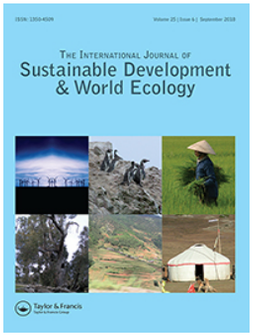

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Perceived Level and Farmer Characteristics Factors Associated with Level of Environmental Sustainability of Cotton Farming System in the Sudanese Gezira Scheme

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ABSTRACT

Cotton production plays an important role in the livelihood of farmers in the Gezira Scheme in the Sudan. It is the main cash crop produced in the scheme. However, sustainability of cotton production in the Gezira Scheme has been a worrying issue, specially, after the noticeable deterioration of the cotton production industry in the last few years. This study aimed to assess the environmental sustainability of cotton production in the Gezira Scheme as perceived by farmers who are the direct beneficiaries of the scheme. Understanding farmers' perspective can help to adopt relevant policy for improving sustainable cotton farming system. Data was collected using interview schedule and analysed using descriptive and inferential statistics. The indicators employed include use of fertilizers, pesticides, farm machinery, soil conservation practices, and availability of water at farm level. The level of environmental sustainability of cotton production was found to be moderate or fairly sustainable. Education level and farmers' age were negatively correlated with environmental sustainability whilst family size was positively correlated with environmental sustainability however; the correlation magnitudes were negligible. The study found adequacy of irrigation water, the appropriate use of pesticides and soil conservation practices as the main contributing factors to the moderate environmental sustainability of cotton production in the Gezira Scheme. Since farmers are not rational in some practices, the study recommended that the Sudanese Ministry of Agriculture and managers of Gezira Scheme should educate and support cotton farmers in the scheme to adopt integrated soil conservation practices with minimal but efficient use of heavy farm machinery.

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Environmental sustainability; cotton; Gezira scheme; agro-ecological management practices

1. Introduction

More than two million rural households in Africa rely on cotton production to earn their living (Baffes, as cited in Lorenzetti 2013). Lorenzetti reported that, in some African regions, cotton is the only cash crop and as such, the most important economic crop. The crop's share in the total merchandise export in West and Central Africa ranges from 25% to 45% and contributes some 4%–6% to the gross domestic product (GDP).

In Sudan, cotton is one of the most important cash crops. It contributes some 1.8% to Sudan's agricultural GDP (Sudan Cotton Company 2013). A major and an important cotton production setup in the Sudan is the Gezira Scheme, which has employed about 130,000 farmers (Salman 2010).

Due to the observed low output of the agricultural sector in Sudan and the Gezira Scheme, the Government of Sudan, as part of its strategic orientation to accelerate agricultural development, came out with programmes such as the Green Mobilization Programme and the Executive Programme for Agricultural Revival (EPAR). The agricultural revival programmes gave support to the cotton farmers and much attention was focused on improving the low productivity of cotton production in the Sudan (Sudan Cotton Company 2013). As part of this overall agenda, the Management of the Gezira Scheme, in collaboration with the Agricultural Research Corporation, also introduced several technologies and inputs under the policy of agricultural intensification to address the problem of low productivity of the crop and to raise the income of the agricultural households in the Gezira area. These inputs include improved seed varieties, chemical fertilizers, pesticides and different types of agricultural machines. Accordingly, to improve the productivity of cotton farmers, agricultural technologies such as pesticides, fertilizers and machines were introduced and have been used extensively in the cotton industry under the Gezira Scheme. Despite the lack of accurate data on types and quantities of inputs used, it has been argued that use of farm machinery (e.g. ploughing

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tractors), inorganic fertilizers and pesticides have caused significant environmental problems in cotton production systems (Faki 2006). Notably, environmental sustainability of cotton farming system in Gezira Scheme has not been empirically assessed to inform extension policy decision on the scheme.

Environmental sustainability requires maintaining ecosystem functions and stable resource base, avoiding overexploitation of renewable resource systems or environmental sink functions and depleting non-renewable resources only to the extent that investment is made in adequate substitute (Harris 2003).

In the context of this study, it is assumed that promoting the adoption of conservation agricultural practices in farming communities must begin with understanding the behavioural and perceptual context of the community. This is important for measuring the 'mental models' of farm communities in order to appropriately frame agricultural behaviour change within the existing context of farming practices using mental cognitive mapping. Halbrendt et.al, (n.d) found that community understanding of cultivation, or agricultural belief systems, reflect local ecological and cultural conditions, which serve to shape the decision-making process on the farm. Thus, to formulate relevant policies and strategies for sustainable production of cotton in the Gezira Scheme, a context specific understanding of environmental sustainability of the Scheme is important. This research therefore, was to assess the environmental sustainability of cotton production in the Gezira Scheme as perceived by farmers who are the direct beneficiaries of the Scheme.

2. Methods

Many scholars used perception to evaluate sustainability and sustainable development (Trotman 2007; and Cattenazzo et al. 2008). The EU. (2008) employed perception to evaluate perceived sustainability and compared it with measured sustainability. The assertion is that the primary goal of perceptual categorization is to estimate the statistical structure of the physical world and most experts assume that perception estimates true properties of an objective world (Hoffman, n.d)

The Gezira scheme is the largest irrigated scheme in Sudan with an area of 900,000 ha (Salman 2010). The scheme depends on small-farm ownership with an area ranging between 6.3 and 16.8 ha. The main agricultural crops cultivated in the scheme include cotton, sorghum, wheat, sunflower, groundnut and vegetables.

The descriptive survey design was adopted to gather the relevant data from the participating farmers. In all, data was collected from 314 sampled cotton farmers using a pre-tested, structured and validated interview schedules. A multistage sampling method was used. In stage one 11 irrigation divisions under cotton cultivation in the Gezira Scheme were purposively selected. The second stage involved random selection of 7 irrigation divisions out of the 11. In the third stage snowball sampling technique was used to select respondents from each of the selected divisions due to lack of sampling frame. The sample size was determined using the Krejcie and Morgan (1970) table for the estimation of sample size. A sample size of 314 was determined for the study. Using the formula: ***Population of subgroup/Total population x Sample size*** (Nwankwo 2010), a proportional allocation of sample size was applied to determine the required sample size from each irrigation division. Depending on the fact that Elshargi irrigation division, Elhajabdalla division, Elturabi division, Tabat division, Elbasatna division, Qurashi division and Abdelmajed division comprise 1139, 1025, 1023, 799, 342, 342 and 288 of the population respectively constituting 4898 cotton farmers (total population of the selected seven irrigation divisions), a sample sizes of 73, 66, 65, 51, 22, 22 and 15 were selected from these divisions respectively.

Regarding measurement and instrumentation, the study quantified sustainability in a five points Likert-type scale ranging from very high = (5), high = (4), moderate = (3), low = (2) to very low = (1) (Chang, 1994). The likert-type scale was used to measure all the indicators of environmental sustainability. Data collected was analysed using Statistical Product and Service Solution (SPSS) Version 20. The analysis was mainly descriptive using frequency, Mean and standard deviation. The inferential statistics test **S**pearman rank correlation was used to test for existence and significance of relationships among the variables.

3. Results and discussion

3.1. Characteristics of the cotton farmers

The ages of the cotton farmers ranged between 18 and 90 years with a Mean of 52 years and standard deviation of 13.9. This Mean age is higher than what (42 years) was found by Abdel Rahman and Hamid (2013) in the region. From the results 36.6% of farmers were in their productive age below 45 years, with 7.3% of them as youth below 33 years old, based on age categorisation by the UN (2013). In all, about 66% fall within productive workforce with age up to 58 years, which according to the Economic Cooperation and Development OECD (2001) are more likely to respond rapidly to changing economic and environmental conditions for sustainable agriculture. Quite substantial numbers of the farmers (33.8%) were aged, above 58 years.

The report of the OECD (1999) indicated that a farmer's educational level can influence effective farm management and farmers' decision to adopt environmentally friendly management practices. The results show that majority (83.3%) of cotton farmers have had access to formal education and therefore are more likely to adopt timely environmentally benign practices and effectively manage their cotton farms. About 37.8%, 27.9% and 11.9% of the farmers have had secondary, primary and bachelor's degree level of education respectively. Only 16.7% of cotton farmers were without formal education.

Majority (87.9%) of cotton farmers studied had family size between 1 and 10 persons (Table 1). About 12.1% of them had family size of more than 10 persons. The average family size was seven persons. This is close to what had been reported (six persons) by the Sudan Central Bureau of Statistics (2010). The number of family members gives significant information about the structure of agricultural household and it highlights the availability of farm labour and the trend of the retention of farm population in the countryside. Shreck et al. (2006) suggested that sustainable agriculture is owner operated in the sense that family members provide all or most of the necessary farm labour and farm income will pay for all necessary expenses. This idea also insures social justice for small folder farming families. Thus, farmers in the study area have mean family size (seven) that is quite suitable for performing agricultural practices in their respective area of cotton farm.

3.2. Level of use of key environmental sustainability factors in cotton production

This section discusses the level of perceived environmental sustainability of cotton production in the Gezira Scheme based on key practices (variables). The variables employed were use of fertilizer, use of pesticides, use of agro-ecological management practices, use of farm machinery and adequacy of irrigation water. Means were calculated from a scale of 1 to 5, for the variables, where using the practice (e.g. fertiliser) five times in the last 5 years is considered as very high (VH = 5), four times as high (H = 4), three times as moderate (M = 3), two times as low (L = 2), and once in the last 5 years as very low (VL = 1). The results are presented in Table 2 and discussed as follows.

Table 1. Frequency distribution of socio-demographic characteristics of respondents.

Characteristics	Frequency	Percentages (%)
Age		
<33	23	7.3
33–45	92	29.3
46–58	93	29.6
>58	106	33.8
Educational level		
No formal education	52	16.7
Primary	88	27.9
Secondary	119	37.8
Diploma	18	5.8
Degree	37	11.8
Family size		
<6	99	31.5
6–10	177	56.4
11–15	32	10.2
>15	6	1.9

Source: Field Data, 2014; n = 314

3.2.1. Level of use of fertilizers

From the results, cotton farmers in the study area use urea and NPK fertilizers. The results showed that they applied urea and NPK about four times in the last 5 years with Mean values of 3.6 and 3.5 respectively (Table 2). The implication is that the level of use of fertilizers by the farmers was high (Means ≥ 3.5). It is worth noting that high level use of fertilizers poses potential threat to environmental sustainability of cotton production in the study area. This argument on the deteriorating effects on soils by chemical fertilizers is unabated (Kooistra et al. 2006).

3.2.2. Level of use of pesticides

Pesticides contribute to agricultural productivity but also pose potential risks to human health and the environment. The risk variations depend on the pesticide's inherent toxicity, exposure, and frequency of use. Irrational use of pesticides leads to pesticide residues affecting the environment and contribute to soil deterioration. The results show that cotton farmers in the study area used pesticides almost three times in the last 5 years as represented by Means of 3.2, 3.4, 3.4 and 2.7 for insecticides, fungicides, pre-emergence herbicides and post-emergence herbicides respectively (Table 2).

With the calculated Means exceeding 2.5 but less than 3.5, the implication is that the pesticides were used almost three times in the last 5 years and can be described as moderate. This contradicts findings of UNEP (n.d) which pointed that an estimated area of 125,000 to 205,000 ha of cotton, representing the whole area under the Gezira Scheme is sprayed with pesticides annually. This moderate used of pesticides from the study gives an indication of a reduction in cotton area that is sprayed annually. However, no matter how moderate it might be, irrational use of pesticides is considered as a threat to environmental sustainability. Pesticides applied in cotton production have been documented as adversely affecting the ecosystems, leading to lower quantities and lessened diversity of water organisms (Hose et al., as cited in Kooistra et al. 2006). In addition to threatening water organ pesticides also pose threat to biodiversity leading to interrupting many ecosystem services and affecting soil structure and microorganisms.

Table 2. Perceived levels of use of key factors of environmental sustainability in cotton production.

Factors	Frequency and percentages F (%)					Mean ($\bar{X}$)	SD
	VH	*H*	*M*	*L*	*VL*		
Use of fertilizer							
– Nitrogen (Urea)	7 (18.6)	101 (32.9)	133 (43.3)	13 (4.2)	3 (1.0)	3.6	.86
– NPK	50 (17.2)	76 (26.2)	146 (50.3)	15 (5.2)	3 (1.0)	3.5	.87
Use of pesticides							
– Insecticides	13 (7.7)	17 (10.1)	79 (47.0)	36 (21.4)	23 (13.7)	3.2	1.0
– Fungicides	12 (4.3)	26 (9.4)	125 (54)	61 (21.9)	45 (19.4)	3.4	1.0
– Pre-emergence herbicides	20 (6.8)	26 (8.8)	112 (38.1)	78 (26.5)	58 (19.7)	3.4	1.1
– Post-emergence herbicides	9 (30.0)	5 (16.7)	8 (26.7)	1 (3.3)	7 (23.3)	2.7	1.5
Agro-ecological management practices							
– Growing the Bt. Cotton	85 (28.4)	113 (37.8)	80 (26.8)	19 (6.4)	2 (0.7)	3.8	0.9
– Crop rotation	87 (28.7)	85 (28.1)	80 (26.4)	28 (9.2)	23 (7.6)	3.6	1.2
– Multiple cropping	34 (16.3)	87 (37.3)	78 (37.3)	17 (8.1)	2 (1)	3.5	0.8
– Applying organic manure	3 (8.6)	9 (25.7)	15 (42.9)	6 (17.1)	2 (5.7)	3.1	1.0
– Mixing crop residues with soil	12 (8.8)	26 (19.1)	58 (42.6)	32 (23.5)	8 (5.9)	3.0	1.0
– Applying green manure	1 (25)	0 (0)	1 (25)	1 (25)	1 (25)	2.7	1.7
Use of farm machinery							
– Ploughing machine	121 (39.5)	123 (40.2)	50 (16.3)	11 (3.6)	1 (0.3)	4.1	0.8
– Sowing machine	42 (27.1)	41 (26.5)	62 (40.0)	10 (6.5)	0.0 (0.0)	3.7	0.9
– Pesticide application machine	62 (26.6)	85 (36.5)	60 (25.8)	18 (7.7)	8 (3.4)	3.7	1.0
– Fertilizer application machine	64 (28.2)	76 (33.5)	60 (26.4)	22 (9.7)	2.2 (%)	3.7	1.0
– Weeding machine	27 (20.9)	50 (38.8)	38 (29.5)	11 (8.5)	3 (2.3)	3.6	0.9
Adequacy of irrigation water							
– Adequacy of irrigation water	98 (31.5)	97 (31.2)	65 (20.9)	46 (14.8)	5 (1.6)	3.7	1.0

Scale: Very high (VH) = 5, High (H) = 4, Moderate (M) = 3, Low (L) = 2, Very Low (VL) = 1.

3.2.3. Level of use of agro-ecological management practices

The key agro-ecological management practices followed by farmers in the Gezira Scheme were the use of genetically modified cotton (also referred as Bt cotton), crop rotation, multi-cropping, applying organic manure, mixing crop residues with soil and applying green manure. The study reveals that farmers in the study area tend to grow the genetically modified cotton, practice crop rotation and multi-cropping almost four times in the last 5 years. Therefore, the three practices are the most contributing practices to soil conservation with Mean of 3.8, 3.6 and 3.5 respectively (Table 2). The study also reveals that mixing crop residues into the soil, applying green manure and organic manure were practiced almost three times in the last 5 years. All the six management practices are known to contribute favourably to soil quality and soil conservation (Dantsis et al. 2010).

3.2.4. Level of use of farm machinery

The Means of level of use of farm machinery in cotton farming were all more than 3.5, reflecting high level of use of farm machinery (Table 2). This means that cotton farmers in the study area were using all the machines mentioned in Table 2 almost four times in the last 5 years. Even though, the mechanization of agricultural practices leads to increase in yield and production efficiency, it is also found to harm the environment by increasing fuel consumption which may contribute to air pollution and global warming. Moreover, the use of heavy machines puts more pressure on soil and causes soil compaction. The results also show that the number of each of the machines entering the field is almost four times in the last 5 years and this is described as high level of use.

3.2.5. Adequacy of irrigation water

Regarding adequacy of water the Mean was computed from a scale of 1 to 5, where water is very much available and adequate was considered as very high (VH = 5), available and adequate as high (H = 4), fairly available and adequate as moderate (M = 3), scarce as low (L = 2), very scarce as very low (VL = 1). Adequate water supply is essential for growth and development of cotton cultivation. In Sudan, irrigation water concerns are related to availability and equity in water distribution (Faki 2006). This study sought to find out cotton farmers' perception on the level of adequacy of supply of irrigation water. With a mean value of 3.7 for adequacy of irrigation water, the results show that the supply of irrigation water for cotton production in the study area is almost sustainable with the perception that it is available and adequate (Table 2).

3.3. Environmental sustainability of cotton production

From the results show in Table 3, the weighted Mean of all environmental indicators was 2.8 constituting moderate level of environmental sustainability of cotton production in the study area.

The study reveals that the use of fertilizers and use of farm machinery were the main threats to environmental

Table 3. Level of environmental sustainability of cotton production.

Variables	Mean $\bar{X}$	Level of sustainability	SD
Adequacy of irrigation water	3.7	High	1.0
Agro-ecological management practices	3.2	Moderate	0.9
Use of pesticides	2.7	Moderate	1.1
Use of fertilizer	2.3	Low	0.8
Use of farm machinery in cotton	2.1	Low	0.9
Weighted mean ($\bar{X}w$)	2.8	Moderate	0.94

Source: Field Data, 2014

sustainability represented by Means of 2.3 and 2.1 respectively, which constitute low level of sustainability (Table 3). Irrational use of fertilizer in agriculture contributes to deterioration of the environment in several ways. For example, in the production of nitrate and ammonium much energy is needed and, this is said to contribute to global warming (Kooistra et al. 2006).

Availability and adequacy of irrigation water, use of agro-ecological management practices and use of pesticides are the most contributing factors to environmental sustainability of cotton production in the study area with Means of 3.7, 3.2 and 2.7 level of sustainability respectively. In the past the use of pesticides was the greatest challenge to environmental sustainability within the Gezira Scheme when the whole area under cotton cultivation was sprayed annually (Eldaw 2004). Now the widely adopted Bt. cotton has contributed to reduction in the use of pesticides on cotton in the study area.

3.4. Farmers' characteristics and their perceived level of environmental sustainability

Based on Davis Convention (1971) for describing correlation coefficient, the results of the Spearman correlation show a negligible positive relationship between family size and the level of environmental sustainability as represented by correlation coefficient r = .019. The results also show a negligible negative relationship between farmers' age and their perceived level of sustainability as represented by r = -.032 correlation coefficient (Table 4). It means that increase in farmer's age reduces the level of sustainability of their farms. The result is consistent with Van Passel et al. (2006) who noted that age has a significant negative effect on the farm sustainability, and as such, the best sustainability scoring farms have younger farm managers.

Table 4. Spearman correlation matrix of relationship between farmers' characteristics and their perceived level of environmental sustainability.

Variable	Environmental sustainability
X_1	.019
X_2	−.032
X_3	−.008

P = 0.05; X_1: family size; X_2: Age; X_3: education level.

The relationship between farmers education level and their perceived level of sustainability is negative but negligible r = -.008 (Table 4). This result somehow contradict the findings of the OECD. (1999) that a farmer's educational level and effective farm management as well as timely adoption of environmentally friendly management practices are positively correlated. In the case of the Gezira Scheme, type and amount of input used on the farm are influenced by the funding organisation that supplies the inputs and, therefore, farmers have no choice other than to apply these inputs. The implication is that acquisition and application of technologies may have little to do with farmers 'education level and as such, may explain the negligible correlation between farmers' education level and environmental sustainability of cotton production on their farms. This argument is supported by Eldaw (2004) who reported that, in Gezira Scheme, the Gezira Board provides seed, sacks, fertilizers and chemicals for plant protection in addition to land preparation, application of fertilizers and spraying of chemicals.

4. Conclusion

Based on the findings, it can be concluded that environmental sustainability of cotton production system in the Gezira Scheme is generally moderate. The availability of adequate irrigation water and the appropriate use of pesticides coupled with moderately effective soil conservation practices such as incorporating crop residues into the soil, application of organic manures and following crop rotation are the major contributors to the moderate environmental sustainability of cotton production in the Gezira Scheme. The application of inorganic fertilizer and high level of use of farm machinery are major possible threats to environmental sustainability of cotton production in the Gezira Scheme. These, suggest the need for the Sudanese Ministry of Agriculture and managers of Gezira Scheme to provide education and support for cotton farmers in the scheme to use integrated soil conservation practices with minimal and efficient farm machinery.

Disclosure statement

No potential conflict of interest was reported by the authors.

Author note

This research work has not been published elsewhere and that it has not been submitted simultaneously for publication elsewhere.

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