	1.0	2.0	0.0	0.28
LR1–2	Change in land cover (before and now)	1.0	1.0	2.0	0.0	0.58
LR1–3	Improvement in conservation sites (wetlands, oasis, etc.)	1.0	1.0	2.0	0.0	0.23
LR1–4	Proportion of local government area covered by the intervention	1.0	1.0	3.0	0.5	0.32
LR2	Increased productivity of land cover	1.0	1.0	2.0	0.0	0.28
LR2–1	An increase in annual farm yield as against pre-intervention…	1.0	1.0	2.0	0.0	0.42
LR2–2	An increase in irrigated fields	1.0	1.0	2.0	0.0	0.35
LR3	Change in phenology	1.0	1.0	2.0	0.0	0.37
LR3–1	Number of floral species that have reappeared	1.0	1.0	3.0	0.0	0.32
LR3–2	Number of fauna species that have reappeared	1.0	1.0	3.0	0.0	0.37
LR3–3	Number of habitats restored by the intervention	1.0	1.0	3.0	0.0	0.48
LR4	Improved surface runoff/water retention	1.0	1.0	2.0	0.0	0.47
LR4–1	Improved soil moisture	1.0	1.0	2.0	0.0	0.55
LR4–2	Number of rivers that got recharged	1.0	1.0	2.0	0.0	0.50
LR4–3	Increased volume of surface water	1.0	1.0	3.0	0.0	0.31
LR4–4	Improved water use efficiency (water sufficiency for plants)	1.0	1.0	3.0	0.0	0.50
Climate/carbon sequestration						
CS1	Yearly sequestered carbon	1.0	1.0	2.0	0.0	0.58
CS1–1	Changes in soil organic carbon	1.0	1.0	3.0	0.0	0.57
CS1–2	Changes in land use, management	1.0	1.0	2.0	0.0	0.35
CS1–3	Variety and the number of seedlings planted concerning carbon…	1.0	1.0	3.0	0.0	0.37
CS2	Improvement in Climate Variability	1.0	1.0	2.0	0.0	0.46
CS–1	Amount of heat sequestered	1.0	1.0	2.0	0.0	0.51
CS–2	Increased (amount of) rainfall in the area	1.0	1.0	2.0	0.0	0.45
Poverty alleviation/empowerment						
PA1	Percentage of people living below the poverty line, by age, and sex	1.0	1.0	2.0	0.0	0.00
PA1–1	Proportion of house heads living below the poverty line	1.0	1.0	2.0	0.0	0.23
PA1–2	Proportion of women living above the poverty line	3.0	1.0	3.0	1.0	0.47
PA2	Proportion of people employed via a variety of local jobs	3.0	1.0	3.0	1.0	0.47
PA2–1	Types/contribution of indigenous knowledge incorporated…	3.0	1.0	3.0	0.0	0.47
PA2–2	Available green agricultural jobs	3.0	1.0	3.0	0.0	0.49
PA2–3	Number of renewable energy options involved	1.0	1.0	3.0	0.0	0.69
PA3	Availability of green jobs/indigenous knowledge	1.0	1.0	3.0	0.0	0.69
PA3–1	Types of indigenous knowledge incorporated	1.0	1.0	3.0	0.0	0.51
PA3–2	Available green agricultural jobs	1.0	1.0	3.0	0.0	0.56
PA3–3	Available renewable energy options involved	1.0	1.0	3.0	0.0	0.57
PA4	Proportion of households with access to basic services	1.0	1.0	2.0	0.0	0.16
PA4–1	Proportion of households with access to healthcare	1.0	1.0	3.0	0.0	0.61
PA4–2	Proportion of children with access to education	1.0	1.0	3.0	0.0	0.40
PA4–3	Proportion of households with access to social welfare	1.0	1.0	3.0	0.0	0.57
PA5	Proportion of children under five years suffering from malnutrition	1.0	1.0	3.0	0.0	0.47
PA5–1	A decline in the number of children with deficiency-related disorder	1.0	1.0	3.0	0.0	0.54
PA5–2	Changes in the number of children with growth restriction…	1.0	1.0	3.0	0.0	0.42
PA5–3	A decline in the number of children suffering from a disease	1.0	1.0	3.0	0.0	0.43
PA5–4	A decline in the number of families facing food insecurity	1.0	1.0	3.0	0.0	0.48

Table 1. Continued.

Indicators/Sub-indicators		Median	Min	Max	IQR	SD
Alternative domestic energy sources						
AE1	Proportion of households with access to alternative energy	1.0	1.0	2.0	0.0	0.60
AE1–1	Number of households connected to the national grid	1.0	1.0	3.0	0.0	0.40
AE1–2	Number of households with access to cooking gas/kerosene	1.0	1.0	3.0	0.0	0.47
AE1–3	Number of families with access to energy-efficient stoves	1.0	1.0	2.0	0.0	0.45
AE1–4	Number of families with access to biogas/briquetting technique	1.0	1.0	3.0	0.0	0.35
Stemming migration						
SM	Migrants proportion and trend as compared with the records	1.0	1.0	3.0	0.0	0.50
SM1–1	A decrease in the number of migrants as compared with the records	1.0	1.0	3.0	0.0	0.48
SM1–2	An increase in the number of youths engaged in the activities	1.0	1.0	3.0	0.0	0.28
Sand dune fixation						
SF1	Dune fixation/Sandstorm decline	1.0	1.0	2.0	0.0	0.40
SF1–1	Percentage of the area of dune fixed	1.0	1.0	3.0	0.0	0.58
SF1–2	A decrease in sandstorm frequency	1.0	1.0	3.0	0.0	0.28
SF2	Availability of technology	1.0	1.0	2.0	0.0	0.47
SF2–1	Availability of equipment for plowing	1.0	1.0	2.0	0.0	0.48
SF2–2	Availability of technique/equipment for dune fixation	1.0	1.0	2.0	0.0	0.61
SF2–3	Ratio of indigenous technology to conventional in the program	1.0	1.0	2.0	0.0	0.55

Note: Min, Minimum; Max, Maximum; IQR, Interquartile range; SD, standard deviation.

were developed.

Assessment of the GGW Intervention

The assessment results show that 73.07% of the respondents are men, while women account for the remaining 26.93%. Also, the results indicated (83.2%) that the inhabitants are aware of a multifaceted intervention involving adaptation and mitigation measures to tackle desertification. The highlights of the assessment of the indicators are presented in Table 2.

The proportion of land area reclaimed over total land degraded

This indicator was evaluated through four sub-indicators: [1] Area covered by the afforestation program, [2] Change in land cover (before and now), [3] Improvement in conservation sites, and [4] Ratio of local governments covered by the intervention. Under the sub-indicator "Improvement in conservation sites", the PCA result shows that three elements/components have eigenvalues of 1 or above, accounting for 70.26% of the total variance. The first component "Fencing of afforestation area" has an eigenvalue of 2.29 and accounts for 32.67% as shown in Table 3. However, the element "fodder area covered" under sub-indicator "Area covered by afforestation program", which scored 2.82 and accounted for 70.56% of the variance, is considered for the weighting of indicators.

Increased productivity of land cover

As shown in Table 1, two sub-indicators formed this indicator. The PCA result indicated that only one component is highly significant. The component "increased (annual) farm yield as against pre-intervention period" has an eigenvalue of 1.33 and accounts for 44.29% of the total variance (Table 3). Therefore, only this sub-indicator was considered for the weighting.

Change in phenology

Change in phenology was evaluated via three sub-indicators (Table 1). As shown in Table 3, the PCA indicated that four components scored an eigenvalue of 1 and above. "Proportion of (lost) fauna species that have reappeared" has an eigenvalue of 2.53 and accounts for 63.31% of the total variance. Therefore, it was considered for the weighting of the indicators.

Percentage of people living below the poverty line, by age, sex, and location

Table 1 shows two sub-indicators measuring this indicator. Three components are scaled through the PCA in Table 3. "Main source of Income" under the sub-indicator "Proportion of house heads living below poverty line (as compared with the pre-intervention records)" had an eigenvalue of 1.78 and accounts for 55.53% of the total variance. Hence, the main source of income is included in the weighting of indicator performance.

The proportion of people employed through local green jobs

Measured through three sub-indicators, one element under the sub-indicator "Available non-agricultural job" was scaled through the PCA. As shown in Table 3,

Table 2. Findings from the assessment of indicators

Indicators	Findings
The proportion of land reclaimed	An average of 38.04, 35.19, and 35.53 hectares of the wood lot, range lands, and others were reclaimed, respectively. Under "improvement in conservation sites", fencing accounts for (85.7%), employment of guards (48.63%), and dredging (1%) as some of the major conservation efforts. Forty-four local government areas out of 258 in the DFS were covered by the GGW, and less than 50% of the 44 LGAs are currently benefiting from the interventions.
Increased productivity of land cover	Figure 3 shows that yearly farm yield increased by an average of 3146.72 kg due to "enhancement in advance planting technique" (23.7%), down to the last option "increase in the irrigated field" with 0.25%.
Change in phenology	The majority of the respondents were adamant. 40.65% did not acknowledge the reappearance of any flora. Also, 50.37% did not have fauna reappearance. However, 16.97% noticed the reappearance of a sparrow (a bird) and 3.5% observed the return of a sanctuary.
Percentage of people living below the poverty line	Earning from self-employment/business (56.61%), agriculture/irrigation (27.63%), public service (8.98%), and others (2.49%), only 4.24% make a living from the GGW. Within many households (63.84%), a woman or a youth earns a complementary income aside that of the household, with women earning less than men. However, the average monthly income of ₦ 19729.40 (US$ 36) for the household is far below the national minimum wage of (₦ 30000) (US$ 62) and the dollar per person per day rate.
The proportion of people employed via local green jobs.	No indigenous/traditional knowledge was recorded. 44.64% are engaged in agricultural jobs (nursery raising, conservation agriculture) while 55.11% are engaged in non-agricultural jobs such as balanite oil extraction, beekeeping, etc. No evidence of climate-smart agriculture, as shown in Figure 4.
Proportion of households with access to basic services/ resources	Schools, hospitals, and markets are present in most of the communities, but only (37.66%) have access to electricity.
The proportion of children under five years suffering from malnutrition	Respondents acknowledged that 67.08% of children under five years have access to healthcare - indicating a decrease in poverty-related ailments.
The proportion of households with alternative energy sources	Despite having other expensive sources of domestic energy, Figure 5 findings indicated a huge reliance on fuel wood/ charcoal (with 99%) as their main energy source.
Migrants' trend and proportion as compared with (previous) records	The respondents disagree strongly (81.02%) with any decrease in emigration, and no returnees were observed.
Dune fixation and sandstorm decline	The result shows no (87.53%) evidence of any engineering work to fix (sand) dune in the area. However, a moderate decrease in the frequency of sandstorms was observed.
Availability of technology	There is neither (95.51%) any equipment for dune fixation nor any conventional technology employed to halt the encroachment.

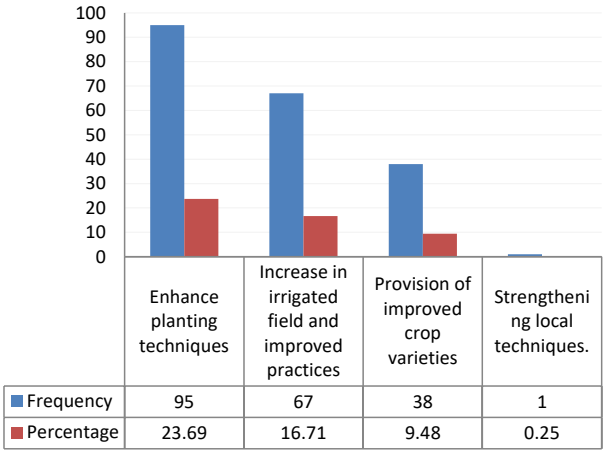

Figure 3. Response to improvement in annual farm yield

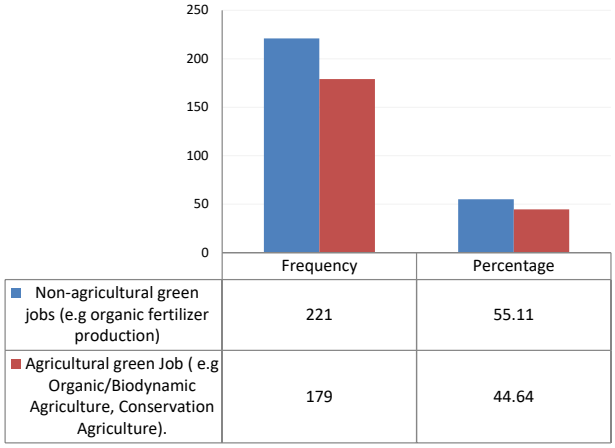

Figure 4. People employed via local jobs

"Beekeeping" has an eigenvalue of 2.13 and accounts for 71.09% of the total variation. Thus, it was included in the weighting.

The proportion of households with access to basic services

As shown in Table 3, the PCA shows that three sub-indicators scaled through. "Proportion of households with access to health care" with an eigenvalue of 4.04 that accounts for 40.42% of the total variance, was included in the weighting.

The proportion of children under five years suffering from malnutrition

Findings show that 67.88% of children under five years have access to healthcare. Thus, the "Decline in the number of children with deficiency" with an eigenvalue of 1.62 and accounted for 80.72% of the total variance in the category was considered.

The proportion of households with an alternative energy source

The results in Figure 5 indicated huge reliance (99%) on

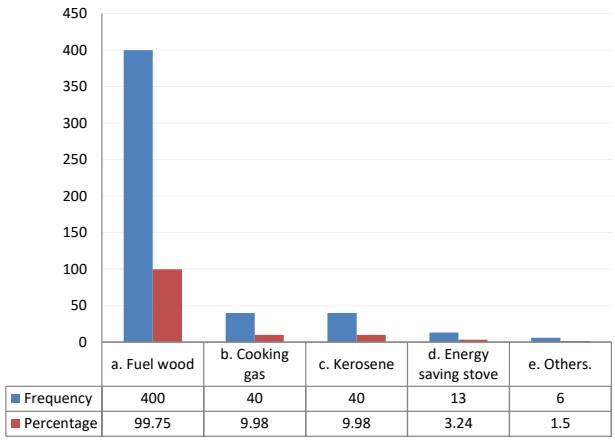

Figure 5. Available means for domestic energy in the areas

fuel wood/charcoal as the main energy source. The PCA revealed two components scored high (Table 3). The component "Fuel Wood" has an eigenvalue of 2.19 and accounts for 71.72% of the total variance. Hence, it was considered for the weighting.

Migrants' trend and proportion

The PCA shows one component with an eigenvalue of 6.53 and accounts for 81.54% of the total variance in Table 3. Therefore, the component "Return of immigrant" was considered.

Dune fixation and sandstorm decline

The component "Effort to fix Dune" has an eigenvalue of 1.16 and accounts for 73.42% of the variance. Being

Table 3. Outlook of indicators from the principal component analysis

Indicators	Sub-Indicators	Components	Initial Eigenvalue			Extraction Sum of Squared Loading			Rotation of Squared Loadings		
			Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
The proportion of land reclaimed...	Fodder area covered	1	2.823	70.575	70.575	2.83	70.575	70.575			
Improvement in conservation sites	Fencing of the afforestation area	3	2.287	32.666	32.666	2.287	32.666	32.666	1.878	26.828	26.828
	Removal of invasive species		1.414	20.194	52.859	1.414	20.194	52.859	1.738	24.834	51.662
	employment of guards		1.218	17.401	70.261	1.218	17.401	70.261	1.302	18.598	70.261
The improvement of land productivity	Annual farm yield	1	1.329	44.291	44.291	1.329	44.291	44.291			
Change in phenology	Reappearance of animal species	4	2.525	28.052	28.052	2.525	28.052	28.052	2.335	25.946	25.946
	Name of animal species that reappeared		1.977	21.964	50.015	1.977	21.964	50.015	2.081	23.124	49.070
	Name of plant that reappeared		1.197	13.297	63.313	1.197	13.297	63.313	1.282	14.243	63.313
	Dredging of drainages		1.000	11.110	74.423						
The proportion of people living below the poverty line	The proportion of people living below the poverty line	3	1.780	22.245	22.245	1.780	22.245	22.245	1.649	20.609	20.609
	The proportion of women living below the poverty line		1.607	20.085	43.331	1.607	20.085	43.331	1.631	20.386	40.995
	Separate/alternative income		1.056	13.203	55.533	1.056	13.203	55.533	1.163	14.539	55.533
The proportion of people employed via local jobs	Bee rearing	1	2.133	71.098	71.098	2.133	71.098	71.098			
The proportion of households with access to amenities	Presence of clinic	3	4.042	40.417	40.417	4.042	40.417	40.417	3.373	33.726	33.726
	Presence of primary school		1.745	17.450	57.866	1.745	17.450	57.866	2.383	23.828	57.555
	Presence of market		1.103	11.030	68.897	1.103	11.030	68.897	1.134	1.134	68.897
The proportion of children under five years suffering from malnutrition	A decline in the number of children. With deficiency	1	1.6185	80.727	80.727	1.6185	80.727	80.727			
The proportion of households with access to alternative energy	Fuelwood	2	2.193	43.852	43.852	2.193	43.852	43.852	2.180	43.597	43.597
	Cooking gas		1.393	27.869	71.721	1.393	27.869	71.721	1.406	28.124	71.721
Migrants' trend and proportion											
	Return of immigrant	1	6.531	81.543	81.543	6.531	81.543	81.543			
Dune fixation	An effort to fix dune	2	1.167	38.910	38.910	1.167	38.910	38.910	1.167	38.900	38.900

the component with the highest eigenvalue here, it was included for the weighting of the overall function of the indicators.

Availability of technology

The findings revealed no (95.51%) presence of equipment for dune fixation nor any conventional technology employed to halt the encroachment. Thus, no component scaled through. Other indicators not captured in the assessment formed the study's limitation.

The weighting of the indicators using the principal component

Sub-indicators with the highest eigenvalue and percentage scores were chosen to represent their indicators in the final phase. The ranking in Table 4 presented the outing of the indicators based on the implementation performance for the GGW intervention in the DFS.

Discussion

The indicator "proportion of land reclaimed" through its sub-indicator "fodder area covered" takes the highest component score of 0.980, therefore, ranked the first. Table 4 shows that the "proportion of children under five years" and "proportion of people employed via local jobs" ranked the second and third with scores of 0.958 and 0.913, respectively.

Despite taking the fifth with the score of 0.891, the indicator "proportion of people with access to social amenities" appears to be the best because three of its sub-indicators scale through the PCA due to their high performance. This means there are many social amenities such as schools, hospitals, markets, etc. in the communities. The proportion of households with access to alternative energy is the sixth indicator having a score of 0.887. Despite the presence of cooking gas/kerosene, the vast majority of people depend largely on firewood as their major source of domestic energy.

The indicator "improved surface water runoff/water retention", ranked the seventh with the score of 0.821. It was observed that two dried up rivers have now regained water flow. There is no further studies or secondary data that link the flow to the success of the GGW. The indicator "Migrant proportion and trend with the records" scored 0.809 and was rated as the eighth in terms of performance. This means more needs to be done in job provision to attract the return of the youth. The ninth indicator with the score of 0.799 is the "Proportion of people living below the poverty line by age and sex". The intervention has brought many jobs to the communities, but the income level has yet to rise above the poverty line.

The sub-indicator "Decrease in a sandstorm" under "Dune fixation" is the eleventh with a score of 0.769. Finally, the last in the rank of performing indicator was "Increased productivity of land". Its sub-indicator "Increased annual yield" scored 0.744, and therefore, ranked the least-performing indicator.

Conclusion

The findings of the study revealed that afforestation is the dominant intervention in the GGW. The presence of enhanced seedlings and access to healthcare facilities have reduced the number of children under five years suffering from malnutrition. Despite employing many people through local jobs, the poverty level is yet to fall drastically in the communities, and thus, the interventions do not

Table 4. Results of the indicator weighting based on the principal component

Indicators	Sub-indicators	Component Scores	Communalities
The proportion of land reclaimed over total degraded	Fodder area covered	0.980	0.961
The proportion of children under five years suffering from malnutrition	The decline in the number of children with deformity	0.958	0.917
The proportion of land reclaimed over total degraded	Fencing of the afforestation area	0.949	0.908
The proportion of people employed via local jobs	Balanite oil extraction	0.913	0.506
The proportion with access to social amenities	The proportion with access to healthcare	0.898	0.807
	The proportion with access to education	0.898	0.807
The proportion with access to social amenities	Presence of markets	0.891	0.659
The proportion of households with access to alternative Energy	The proportion of households with access to cooking gas/kerosene	0.887	0.787
Improved surface water runoff desertification	Number of rivers recharged by intervention	0.821	0.674
Migrants' proportion and trend	Decreases in the number of migrants	0.809	0.654
The proportion of people living below the poverty line by age and sex	The proportion of householeads living below the poverty line	0.799	0.659
Change in phenology	Number of animal species that reappeared	0.781	0.826
Dune fixation	Decrease/increase in (sandstorms)	0.769	0.666
Increased productivity of land	Increased annual yield	0.744	0.553

PCA Extraction Method: Varimax and Keiser Normalization.

attract the return of youth who have migrated. The results show little evidence of the return of fauna, flora, and habitats due to the GGW, and the absence of intervention component on energy-efficient products as well as over-dependence on fuelwood for domestic energy indicated the continued incidence of deforestation. The assessment revealed the lack of site monitoring and community ownership of the GGW intervention components across the study area. Therefore, to achieve the goals of GGW by 2030, there is a need to scale up implementation and support the DFS with alternative domestic energy.

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Competing interests

The authors declare that they have no competing interests.

Ethical issues

This research passed through the UPM Ethical Committee standards and approval Ref. No: UPM/TNCPI/RMC/JKEUPM/1.4.18.2 (JKEUPM) 27 May, 2021. Human consent was obtained from the respondents who were all above 18 years. The authors certify that all data collected during the study are presented in this manuscript, and no data from the study is intended to be published elsewhere separately.

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