

Socio-economic impacts derived from large scale restoration in three Great Green Wall countries

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ABSTRACT

Africa's Great Green Wall (GGW) is an ambitious initiative that prioritises large-scale restoration as the key approach to combat desertification and improve the livelihoods of rural communities south of the Sahara. The Food and Agriculture Organization of the United Nations (FAO) is supporting its implementation through a community-centred intervention to generate positive impacts on livelihoods and increase socio-ecological resilience. An evaluation of socio-economic impacts was carried out based on household surveys conducted in the intervention areas in Niger, Nigeria, and Senegal between 2016 and 2020. Both diachronic (before and after the implementation) and synchronic (beneficiaries vs. control group) assessments of the socio-economic status of the communities were conducted using a set of indicators derived from the Sustainable Livelihoods Framework. Results revealed significant improvements in the socio-economic situation of the intervention populations. Household income improved after the interventions in all three countries, with positive significant differences against the control groups particularly in Nigeria and Senegal. In addition, perceived food insecurity significantly decreased in 2020 compared to 2016 observations, dropping from 46% to 15% in Senegal and from 69% to 58% in Niger. This study confirms the dual benefits of land restoration, both increasing vegetation cover and improving the livelihoods of rural communities.

1. Introduction

Drylands are often associated with unsustainable human practices, including for example the removal of natural vegetation due to deforestation, unsustainable grazing and farming practices and other negative changes in land uses. The impacts negatively affect the provision of ecosystem services, crop productivity, water quality and availability, carbon storage and biodiversity. It is estimated that land degradation negatively affects 3.2 billion people and represents an economic loss of around 10% of annual global gross product (IPBES, 2018). Desertification hotspots have been estimated to extend to about 9.2% of drylands

(±0.5%), affecting about 500 million (±120 million) people in 2015 (IPCC, 2019). Globally, increasing aridity, temperature and population growth will further exacerbate the risk of desertification (Huang et al., 2016), particularly so in dryland developing countries. In Africa, the Sahara expanded significantly over the twentieth century, by 11%–18% depending on the season (Thomas and Nigam, 2018).

Action to avoid and reverse ecosystem degradation is a prerequisite for the development of dryland regions in developing countries (MEA, 2005). The global agenda for sustainable development recognizes the importance and relevance of restoration by setting a specific target within the SDG's,¹ and the United Nations have declared 2021–2030 as

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¹ Sustainable Development Goal target 15.3 “By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world” (<https://sdgs.un.org/goals>).

the Decade for Ecosystem Restoration.² Trees and forests play a crucial role for the resilience of socio-ecological systems in drylands, providing goods and environmental services to the local communities (Maestre et al., 2012). In drylands, enrichment planting in agro-sylvo-pastoral systems of trees, shrubs and grasses is widely recognized as key to restore degraded lands, build landscape resilience and strengthen rural livelihoods (Berrahmouni et al., 2015; Ellison and Ifejika Speranza, 2020; Yirdaw et al., 2017). Drylands have the potential to increase global tree and forest cover as a part of an additional 0.9 billion hectares of forests across the world according to Bastin et al. (2019), with substantial carbon sequestration benefits.

Africa's Great Green Wall (GGW) is an ambitious initiative that prioritises large-scale land restoration as the key approach to combat desertification and improve livelihoods of rural communities (AUC/PAGGW, 2012). The programme aims to restore 100 million hectares of degraded land by 2030. The Food and Agriculture Organization of the United Nations (FAO) is supporting its implementation through community-centred interventions to generate positive impacts on livelihoods and increase socio-ecological resilience.

Success and impacts of land restoration through socio-economic lenses, livelihoods and poverty are complex and multidimensional in nature. Specific indicators are therefore required to monitor and evaluate their impacts on local livelihoods, well-being, and climate change resilience (Adams et al., 2016; Le et al., 2012; Wortley et al., 2013; Erbaugh and Oldekop, 2018; Sacande et al., 2020a). By tracking the conditions of the local communities before, during and after the interventions, assessments of socio-economic impacts derived from land restoration describe the intrinsic and complex link between people and the landscapes in which they live.

In this paper, we focus on the evaluation of socio-economic impacts derived from land restoration interventions implemented in Niger, Nigeria, and Senegal, three GGW countries in the Sahel. The interventions are centred on rural communities to restore their degraded agro-sylvo-pastoral lands at a large scale and through those restoration actions simultaneously improve their livelihoods.

Field data from household surveys are presented in diachronic assessment at two-time points and discussed, comparing the socio-economic conditions of beneficiary communities before and after restoration interventions. We also included synchronic assessment through counterfactual analysis of the situation of non-beneficiary communities in the same regions.

2. Materials and methods

2.1. The context of restoration interventions

As a part of the implementation of the Great Green Wall, the beneficiary communities defined the selection of planting sites, the localities of interventions and the prioritisation of species for restoration, following an innovative approach based on a combination of biophysical and socio-economic considerations (Sacande et al., 2020a). Localities, main activities, and results of interventions are presented in the map in Fig. 1 and in Table 1.

The intervention areas in all three countries span through both the *Hot semi-arid* and *Hot desert* climate zones of the Köppen-Geiger climate classification (Peel et al., 2007). Climate is strongly influenced by the Harmattan wind blowing from the Sahara during the nine to ten month long dry season, which exacerbates soil erosion. The rainy season is from June to August, with annual rainfall ranging from 300 to 500 mm with high interannual variability. Maximum temperatures can reach 45 °C, with the hottest months from March–June. Landscapes in these areas are dominated by grasslands with sparse trees and shrubs and rainfed crops, combined in agro-pastoral, sylvo-pastoral, agro-sylvo-pastoral or

agro-forestry systems.³

2.2. Methodological approach

This study combines prospective and retrospective socio-economic evaluations. The baseline data were collected in 2016, before the interventions. This assessment at “time zero” or “t₀” allows for a prospective evaluation and establishment of the benchmark against which the effect of the activities should be evaluated. Hence, a second socio-economic survey was conducted in 2020 at the endpoint after five years (or “t₁”). An additional evaluation was conducted on a control group (or “comparison group”) of communities in the vicinities that did not benefit from any restoration activities. This retrospective counterfactual analysis supports a synchronic evaluation of the effects of the interventions, comparing similar communities with and without activities. The counterfactual analysis helped to determine if the changes observed could be attributed to the activities (Gertler et al., 2016).

The household surveys were carried out in two sets, the baselines in early 2016 and in late 2020 for each beneficiary community. A customized questionnaire was used for this purpose (see Section 3.4), which was designed to capture a full representation of the livelihoods of the target communities. Trained enumerators contributed to administer the household surveys.

For both sets, the sample size of the survey was determined based on census data (number of households) to ensure a confidence level of 95% and a 5% margin of error. Another size of 10% of each sample was used for the control groups. Multi-stage random sampling was used to select the households to be interviewed, wherever comprehensive lists of households were available. When this was not possible, multi-stage systematic sampling was used, by selecting the household to be interviewed based on the location of the house in the roads of the villages. In this way, the highest possible representativeness of the sample with respect to the entire population was achieved (Table 2).

The two situations were then compared in a diachronic or two-time points analysis to derive key insights into the effects of the interventions on the livelihoods of beneficiary communities. A positive impact was considered if (i) “positive” change was observed through an increase in livelihood conditions and (ii) these changes could be attributed to the intervention activities.

2.3. Socio-economic questionnaire

A common template of questionnaire was used in all the countries concerned by the study. This questionnaire was designed based on the Sustainable Livelihoods Framework, developed by the United Kingdom's Department for International Development (DfID, 1999) to conceptualize socio-economic outcomes of the AAD project. This framework considers people's livelihoods as a combination of access to five classes of assets, or capital – human, social, natural, physical, and financial. These five assets made up the five sections of the questionnaire (Fig. 2). This tool is widely used in development studies as it allows a comparable mapping of changes across projects and regions based on common indicators along these five essential dimensions (Homewood, 2013) providing useful metrics to assess the livelihoods, well-being and climate resilience impacts of restoration interventions (Erbaugh and Oldekop, 2018).

A sub-section was added to detect the level of food insecurity of the surveyed households, based on the FAO's Food Insecurity Experience

² <https://www.decadeonrestoration.org/>.

³ The area labelled as “GGW core area” on the map was identified by the FAO to be the most accurate geographical definition of the GGW in the Sahel at the time of this study. It was defined based on a combination of (i) the initial 15 km-wide “wall” track where available, (ii) subnational administrative units as indicated by national plans and (iii) subnational administrative units identified as GGW project areas.

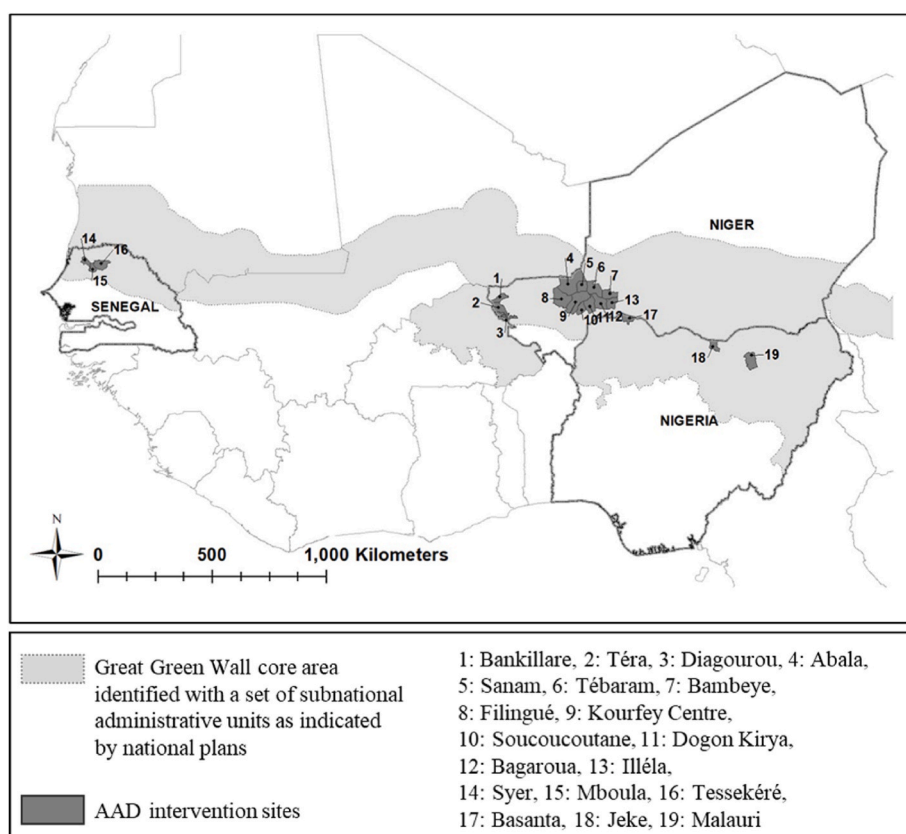


Fig. 1. Map of the 19 restoration intervention areas in the Great Green Wall in Niger, Senegal, and Nigeria.

Table 1
Intervention areas, activities and results of implementation.

Country	Areas of intervention	Main activities and results
Niger	35 villages in 13 communes in the Tillabéry, Tahoua and Dosso regions: Illéla, Bagaroua, Tebaram, Bambeye, Tebaram, Dogon Kiriya, Soucoucutane, Filingue, Kourfey Centre, Abala, Sanam, Tera, Bankilare and Diagourou	Manual and mechanized large-scale restoration (direct sowing and seedlings plantation) and assisted natural regeneration on a total of 13 432 ha, support to the development of 7 NTFP value chains
Nigeria	35 villages located in 3 Local Government Authorities (LGA) in three different States: (i) Jeke, Jigawa State, (ii) Malaoui, Bauchi State and (iii) Basanta, Sokoto State	Manual and mechanized large-scale restoration (direct sowing and seedlings plantation), on a total of 1680 ha, establishment of 5 solar boreholes, support to the development of NTFP value chains, micro-gardens and community nurseries
Senegal	3 villages in the departments of Linguère and Louga, Louga Regions: Tèssékéré (Widou plot) and Mboula (community natural reserve of Koyli-Alpha) in Linguère and Syer in Louga	Manual and mechanized large-scale restoration (direct sowing and seedlings plantation), on a total of 6733 ha, support to the development of 3 NTFP value chains, micro-gardens and community nurseries

Scale (FIES). This easy-to-use survey module was developed by FAO in 2014 to rapidly collect reliable information on food-related behaviours. It consists of a set of eight standard questions, referring to the past 12 months, which analysed together measure people's access to adequate food, enabling a comparison of results across different countries (Cafiero et al., 2018; Sacande et al., 2020b).

In total, the questionnaires counted about 60 different items, and required up to 90 min to be administrated. They were completed within 20–30 days, each enumerator completing efficiently about 5 interviews

in a day. The questions were asked either to the head of the household, or to anyone knowledgeable on the household situation. Depending on the definition of “household” applied (e.g. “group of people who live under the same roof and share the same source of food”), the composition of the household may change, thus including or excluding some people, which could affect the results (Beaman and Dillon, 2012). Based on the cultural and social norms of each country, the same household definition was used consistently in the baseline and end-line surveys. The answers were encoded in a Microsoft Excel database, checked, and then analysed for further verification and elaboration.

2.4. Indicators and data elaboration

Answers by the respondent households were recorded by a unique code in each country database and used for the diachronic evaluation, thus showing the answers obtained in 2016 and 2020 (except the control group). A separate sheet reported the answers intended for the synchronic evaluation, thus including all data differentiating the beneficiaries from the control group.

As a first step of the elaboration, descriptive statistics were calculated for all countries, showing the general features of the households participating in the survey. In the second step, key items were selected from the questionnaire and considered as indicators of the livelihoods of the households. The selection of the items followed a criterion of consistency; the analysis was thus limited to the items that could be compared among the considered countries. The indicators were compared in a synchronic and diachronic manner for the evaluation of the project's success. These indicators included the following (Table 3):

- Human capital: percentage of households having received a technical education; FIES level;
- Social capital: involvement in community groups and associations; women participation in groups and decision making;

Table 2

Sampling methodology and sizes of household surveys in the beneficiary communities. In total, 1113 972 households were interviewed in the baseline survey (2016) and 1274 in the evaluation survey (2020), including 315 households in the control group.

Country	Sample selection	Surveyed households	Sample selection	Surveyed households
	T0 (baseline, 2016)		T1 (evaluation, 2020)	
Niger	28 villages selected randomly (3 per commune) in 10 communes based on demographic weight of each commune.	398	54 villages selected randomly (34 villages of intervention and 19 control villages) in 13 communes based on demographic weight of each commune.	474 (388 beneficiaries and 86 non-beneficiaries)
	Number of households in each village based on demographic weight. Systematic sampling of households (every 10th household) in each village.		Number of households in each village based on demographic weight. Systematic sampling of households (every 10th household) in each village.	
Senegal	22 villages selected based on demographic weight (10 in Koyli Alpha and 12 in Widou) and within a 7 km radius around the restored plots.	120	54 villages randomly selected based on demographic weight and within a 7 km radius around each of 11 restored plots.	405 (353 beneficiaries and 52 non-beneficiaries)
	Number of households based on the demographic weight of each village.		Number of households based on the demographic weight of each village.	
Nigeria	One community selected in each of the three States. Number of households based on the demographic weight of each of the three communities. Households selected using a random number generator.	595	One community selected in each of the three States. Number of households based on the demographic weight of each of the three communities. Households selected using a random number generator.	395 (218 beneficiaries and 177 non-beneficiaries)

- Natural capital: self-perception of soil erosion; perceived trend of vegetation cover; satisfaction for household's access to natural, self-perception of conflicts around the use of natural resources;
- Financial capital: perceived trend of income in the past two years; income from livestock and commerce; cattle, goats, sheep, and poultry heads owned by the household; engagement in economic activities related to non-timber forest products (NTFP).

No indicators could be identified for the physical capital assets. Items to this regard reported the tools and machinery owned by the household, but the questions were highly tailored on the specific rural context, thus

not being consistent across the countries.

The level of these indicators was calculated with respect to the end-of-project situation, among the households that participated in the activities. These values were compared to the level of the same indicators calculated before the interventions and to the level of the same indicators in households that were not involved in the activities.

For each indicator, a bivariate statistical analysis was performed against the baseline or counterfactual conditions. A one-way ANOVA was used to compare numerical variables before and after the interventions, whereas a Chi-Square analysis on contingency tables was used to analyse the difference in categorical variables. Observations with missing values in the pairs of variables considered for each statistical test were excluded. Even though part of the data collected through these surveys included some biophysical elements such as data on the natural capital, i.e. household perception of the natural resources' stocks, this information was not analysed here.

3. Results

3.1. Sample description

The survey covered 2387 households in total, considering both waves of questionnaires' administration and the three countries. Basic socio-demographic descriptors information was collected to characterize the households. In Niger, 90% (baseline survey) and 73% (evaluation survey) of household heads was a male. In Senegal, male heads were reported for 67% of the households in the baseline survey, while the same figure raised to 81% in the evaluation survey. In Nigeria, male household heads were largely predominant (98% in the baseline survey; 92% in the evaluation survey). The age of the household heads was also noted: in Niger and Senegal over 70% of the respondents were over 36, with the age classes 36–50 years old and 51–65 years old being most common; instead, in Nigeria the frequency of young household heads was higher, especially in the evaluation survey where 39% of the respondents was below 35 years old. Over 70% of the households' heads interviewed in Niger never attended school; in Senegal the same rate was around 40%, while in Nigeria it was well below 10% because most of the respondents declared to have received Arabic education.

The average size of the surveyed households was around 10 members: the highest average value of 12.1 members recorded in the baseline survey in Niger, whilst the lowest average value was 8.2 members, recorded in the baseline survey in Nigeria.

3.2. Diachronic socio-economic assessment

Data collected at the end of the interventions were compared with those gathered during the baseline survey (Table 4), showing that most of the socio-economic indicators had improved over the 5-year time span considered.

The perception of food insecurity, assessed with the FIES scale, showed a statistically significant improvement across the two periods in all the three countries. The percentage of households that declared to be worried for food availability dropped by 7%, 12% and 13% between the first and the second survey in Niger, Senegal, and Nigeria, respectively; all these changes proved significant when statistically tested. Another item that can be compared is FIES 5, describing the share of households that declared to eat less than they should; this figure also decreased in all the three countries covered by this study, showing statistically significant differences of –8% in Niger, –31% in Senegal and –9% in Nigeria. Another interesting result to this regard is the percentage of households that did not eat for a whole day during the previous 12 months, dropping from 46% to 15% in Senegal and from 69% to 58% in Niger. In Nigeria, this information was not available in the baseline survey.

For social capital, contrasting evidences emerged about participation in community-related activities implemented during the interventions. Households' participation in community groups significantly increased

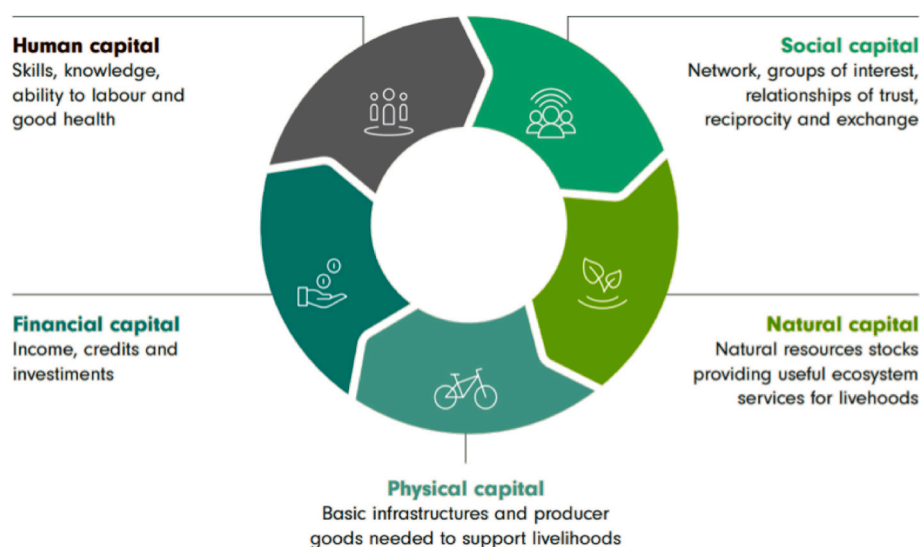


Fig. 2. Description of the five sections of the questionnaire, corresponding to the five capital assets of the Sustainable Livelihood Framework, where the socio-economic conditions of the households are described by their level of human, social, natural, physical, and financial capital. Source: Authors elaboration based on DfID (1999).

Table 3

Indicators used to evaluate the level of the capital assets before and after the intervention.

Indicator code	Description of the indicator	Categories	Notes
IND-HC-1	Technical training-AGRI	1 = yes/0 = no	
IND-HC-2	Technical training-Forest RESTORATION	1 = yes/0 = no	*
FIES1	FIES1 – worry for food	1 = yes/0 = no	
FIES2	FIES2 – unable to eat healthy food	1 = yes/0 = no	^
FIES3	FIES3 – ate only few kinds of food	1 = yes/0 = no	^
FIES4	FIES4 – skip a meal	1 = yes/0 = no	^
FIES5	FIES5 – ate less than they should	1 = yes/0 = no	
FIES6	FIES6 – ran out of food	1 = yes/0 = no	^
FIES7	FIES7 – hungry but did not eat	1 = yes/0 = no	^
FIES8	FIES8 – did not eat for a whole day	1 = yes/0 = no	^
IND-SC-1	Participation to community groups	1 = yes/0 = no	
IND-SC-2	Women participation to community groups	1 = yes/0 = no	
IND-SC-3	Women participation in decisions	1 = yes/0 = no	
IND-NC-1	Experienced soil erosion	1 = yes/0 = no	
IND-NC-2	Perceived trend of vegetation cover in the last 5 years	1 = decrease/2 = stable/3 = increase	*
IND-NC-3	Satisfactory access to natural resources	1 = yes/0 = no	
IND-NC-4	Conflicts on access to natural resources	1 = yes/0 = no	*
IND-FC-1	Livestock is a source of income	1 = yes/0 = no	
IND-FC-2	Commerce is a source of income	1 = yes/0 = no	
IND-FC-3	Trend of household income in the last 2 years	1 = decrease/2 = stable/3 = increase	
IND-FC-4	NTFP economic activity	1 = yes/0 = no	*
IND-FC-5	Cattle heads	Number of heads	
IND-FC-6	Goats heads	Number of heads	
IND-FC-7	Sheep heads	Number of heads	
IND-FC-8	Poultry heads	Number of heads	

*survey data not available for Senegal; ^ Data not available for Senegal's baseline survey.

in Niger, but decreased in Senegal, while no significant difference was found in Nigeria. Women's participation and decision making also showed a different trend in the three countries. It increased in Niger and

Nigeria, but some decline in women's role was noticed in Senegal.

Respondents to natural resources from Niger and Nigeria reported a significant increase in the trend of vegetation cover after interventions. In all three countries, the satisfaction for access to natural resources significantly increased.

Other interesting insights were gathered from indicators referring to the economic assets of the households. An increase in income was reported significantly more often in the 2020 surveys after interventions in the three countries. Compared to the previous two years, respondent households related income increases from 13% to 30% in Niger, from 8% to 35% in Senegal and from 19% to 46% in Nigeria. Moreover, in Niger and Nigeria the share of households that conducted economic activities linked to NTFPs increased by 10% ($p < 0.0001$). Also, Niger's respondents reported a statistically significant increase in the numbers of cattle, goat, sheep, and poultry heads owned by the family, although, this result did not correspond to a higher number of households declaring livestock as a source of income.

Regarding human capital, the share of respondents declaring to have received or benefitted from a technical education or training decreased over the surveyed period in Niger and Nigeria (while it was not evaluated in Senegal); though this difference does not always reach a statistical significance.

3.3. Synchronic socio-economic assessment

The comparison between the data collected from the beneficiaries at the end of the intervention and the data from a control group of non-beneficiaries in the same period showed some significant differences in the socio-economic condition of the two groups (Table 5). Of course, as the size of the control groups increased, the differences were more likely to be significant. For example, in Nigeria, the improvement in women participation emerging from the diachronic analysis was also confirmed by the counterfactual analysis. Indeed, the shares of households declaring a full participation of women in community groups and decision making were significantly higher among the beneficiaries of the interventions compared to the control group.

The increase in vegetation cover was reported more frequently by the beneficiaries of the interventions than in the control groups. The difference was statistically significant in Nigeria, but not quite significant in Niger. However, in the synchronic analysis, there was no improvement in the access to natural resources, nor a reduction of conflicts

Table 4

Values of socio-economic indicators in the diachronic analysis, baseline vs. evaluation survey, with statistical significance.

Indicator code	Description of the indicator	Unit	NIGER			SENEGAL			NIGERIA		
			Baseline	Evaluation	p-value	Baseline	Evaluation	p-value	Baseline	Evaluation	p-value
			N = 398	N = 388		N = 120	N = 353		N = 595	N = 218	
IND-HC-1	Technical training-AGRI	% of YES	86%	66%	0.0006	15%	8%	0.0319	54%	42%	0.0027
IND-HC-2	Technical training-FOREST RESTORATION	% of YES	78%	57%	<0.0001	nan	n.a.	n.a.	10%	28%	<0.0001
FIES1	FIES1 – worry for food	% of YES	89%	82%	0.0036	98%	86%	0.0007	99%	86%	<0.0001
FIES2	FIES2 – unable to eat healthy food	% of YES	90%	75%	<0.0001	98%	82%	<0.0001	n.a.	89%	n.a.
FIES3	FIES3 – ate only few kinds of food	% of YES	88%	79%	0.0002	98%	77%	<0.0001	n.a.	89%	n.a.
FIES4	FIES4 – skip a meal	% of YES	82%	67%	<0.0001	84%	50%	<0.0001	n.a.	89%	n.a.
FIES5	FIES5 – ate less than they should	% of YES	89%	81%	0.0017	94%	63%	<0.0001	99%	90%	<0.0001
FIES6	FIES6 – ran out of food	% of YES	84%	66%	<0.0001	65%	34%	<0.0001	n.a.	89%	n.a.
FIES7	FIES7 – hungry but did not eat	% of YES	81%	67%	<0.0001	66%	24%	<0.0001	n.a.	89%	n.a.
FIES8	FIES8 – did not eat for a whole day	% of YES	69%	58%	0.0016	46%	15%	<0.0001	n.a.	89%	n.a.
IND-SC-1	Participation to community groups	% of YES	27%	69%	<0.001	86%	4%	<0.0001	88%	91%	0.2199
IND-SC-2	Women participation to community groups	% of YES	50%	72%	<0.001	83%	67%	0.0005	19%	69%	<0.0001
IND-SC-3	Women participation in decisions	% of YES	67%	83%	<0.001	65%	66%	0.8293	17%	67%	<0.0001
IND-NC-1	Experienced soil erosion	% of YES	88%	90%	0.4870	32%	25%	0.1446	61%	75%	0.0003
IND-NC-2	Perceived trend of vegetation cover in the last 5 years	% for each category	1 = 86%; 2 = 3%; 3 = 12%	1 = 58%; 2 = 6%; 3 = 36%	<0.001	n.a.	n.a.	n.a.	1 = 54%; 2 = 40%; 3 = 6%	1 = 51%; 2 = 29%; 3 = 20%	<0.0001
IND-NC-3	Satisfactory access to natural resources	% of YES	31%	79%	<0.001	61%	86%	<0.0001	66%	81%	<0.0001
IND-NC-4	Conflicts on access to natural resources	% of YES	42%	49%	0.0387	n.a.	n.a.	n.a.	37%	30%	0.0840
IND-FC-1	Livestock is a source of income	% of YES	39%	9%	<0.001	83%	84%	0.6757	49%	45%	0.3335
IND-FC-2	Commerce is a source of income	% of YES	12%	9%	0.1309	8%	3%	0.0245	2%	13%	<0.0001
IND-FC-3	Trend of household income in the last 2 years	% for each category	1 = 78%; 2 = 9%; 3 = 13%	1 = 59%; 2 = 11%; 3 = 30%	<0.001	1 = 67%; 2 = 25%; 3 = 8%	1 = 40%; 2 = 25%; 3 = 35%	<0.001	1 = 35%; 2 = 46%; 3 = 19%	1 = 39%; 2 = 15%; 3 = 46%	<0.001
IND-FC-4	NTFP economic activity	% of YES	7%	17%	<0.001	n.a.	n.a.	n.a.	4%	14%	<0.0001
IND-FC-5	Cattle heads	Average	1.8	2.0	0.6449	12.4	46.2	<0.0001	3.2	2.9	0.5832
IND-FC-6	Goats heads	Average	2.3	2.5	0.7044	16.6	44.1	<0.0001	4.7	4.8	0.9376
IND-FC-7	Sheep heads	Average	2.5	2.6	0.7584	39.9	74.7	0.0062	3.9	2.9	0.0172
IND-FC-8	Poultry heads	Average	5.0	5.5	0.4615	3.0	6.2	0.0007	3.5	6.2	0.0001

concerning their use. It might just be either a bit early to access these resources and impact conflicts mitigation despite increased restoration activities, or that some conflicts may not be driven directly by access to the type of resources made available through restoration activities.

Considering the economic assets of the households, it was worth noting that the proportions of households declaring an increase in the income in the last two years of interventions were significantly higher among the beneficiaries of Senegal, Nigeria and Niger than in the respective control groups of non-beneficiaries; this difference was found statistically significant for Senegal and Nigeria, while not in Niger.

Other changes that had been detected did not reach a statistical significance. For example, contrary to the diachronic analysis, no evidence could be found that the perception of food insecurity was different among the beneficiaries of the interventions and the control groups in all the three countries, meaning that the improvement in the perception of food security may be due to factors unrelated with the interventions.

4. Discussion

Land restoration is a long-term process because it needs to be embedded in the local agricultural practices and culture and tailored to the ecological features of the different sites (Ceci et al., 2018; Chokkalingam et al., 2005; Meli et al., 2014; Sacande and Berrahmouni, 2016). In this study, the socio-economic impacts derived from large-scale land restoration, implemented under the Great Green Wall initiative, was assessed by means of indicators fed by field data collected through household surveys. The impact of interventions on social capital showed that contrasting evidence emerges about the efficacy of the strengthening of technical education among beneficiary households. Where this impact was negligible, communities might have already benefitted from capacity development activities from other development programs before the baseline survey was carried out. Improvement of human capital assets has been found in previous studies to be enabling factor for the spread of sustainable land management practices (Ceci et al., 2018;

Table 5

Values of socio-economic indicators in the evaluation vs. control group survey, with statistical significance.

Indicator code	Description of the indicator	Unit	NIGER			SENEGAL			NIGERIA		
			Evaluation	Ctrl group	p-value	Evaluation	Ctrl group	p-value	Evaluation	Ctrl group	p-value
			N = 388	N = 86		N = 353	N = 52		N = 218	N = 177	
IND-HC-1	Technical training-AGRI	% of YES	76%	62%	0.0061	8%	10%	0.2156	42%	20%	<0.0001
IND-HC-2	Technical training-Forest Restoration	% of YES	57%	38%	0.0017	n.a.	n.a.	n.a.	28%	12%	<0.0001
FIES1	FIES1 – worry for food	% of YES	82%	88%	0.1376	86%	77%	0.0727	86%	88%	0.6046
FIES2	FIES2 – unable to eat healthy food	% of YES	75%	80%	0.3466	81%	75%	0.3316	89%	86%	0.5318
FIES3	FIES3 – ate only few kinds of food	% of YES	79%	88%	0.0392	76%	75%	0.5039	89%	89%	0.9276
FIES4	FIES4 – skip a meal	% of YES	67%	72%	0.3702	48%	40%	0.0260	85%	86%	0.7518
FIES5	FIES5 – ate less than they should	% of YES	80%	83%	0.6795	61%	60%	0.1314	90%	88%	0.5749
FIES6	FIES6 – ran out of food	% of YES	66%	72%	0.2892	32%	42%	0.4921	85%	82%	0.4343
FIES7	FIES7 – hungry but did not eat	% of YES	66%	77%	0.0690	22%	35%	0.6826	87%	79%	0.0317
FIES8	FIES8 – did not eat for a whole day	% of YES	58%	64%	0.2373	14%	23%	0.8389	74%	71%	0.5555
IND-SC-1	Participation to community groups	% of YES	69%	67%	0.8410	4%	4%	0.4227	91%	77%	0.0002
IND-SC-2	Women participation to community groups	% of YES	72%	78%	0.2525	63%	75%	0.2051	70%	56%	0.0045
IND-SC-3	Women participation in decisions	% of YES	83%	88%	0.2362	64%	52%	0.0178	67%	51%	0.0016
IND-NC-1	Experienced soil erosion	% of YES	90%	91%	0.7794	24%	48%	0.0004	75%	66%	0.0452
IND-NC-2	Perceived trend of vegetation cover in the last 5 years	% for each category	1 = 6%; 2 = 58%; 3 = 36%	1 = 5%; 2 = 73%; 3 = 22%	0.0457	n.a.	n.a.	n.a.	1 = 51%; 2 = 29%; 3 = 20%	1 = 72%; 2 = 21%; 3 = 6%	<0.0001
IND-NC-3	Satisfactory access to natural resources	% of YES	79%	73%	0.2579	80%	73%	<0.0001	81%	81%	0.8758
IND-NC-4	Conflicts on access to natural resources	% of YES	49%	56%	0.2794	n.a.	n.a.	n.a.	30%	18%	0.0033
IND-FC-1	Livestock is a source of income	% of YES	9%	17%	0.0271	84%	73%	0.0086	45%	57%	0.0213
IND-FC-2	Commerce is a source of income	% of YES	9%	5%	0.2048	2%	8%	0.7072	13%	11%	0.6413
IND-FC-3	Trend of household income in the last 2 years	% for each category	1 = 59%; 2 = 11%; 3 = 30%	1 = 67%; 2 = 14%; 3 = 19%	0.1304	1 = 40%; 2 = 25%; 3 = 35%	1 = 41%; 2 = 42%; 3 = 17%	0.0085	1 = 39%; 2 = 15%; 3 = 46%	1 = 63%; 2 = 20%; 3 = 17%	<0.0001
IND-FC-4	NTFP economic activity	% of YES	17%	15%	0.7119	n.a.	n.a.	n.a.	14%	11%	0.3654
IND-FC-5	Cattle heads	Average	2.03	1.36	0.3734	46.23	30.34	0.1152	2.91	1.81	0.1060
IND-FC-6	Goats heads	Average	2.47	2.09	0.5789	43.48	35.13	0.1295	4.77	3.53	0.0591
IND-FC-7	Sheep heads	Average	2.59	1.85	0.3303	74.51	51.83	0.2199	2.90	2.18	0.1592
IND-FC-8	Poultry heads	Average	5.48	1.55	0.4546	5.90	6.02	0.0960	6.20	5.85	0.7498

D.A. and J.K., 2014; Fakoya et al., 2007), suggesting that the lack of appropriate training may hinder positive outcomes of interventions. Because communities' sustainable development is at the centre of interventions, the perception of food insecurity was analysed and showed a significant improvement in food availability during the five-year implementation in all the three countries. Although improvement of land productivity for crop production was a part of the restoration objectives in agro-forestry systems, it was not clear to what extent the positive change could be attributed to the interventions. The diachronic analysis showed similar improvement in both beneficiary and non-beneficiary communities.

Women's participation and their representation were set as a specific objective of the interventions and for the Great Green Wall. Because they are often a part of disadvantage groups in rural communities, women's involvement was pre-selected as a key indicator. In that regard, a remarkably positive result was found in the synchronic analysis of women's contributions. This is essential as they play a key role in the management of lands and forests, and in the development of value chains such as the NTFPs (Agarwal, 2009; Shackleton et al., 2011).

Women perform several functions at different stages of the value chains, but their role needs to be adequately visible and acknowledged in order to make it effective and replicable (Shackleton et al., 2011).

The evidence shows that the interventions have improved vegetation cover, the core activity of the restoration programme. Although in this study we could not demonstrate that this positive change is uniquely due to the interventions, both diachronic and synchronic evaluations suggest that the restoration activities in the target areas have helped to break the negative feedback loops that link the loss of rainfall due to climate change, the use of natural resources for agriculture and livestock, and the collection of biomass for human use (Wei et al., 2021a). These observations are often made about African drylands and depleting agro-sylvo-pastoral systems that are particularly sensitive to environmental changes, but also play an important role in carbon dynamics while supporting local livelihoods (Wei et al., 2021b).

The evidence concerning financial assets deserve particular attention. The most socio-economic effect of restoration activities was on the observed increased level of income of households. This indicator is important because of communities response to the adoption of

sustainable land practices largely depends on the direct economic benefits that they can derive from their application (Blate et al., 2002; Boscolo et al., 2009; Ceci et al., 2018). This response, in turn, is crucial to achieve medium- and long-term positive effects of restoration actions. However, no significant effect was found on livelihoods diversification and off-farm employment opportunities; therefore, we cannot confirm previous findings about the role of forest and landscape restoration initiatives in fostering income diversification in developing countries (Erbaugh and Oldekop, 2018).

Similarly to other forest-related projects in Africa (Ulian et al., 2017), it appears that the success of these interventions is rooted in its participative approach, that led to a shared choice of restoration actions, combining sustainable land use with income generation and livelihoods improvement. The positive changes observed in different local contexts confirm that an appropriate approach to implement restoration actions should consider holistic socio-ecological systems (Adams et al., 2016; Goffner et al., 2019), defined as geographical units with a specific set of environmental and social components. As highlighted in the Great Green Wall Initiative,⁴ it is the combination of these components that makes up a fruitful environment where the restoration initiatives can effectively contribute to communities' livelihoods and resilience.

The limitations of the study are mostly linked to the complexity of conducting a socio-economic analysis in rural areas. For instance, some activities were ongoing on an informal basis, thus potentially altering the results obtained in the baseline survey and/or among the control groups. Also, the time frame (2016–2020) was relatively short when compared to the time needed for ecosystems, especially those with trees, to be fully restored. Although many individuals involved have already seen direct improvements in the environment from the interventions (mainly linked to the rapid establishment and use of herbaceous species), most tree species planted will only reach maturity and full production potential much later. Similarly, for the synchronic assessment, some households may have participated more actively than others and therefore, may have benefited more. Synchronic assessment was limited, for example, by the small sample size of control groups and the difficulty in accessing similar communities which have not benefitted indirectly from spill-over effects (as neighbouring communities may visit and copy each other for example). Despite these limitations, this study provides evidence of livelihood improvement in populations targeted in the Great Green Wall areas through a devised large-scale restoration approach. The results show the importance of setting methodologies and technologies with a structured monitoring and evaluation plan (Sacande et al., 2020a) to obtain socio-economic effects of land restoration interventions.

5. Conclusions

Large-scale restoration is recognized as a main tool to combat desertification, improve livelihoods, and mitigate climate change. It is being implemented as priority intervention of Africa's Great Green Wall, combining land restoration objectives with livelihood and socio-economic improvement targets. While the biophysical impacts of these interventions are usually monitored closely, the same cannot always be said for the socio-economic impacts. This study aims to fill this gap by providing evidence of the changes in livelihood conditions among target populations in Niger, Senegal, and Nigeria. The changes are assessed both with a diachronic approach, by comparing the conditions of a sample of households before and after the intervention, and under a counterfactual perspective, with a synchronic evaluation of the conditions of beneficiaries against non-beneficiary households. It is important to highlight that the uptake of sustainable land and forest management practices by rural communities largely depends on the direct economic benefits that they can derive in the short term and continue to engage

restoration activities.

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