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Research Article

Farmers' perceptions of climate change and its impact on gum *Talha* (*Acacia seyal var. seyal*) production in Bahar Alarab locality, East Darfur State, Sudan

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Abstract
Acacia seyal var. seyal is an essential source of income to farmers in the *Bahar Alarab* locality in Sudan. Farmers' perceptions of current climate conditions and their subsequent repercussions on Gum Talha (*Acacia seyal var.* seyal) production remains poorly investigated and understood. To fill this gap, a survey was carried out within six villages at *Bahar Alarab* locality in East Darfur State, Sudan, and a total of 391 randomly selected farmers were included in the study. Moreover, rainfall and temperature data over 30 years (1988 – 2020) were analysed. The results revealed that climate change signs were perceived by farmers based on the size of gum production (27.4%), early falling of leaves (26.1%), decline in production (24.3%), and persistent insect attack (22.3%). Moreover, farmers also reported increases (65%) and decreases (19%) in temperature. In contrast, 46.5% of farmers reported that rainfall deficiency was a decreasing factor of production. Accordingly, 69% of respondents perceived an increase in temperature, whereas 49.4% reported a decrease in rainfall frequency. Additionally, the results showed that there was long-term variability in temperature over the past three decades. The results of multinomial logistic regression highlighted that household size is an important factor contributing to the increasing trend of temperature. In addition, the growth and productivity of acacia trees were found to be determinants of farmers' perception of temperature and precipitation change over the past 30 years. The study suggests a tailored policy that could reduce climate-induced impacts on gum Talha productivity and increase farmers' gain to avoid poverty in this locality.

Keywords: Climate-induced impacts, Climate change, Gum production, Gum *talha,* Seyal

INTRODUCTION

Climate change will have devastating impacts on the world's socioeconomic sectors, especially agricultural systems, where many people are strongly dependent (Shiferaw *et al*., 2014). Climate change (CC) impacts on agricultural systems, especially on Gum talha production, will be most devastating due to its sensitivity to climate variability (Siddig et al., 2020). However, Gum talha production is a key economic sector of Sudan that contributes significantly to household income generation and food security (Ibrahim *et al.,* 2015).

Gum *talha* (*Acacia seyal* var. *seyal*) production is an important source of income in many developing countries, particularly in rural areas where people's livelihood depends on it (Ibrahim *et al.,* 2015). Gum talha contributes to approximately 10 per cent of the total gum production. The mean annual production is approximately 3,739 tons per year, and the annual exportation is between 3,000 and 5,000 tons (IPCC, 2007). Apart from being cultivated as a means of subsistence and income generation of rural communities, Gum talha supports small-scale to large-scale enterprises' diverse incomes (Younis, 2018; Revesz, 2020) and contributes to food security, production of medicines, construction, and fodder (Badi, 1993; Badi *et al.,* 1989). However, current climatic conditions are likely to negatively influence its production. Subsequently, this will negatively affect producers' gain, food security and welfare in the study area (Sofoluwe *et al.,* 2011*).*

Farmers' perceptions of climate-induced changes have played a critical role in developing mitigation and adaptation strategies for CC (Callo-Concha, 2018; Atube *et al.,* 2021), including crop diversification, crop rotation, changing planting dates, and utilization of improved seed varieties (Paudel *et al.,* 2020). Such adaptation strategies are influenced by local socioeconomic characteristics and farmers' perceptions and knowledge of climate change (Asrat *et al.* 2018; Saha *et al.* 2019). Subsequently, many scholars have already undertaken investigations on farmers' perceptions of climate change in the scientific literature since it is the most urgent threat to the sustainability of our planet and the risks associated with it are increasing worldwide (Altea, 2019). The perception of climate change and its impacts can motivate adaptive farmers' behaviors through multiple external factors. These factors can either act as a barrier or support adaptation behavior or include access to our lack of resources and capital, such as financial means, technology, information, and societal and systemic support (Woods *et al*., 2017; Traoré *et al*., 2021).

Therefore, investigating the effects of climate change and understanding farmers' perceptions are the right of way to understand the fluctuations in production in Gum Talha (Acacia seyal var. seyal) (Hyland et al., 2015). Farmers' behaviors are also strongly shaped by personal, environmental, and socioeconomic contexts, which determine whether farmers adapt or cope with climate change. This is important for developing policies that foster not only short-term, temporary adjustments but also enduring adaptation in the face of environmental change (Takahashi *et al*., 2016).

Alvar-Beltrán *et al.* (2020) in Burkina Faso indicated that farmers are aware of changing climatic conditions through increased temperatures, rainfall variability, and early offset of the rainy season. The same observations were made by Sippel *et al*. (2020) and Fosu-Mensah *et al*. (2012) in Ghana, where perceived increases in temperature and decreases in precipitation over years were observed by 92% and 87% of respondents, respectively. The planting of short-season varieties, crop diversification, the shift in planting date, and changing crop species were major identified adaptation strategies used by Ghanaian farmers. Moreover, the study conducted by Limantol *et al*. (2016) and Nyang'au *et al*. (2021) on farmers' perception of climate variability in the Vea catchment in Ghana showed that approximately 90% of interviewees believed that temperature has increased over the past 30 years, while approximately 94% of respondents believed that rainfall balance, duration, intensity and rainy days have decreased. A rising trend in temperature but with no long-term changes in annual and monthly rainfall was observed in climatic data in this catchment (Kahsay *et al*., 2019; Teshome *et al*., 2021).

Hence, farmers practicing rain-fed practices had to adjust to climate change and variability through crop rotation or varying crop types. However, in the case of gum production, farmers' perception of climate change has a critical role in offsetting the negative impact of climate change, as gum production contributes significantly to farmers' economic gains. However, there are few evidence-based data demonstrating such factors. Therefore, this study aimed to understand farmers' perceptions of climate change to adapt and mitigate the adverse effects of climate change on Gum Talha (*Acacia seyal* var. *seyal*) production, and adaptation strategies over the past three decades in the *Bahar Alarab* locality in East Darfur State of western Sudan.

MATERIALS AND METHODS

Description of the study area

The study was conducted at the *Bahar Alarab* locality, which is located in the southern part of East Darfur State of western Sudan (35 km from Ed Daein - the capital of East Darfur State (Fig. 1)). It covers 23,000 km^2 (FNC, 2013), and it is a part of the gum belt in Sudan with a latitude of 10°-13° N and a longitude of 25°-27° E. The *Bahar Alarab* locality shares borders with the Republic of South Sudan. The climate is tropical with rainfall ranging between 200 and 500 ml. Sandy soil is dominant in the northern and eastern parts of the state, covering approximately 70% of the total area (Elnour., 2007). The soil in the middle and south of the state is heavy clay as well as in the southern part and covers approximately 30% of the area (Younis *et al.*, 2018). *Bahar Alarab* occupies a total area of 23,000 km^2 and has a population of approximately 168,028 people. Summer (dry season) starts in March and ends in May, with an average daily temperature of 40°C (Younis, 2018).

Methodology

A descriptive statistic was used to describe respondents' socio-demographic conditions as well as their perception about climate change and its impact on Gum *Talha* (*Acacia seyal var. s*eyal) production in *Bahar Alarab* locality. The Multinomial logit model was used to analyze factors that drive farmers' perception on temperature and precipitation change in *Bahar Alarab* locality. The logistic model is popular because the logistic function in which the model primarily focuses on log model.

The Logistic Model used is presented below:

$$P(\mathrm{Y}) = \frac{1}{1+e^{-(\alpha+\sum B_i X_i)}} \quad \textbf{(1)}$$

The multiple logistic regression models consider a collection of p independent variables demented by the vector x

$$\mathrm{x}' = (\mathrm{x}_1, \mathrm{x}_2, \dots, \mathrm{x}_p) \quad \textbf{(2)}$$

For the p independent variables denoted, we assume that each of these variables is at least interval scaled. The outcome is present be denoted by pro $\mathrm{pr} = (\mathrm{y} = 1/\mathrm{x}) = \pi(\mathrm{x})$. The legit of the multiple logistic regression models is given by equation 3:

$$\mathrm{p(Y)} = lin\left(\frac{\pi x}{1-\pi x)}\right) = \beta_0 + X_1 B_1 + +X_2 B_2 + \cdots +X_n B_n \quad (3)$$

Considering a collection of p independent variables denoted by the vector $= x1, x2, \dots, xp$. We assume that each of these variables is at least interval scaled. The conditional probability that the outcome is present is being denoted by $\mathrm{pr}(\mathrm{Y} = {}^1/_\mathrm{x}) = \pi(\mathrm{x})$. The logit of the multiple logistic regression models is $\mathrm{p(Y)} = \ln(\pi x) - (1 - (\pi x) = \beta_0 + X_1 B_1 + +X_2 B_2 + \cdots +X_n B_n$ (Chatterjee and Simonoff, 2013).

Sampling and sample size

A multistage sampling method was used to select the sample size from six villages, namely, Abunmh, Alkabw, Boro, Dalbug, UmSigyei, and Umm Ajaj (Table 1). In the first stage, the Bahar Alarab locality was selected. In the second stage, six villages were purposely selected. In the third stage, single samples were ran-

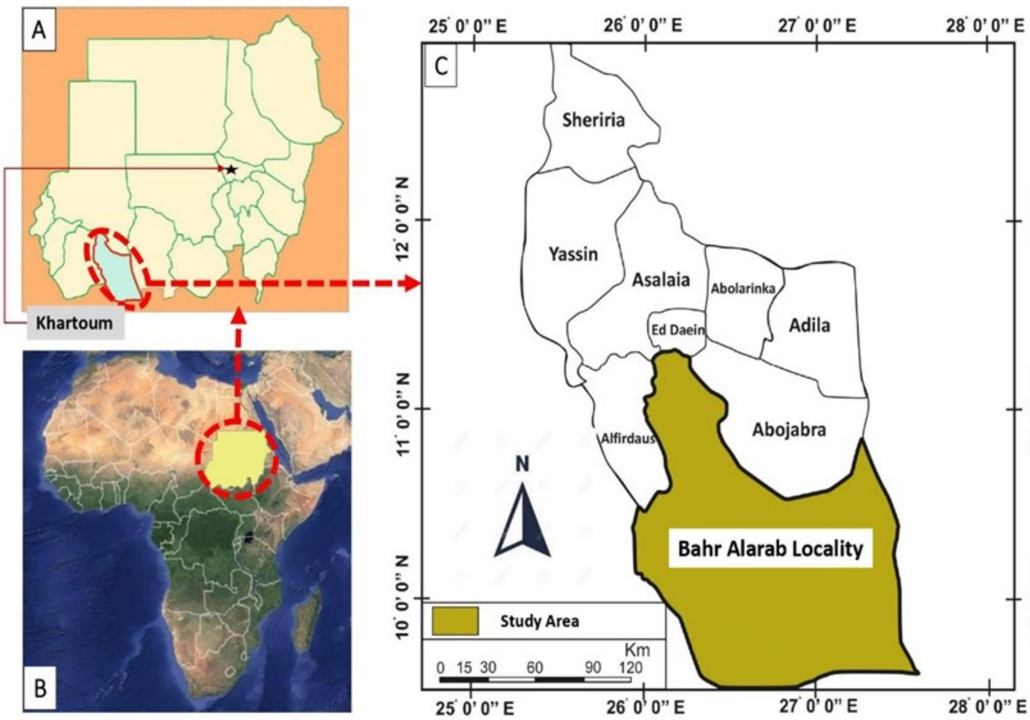

Fig. 1. *Map of Africa showing Sudan, while (b) is Sudan showing East Darfur and (c) is East Darfur showing the Bahar Alarab locality, the study area (Source: Author's work, 2021)*

Table 1. Distribution of the villages households and sample size at *Bahar Alarab* locality East Darfur State, Sudan.

Respondent (Villages)	Household Size	Sample Size
Abunmh	3957	75
Alkabw	2216	42
Boro	3957	75
Dalbug	3957	75
Umm Ajaj	2638	50
UmSigyei	3957	75
Total	20680	392

Source: Author's computation from survey data (2021

domly selected. The sample unit was a head of household, and the sample was chosen based on the population size of each village. Finally, a total of 392 respondents were selected, which constituted approximately 5% of the total number of households in these villages, which is approximately 20680 households' families. The sample size was obtained by using formula 4:

$$n = \frac{N}{1+N(e^2)} \quad (4)$$

where n represents the sample size, N represents the population size, and e denotes the level of precision at $\propto=$ 0.05. Then, the sample size of each village was determined by dividing the total number of households by the total number of households producing gum arabic in the six villages and multiplying it by the sample size of the study area. Formula 5 was used for computation:

$$\text{Sample Size of RV} = \frac{RPS}{N}(n) \quad (5)$$

where RPS denotes the respondents' population size, N= total population size and n = sample size of the population.

Data collection method

The primary data were collected from a household survey using a structured questionnaire. The survey assessed farmers' different socioeconomic characteristics, including their perceptions, responses, and knowledge of climate change. In addition, parameters such as rainfall balance and temperature were assessed to show how climate changes have affected gum Talha production. During the surveys, farmers were asked whether the degree of temperature and rainfall amount had increased, decreased, or remained the same over the last 33 years. The explanatory variables were used to understand the factors that determine farmers' perception of climate change and variability, which are given in Table 10, and production data of gum Arabic were used as the dependent variable.

Data analysis

Household and historical meteorological data were used for statistical analysis of the farmers' perceptions of climate variability and climate change's impact on gum Talha production. Descriptive statistics were used to display frequencies, percentages, graphs, figures, and tables. Additionally, chi-square tests were used to compare the differences among groups for different socioeconomic and demographic variables, and regression analysis was used to determine factors that influence climate change perception through the Statistical Package for Social Study (SPSS) version 26.

RESULTS AND DISCUSSION

Demographic characteristics of respondents

The demographic characteristics of the respondents in the study area are indicated in Table 2. Most of the respondents (71.1%) were males, while 28.9% were female. The sampled households showed that 93% of respondents were married, 4% were single, and 3% were widowed. Regarding the age distribution of household heads, the majority (71%) of respondents had an age range from 40 to 59 years old. This showed that most of the respondents were still young and active. They may contribute significantly to gum production. Approximately 18% of the respondents were between 60 and 69 years old, and 11% were above 70 years old. Generally, the older respondents had a high perception of climate change because of their long experience in the region. According to age groups, adults (more than 70 years) in the study area would better understand climate change as opposed to the younger population. This is similar to the report by Gnanglé et al. (2012), who explained that the population at a young age does not have good knowledge of the perceptions of climate change because of their age.

Approximately 44.8% of the household heads interviewed were illiterate with no formal education, while 35.3% had *Khalwa* (can read and write), 13% and 6% were educated at basic and secondary school levels, respectively, while only 0.3% of the respondents graduated from university. A higher level of education may slightly translate into increased awareness of climate change as a real problem of immediate global concern; thus, this increases the likelihood that changes in agriculture practices will be attributed to climate change impacts. This study revealed that higher educational levels among farmers' access to climate information and extension services strongly influence and increase the perception of climate change and its impact on gum production. A higher level of education may slightly result in a greater

Table 2. Sociodemographic Characteristics of Respondents in the *Bahr Alarab* locality

Characteristics	Variables	Frequency	Per cent
Gender Composition	Male	278	71
	Female	113	29
	Total	391	100
Marital Status of Respondent	Single	16	04
	Married	363	93
	Widow	12	03
	Total	391	100
Distribution of Respondent ages group	40-49 year	135	35
	50-59 year	141	36
	60-69 year	71	18
	>70 year	44	11
	Total	391	100
Education levels	Illiterate	175	45
	Khalwa	138	35
	Primary school	50	13
	Secondary school	27	6.9
	University	1	0.3
	Total	391	100
Occupation Status of Respondent	Farmer	160	41
	Employee	20	5.1
	Trader	37	9.5
	Grazer/Herder	165	42
	Unemployed	9	2.3
	Total	391	100
Numbers of families	1-5 Person	195 (50)	50
	6-10 Person	147	38
	11-15 Person	39	10
	15>Person	10	02
	Total	391	100

Data source: Household survey data (2021).

Table 3. The current and past status of (*Acacia seyal* var. *seyal*) associated with other trees in the study area.

Species	Farmers' observation in			
	Past (1988)	%	Current (2020)	%
Acacia seyal (Gum Talha)	222	57	351	89.8
Balanites aeygtiaca (Laloub)	147	38	18	4.6
Acacia nilotica (Garad)	7	1.8	22	5.6
Other	15	3.5	00	00
Total	391	100	391	100

Data source: Author's computation from survey data (2021).

awareness of climate change as a real issue of global and immediate concern, thus increasing the likelihood that changes in farming practices are attributed to climate change.

Status of vegetation coverage in the study area

The farmer's perception about the past and status of vegetation covered in the study area is indicated in Table 3. The results showed that *A. seyal* associated with *Balanites aegyptiaca and Acacia nilotica* (*Acacias*) dominated the vegetation cover, while thorny and broad -leafed, nonthorny woody species were found to be more scattered. However, the current number and density of *Acacia seyal* trees in natural stands increased from 57% to 89.8%.

Meteorological data analysis

The temperature data from the *Bahar Alarab* locality in East Darfur State between 1988 and 2020 showed a warming trend over the last 32 years. Considering the annual maximum temperature, the highest (28.9°C) and lowest (27.9°C) values were recorded in 1990 and 2009, respectively, while for the annual minimum temperature, the lowest (27.1°C) and highest (27.3°C) values were recorded in 1989 and 1996, respectively (Fig. 2). Precipitation data were computed to obtain total annual rainfall variations for the period of 1988 to 2020. The annual precipitation in the *Bahar Alarab* locality in East Darfur State of western Sudan varied from 100 to 800 mm, with the highest and lowest values recorded in 1997 (790 mm) and 2015 (380 mm), respectively (Fig.

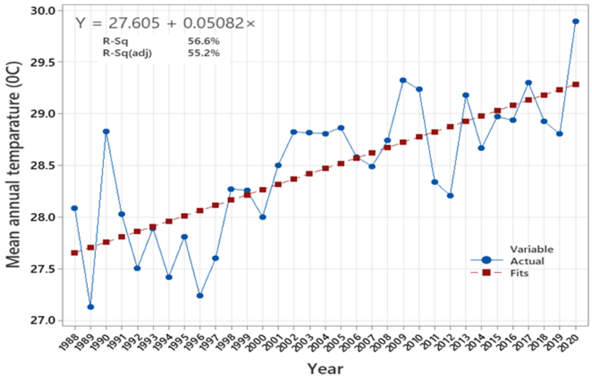

Fig. 2. *Trend of seasonal and annual temperature (°C) for the period 1988-2020.Source: Author's analysis (2021).*

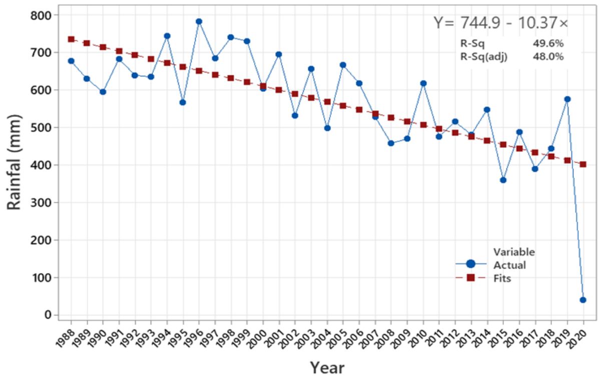

Fig. 3. *Rainfall (mm) for the period between 1988 and 2020, Source: Author analysis (2021)*

Table 4. Indicators of climate change on Gum *Talha* (*Acacia seyal var.* seyal) trees in the study area

Indicators of climate change	Frequency	Per cent (%)
Decline and Low production	95	24.3
Reduce in size of gum product	107	27.4
Felling and dying leaves	102	26.1
The infection of diseases and insects	87	22.3
Total	391	100.0

Data source: Author's computation from survey data (2021).

3). That is, the first season runs from December through February, the second season runs from March through May, the third season runs from June to August and the fourth season runs from September to November. The results showed a variation in the amount of annual seasonal precipitation received, with some years (e.g., 2008, 2009, 2012, 2014, 2015, 2017 and 2018) noticeably receiving lower than normal precipitation and other years receiving higher than normal precipitation (e.g., 1988, 1992, 1995, 1998, 1999, 2001, 2003, 2005 and 2010). The year 2015 was perceived to have had low levels of precipitation, probably because there was an uneven distribution of rainfall within the seasons. The third season from June to August, which is usually the most precipitation and better season for crop production, had low levels of precipitation. We conclude, therefore, that the community's perceptions of changes in precipitation are due to seasonal variations rather than the total amount of precipitation received in a year.

Response of the local community to climate change

The results in Fig. 4 show that most of the respondents per-ceived that there was long-term variability in temperature in the *Bahar ALarab* locality over the past three decades. The results indicated that the majority of the farmers (more than 69%) responded that they had experienced a change in climate with an increasing temperature. Additionally, more than 49.4% of the respondents reported a decrease in the pattern of rainfall amount and distribution in the main rainy season in recent years. Approximately 55.8% of respondents had experienced a high increase in wind intensity, while 28.6% and 15.6% of respondents had experienced a low and medium change in wind intensity, respectively. In the past three decades, the trend in humidity showed that large respondents (38%) had experienced high humidity, while 45% reported that humidity had decreased and 15% noticed that the humidity remained unchanged (Fig. 4).

Perception of climate change

The results revealed that 27.4% of respondents perceived a reduction in the amount of gum produced over

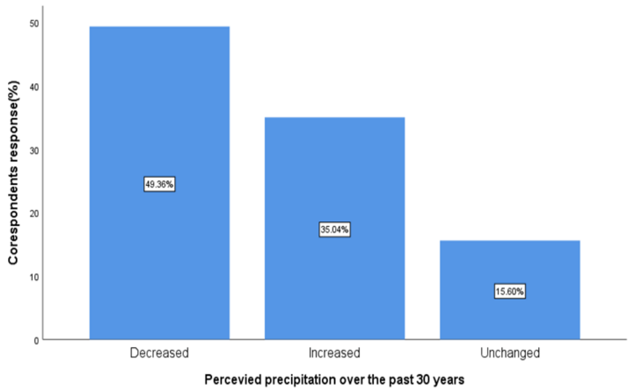

Fig. 4. *Forest farmers' perception of trends of the general temperature, rainfall, humidity, and wind change in this region over the past 30 years (1988 -2020), Data source: Author's computation from survey data (2021)*

Table 5. Potential impacts of temperature changes in the agricultural production study area

Potential impacts	Frequency	Per cent
Decrease in the productivity of gum Talha trees	78	19.9
An increase in the productivity of gum Talha tree	252	64.5
There is no impact on productivity	33	8.4
Decrease in soil fertility	2	0.5
Increase in soil fertility	3	0.8
Displacement	3	0.8
An increase in the productivity of crops	3	0.8
A decline in the productivity of crops	1	0.3
Change in biodiversity	16	4.1
Total	391	100.0

Data source: Author's computation from survey data (2021).

Table 6. Potential impacts of rainfall changes in the study area

Potential impacts	Frequency	Per cent
Decrease in the productivi-	182	46.5
An increase in the productivity of gum Talha trees	150	38.4
There is no impact on productivity	29	7.4
Decrease in soil fertility	2	0.5
Increase in soil fertility	1	0.3
Displacement	1	0.3
An increase in the productivity of crops	1	0.3
A decline in the productivity of crops	7	. 1.8
Change in biodiversity	18	4.6
Total	391	100.0

Data source: Author's computation from survey data (2021).

the last 10 years. Similarly, 26.1% indicated felling and dying leaves, while 22.3% reported decline and low production as an indicator of climate change. In contrast, 22.3% of the respondents perceived infection of diseases and insects as an indicator of climate change (Table 4).

Farmers' perceptions of the potential impacts of temperature change

Farmers responded that climate change has both positive and negative impacts on rural livelihood. Agriculture was the main practice in the study area, and more than 70% of people follow traditional cultivation practices that rely on seasonal rainfall. When respondents were asked about the potential impacts of temperature and rainfall change on gum Talha production (Table 5), they (64.5%) pointed out that one of the positive impacts in the increase in temperature was an increase in gum Talha production, while few of respondents (19%) attributed gum production failure due to temperature changes. In contrast, 8.4% responded that there was no impact on productivity, while 0.5% attributed a decrease in soil fertility to a change in temperature. Some respondents linked displacement (0.8%), an increase in productivity of crops (0.8%), a decline in productivity of crops (0.3%) and a change in biodiversity (4.1%) to change in temperature (Table 5).

Farmers' perceptions of the potential impacts of rainfall change

Most respondents (46.5%) reported that there were negative impacts of climate changes on gum Talha production, whereas 38.4% ascribed the change in rainfall to have caused an increase in productivity. Approximately 7.4% responded that rainfall change had no impact on productivity, while 0.3% linked to a change in rainfall to an increase in soil fertility, displacement and productivity of crops. The decline in productivity of crops (2%) and change in biodiversity (5%) were ascribed to changes in rainfall patterns (Table 6).

Farmers' perceptions of the potential impacts of wind speed changes

The potential impact of changing wind speed on Talha gum production showed that 62% experienced a decrease in the productivity of *Acacia seyal* trees, while 23.8% said there was an increase in Talha production. Few respondents (5.9%) indicated that a change in wind speed had no impact on their productivity. Moreover, soil fertility in terms of increase and decrease (5% and 8%) was influenced by the change in wind speed. Similarly, an increase (5%) and a decrease (3%) in crops were experienced because of a change in wind speed (Table 7).

Farmers' perceptions of the impacts of climate change on the study area

It was observed that 39.1% of the respondents started noticing the impact of climate change in the last five years, while only 18.2% have started noticing the change in climate impact for the past 30 years, as shown in Fig. 5. Many (18.7%) of the respondents claimed that climate change was noticed by an increase in temperature in the last 30 years (Table 8). Other respondents (16.1%) indicated that heavy late rainfall was the change that heralded the commencement of climate change in the past three decades. On the other hand, the occurrence of climatic phenomena was indicated by frequent dryness, as explained by 15.1% of the respondents. Some other respondents indicated light early rains (13.8%), heavy early rains (13.3%) and light late rain (13.0%) as indicators of the occurrence of climate change in the study area. Few respondents, however, implicated reduced temperature

Table 7. Potential impacts of wind speed changes in the study area.

Potential impacts	Frequency	Per cent
Decrease in the productiv-	243	62.1
An increase in the productivity of acacia trees	93	23.8
There is no impact on productivity	23	5.9
Decrease in soil fertility	2	0.5
Increase in soil fertility	3	0.8
Displacement	3	0.8
An increase in the productivity of crops	2	0.5
A decline in the productivity of crops	1	0.3
Change in biodiversity	21	5.4
Total	391	100.0

Data source: Author's computation from survey data (2021).

Table 8. Farmers' perceived change in rainfall over the past 30 years (1988 -2020)

Items	Frequency	Per cent
Heavy early rains	52	13.3
Light early rain	54	13.8
Heavy late rain	63	16.1
Light late rain	51	13.0
Frequent dryness	59	15.1
high temperature	73	18.7
Reduced temperature	12	3.1
Floods	2	.5
Wind erosion	10	2.6
Other	15	3.8
Total	391	100.0

Data source: Author's computation from survey data (2021).

(3.1%), wind erosion (2.6%) and floods (0.5%) as indicators of the occurrence of climate change in the study area (Table 8).

The majority of the respondents indicated that climate change harmed the growth of the acacia tree (54%) and its productivity (61%). In contrast, 29 and 24% of the respondents showed that the growth and productivity of acacia trees were positively affected, respectively. However, few respondents showed that climate change neither has a positive nor negative impact on the growth (17%) or productivity (15%) of acacia trees in the region (Table 9).

Factors influencing farmers' perceptions of climate change parameters

The multinomial logistic (MNL) model was used to analyse the determinants of farmers´ perception of climate change and variability. The MNL model aims to investigate the relationship between a nominal dependent variable (general increasing temperature and rate increases in precipitation) and a set of independent explicative variables that are either binary, nominal or continuous variables, as given in Table 10.

In this study (Table 10), gender, number of families, social status, and indicators of climate change on the acacia trees started noticing the climatic phenomena. The effect of climate change on the growth of acacia trees and education level did not significantly influence farmers' perception of climate change in the study area. It should be noted that the majority (45%) of the farmers had no formal education, with only 6.9% having a secondary education. However, the age group, the current state of acacia trees, and climatic phenomena over the past 30 years had a significant influence on farmers' perception of climate change in increasing temperature in the study area. Additionally, in the current state of acacia trees, climatic phenomena have occurred over the past 30 years, noticing climatic phenomena, and the effect of climate change on the growth of acacia trees has a significant influence on farmers' perception of climate change in increasing precipitation and the current state of acacia trees. Long-term changes in climate change over the last 30 years and the effect of climate change on the growth of acacia trees have a very significant influence on farmers' perception of climate change in increasing precipitation (Sofoluwe *et al.* 2011; Odewumi *et al*. 2013). The number of families has a significant impact on the increase in temperature by increasing the family's consumption of charcoal, firewood and building materials from trees as their member's increase, and this human activity in turn leads to the decline of trees. Through this study, we found that the number of family members was large in the study area. Studies have shown that many respondents' ages ranged from 40 to 59 years, and it is the most common age group that works on cutting trees in the study area for various purposes, including coal, firewood, building firewood and others. Thus, the continuous activity of this age group in cutting trees contributed to the increase in temperatures in the study area.

The study showed that the current condition of acacia trees is in a continuous deterioration because of climatic changes and excessive cutting of trees, which in turn influences increasing temperatures in an area of declining trees. According to the meteorological station in East Darfur and the observations of the local communities in the study area, there have been increases in temperature in the past thirty years. From the observations of societies, there is an increase in the productivity of acacia gum, and this increase is the result of increases in temperature. The results showed that the current state of acacia trees is a positive indicator of

Table 9. Farmers' perceived impact of climate change on the growth and productivity of acacia trees

Items	Growth of acacia trees	Productivity of acacia trees
Negative	209 (54)	238 (61)
Positive	115 (29)	94 (24)
There is none	67 (17)	59 (15)
Total	391 (100)	391 (100)

Data source: Author's computation from survey data (2021).

Table 10. Likelihood ratio tests of increasing temperature and general rate change of precipitation over the past 30 years (1988 – 2020)

Explicative variables	Dependent variables			
	Temperature increases		Precipitation increases	
	Chi-Square	Sig.	Chi-Square	Sig.
Gender	1.669	0.434	1.89	0.387
Group of Age	16.32	0.012*	6.01	0.423
Numbers of family	11.552	0.073	9.01	0.173
Education levels	8.818	0.358	7.49	0.484
Social status	5.49	0.241	6.6	0.159
Current state of acacia trees	12.722	0.013*	11.44	0.022*
Indicators of climate change on the acacia trees	6.435	0.376	4.54	0.603
Climatic phenomena occurred over the past 30 years	30.057	0.037*	15.90	0.001**
Start noticing the climatic phenomena	3.397	0.758	13.03	0.043*
Effect of CC on the growth of acacia trees	6.611	0.158	12.02	0.017*
Effect of CC on the productivity of acacia trees	27.127	0.001**	7.061	0.133

*: significant at the 0.05 cut-off; **: very significant at the 0.05 cut-off

the increase in rainfall rates in the study area, which in turn leads to the effect of climate change on the growth of acacia trees. The results of the logit regression suggest that the age group of farmers is also a good predictor associated with the farmers' perception of the continuous decrease and lack of change in the rainfall pattern, drought, flood, temperature and winds in Sudan. Indeed, older farmers have been exposed more to changes in the climate than younger farmers in the *Bahar ALarab* locality, Sudan; the result is in agreement with reported by Asrat and Simane (2018), Jin et al. (2020), and Fieroz-González et al. (2021) in Ethiopia, China, and Latin America regions respectively, but the findings contradict those reported by Nyang'au et al. (2021) in Kenya. The results highlighted that 80% of respondents were illiterate and Khalwa levels. Therefore, the lower educational level of farmers is also a good predictor associated with the farmers' perception of change in rainfall pattern, drought and flood occurrence, temperature, and winds in Sudan. As in Kenya Wetende *et al*. (2018) revealed that farmers' educational levels, access to climate information and extension services influence and increase the perception of climate change and its impact on gum production. Thus, better educated farmers perceived climate change to be more likely than no educated farmers.

From Table 11, the results indicated that farmers are aware of climate change, but only 69.3% took increasing temperatures as indicators of climate change. The study also revealed farmers' perception of climate change response that numbers of families, the disappearance of the past dominant tree, climatic phenomena occurring over the past 30 years, the effect of climate change on the growth of acacia trees and the effect of climate change on the productivity of acacia trees all have significant impacts as a result of the large increasing temperature. Gender, level of education, age group, social status, current state of acacia trees, current dominant tree, indicators of climate change on the acacia trees and start noticing the climatic phenomena did not significantly influence farmers' perception of increasing temperature over the past 30 years.

Consequently, government policies that aim to promote adaptation strategies to climate change need to consider these factors to enhance the chances of farmers adopting measures to minimize the adverse effects of climate change on *Acacia seyal* (Gum Talha) production (Hameso, 2018). It is essential for the government

Table 11. Multinomial logistic regression model of farmers' perception of increasing temperature over the past 30 years (1988 – 2020).

Predictor variables	OR	Coef	SEc	Z	P>z	95% CI	
						Lower	Upper
Constant		6.63	1.96	3.39	0.001		
Gender	0.78	-0.25	0.37	-0.67	0.505	0.38	1.61
Group of Age	1.43	0.36	0.22	1.59	0.111	0.92	2.21
Numbers of family	0.51	-0.67	0.29	-2.3	0.022*	0.29	0.91
Education levels	0.93	-0.07	0.18	-0.37	0.711	0.65	1.34
Social status	1.39	0.33	0.60	0.55	0.58	0.43	4.54
Current state of acacia trees	0.69	-0.37	0.28	-1.29	0.197	0.4	1.21
Indicators of climate change on the acacia trees	1.05	0.05	0.16	0.31	0.754	0.77	1.43
CC occurred over the past 30 years	0.89	-0.12	0.06	-1.86	0.063*	0.78	1.01
Start noticing the climatic phenomena	1.07	0.07	0.15	0.44	0.664	0.8	1.43
Effect of CC on the growth of acacia trees	0.58	-0.54	0.21	-2.56	0.011*	0.39	0.88
Effect of CC on the productivity of acacia trees	0.61	-0.50	0.21	-2.41	0.016*	0.4	0.91

where Prob> Chi-Square= 0.0001, Chi-Square = 139.5, -2Log Likelihood = 505.7, Pseudo R-Square= 0.37, RO= Odds Ratio, Coef= Coefficient, SEc= Standard error Coefficient, CI= confidence interval, CC= Climate Change

Table 12. Multinomial logistic regression model of determinates of farmers' perception of general rate change in precipitation over the past 30 years (1988 – 2020).

Predictor variables	OR	Coef.	Sec	Z	P>z	95% CI	
						Lower	Upper
Constant		8.60	1.99	4.32	0.00		
Gender	0.78	-0.25	0.37	-0.69	0.49	0.38	1.60
Group of Age	0.80	-0.22	0.23	-0.97	0.33	0.51	1.25
Numbers of family	1.45	0.37	0.31	1.19	0.23	0.79	2.68
Education levels	1.27	0.24	0.19	1.29	0.20	0.88	1.83
Social status	0.39	-0.94	0.65	-1.45	0.15	0.11	1.39
Current state of acacia trees	0.50	-0.70	0.29	-2.44	0.02	0.28	0.87
Indicators of climate change on the acacia trees	0.86	-0.15	0.16	-0.98	0.33	0.63	1.16
CC occurred over the past 30 years	0.90	-0.11	0.07	-1.56	0.12*	0.78	1.03
Start noticing the climatic phenomena	0.88	-0.13	0.15	-0.84	0.40	0.65	1.19
Effect of CC on the growth of acacia trees	0.61	-0.49	0.22	-2.24	0.03*	0.40	0.94
Effect of CC on the productivity of acacia trees	1.26	0.23	0.23	1.01	0.31*	0.81	1.96

where Prob> Chi-Square= 0.0001, Chi-Square = 136.2, -2Log Likelihood = 650.3, Pseudo R-Square= 0.34, RO= Odds Ratio, Coef = Coefficient, SEc= Standard error Coefficient, CI= confidence interval, CC= Climate

of Sudan to ensure that terms for credit facilities are flexible to enhance farmers' access to credit, which will in turn increase their ability to change tree management strategies and reduce tree consumption in response to climate change. Additionally, the disappearance of the previous dominant tree is addressed through the planting of more trees and the issuance of legislation prohibiting the cutting of acacia trees with the use of environmentally friendly energy alternatives (Suleiman, 2012). We also need studies and research on the climatic phenomena of previous periods and predictions of future studies of these phenomena to contribute to and assist the government of Sudan in setting development plans. The study concluded that the increase in temperature has a positive effect on the growth and productivity of acacia gum and a negative effect on the growth of acacia trees. This is due to water loss and drought and thus leads to the death of trees. Given the inadequacy of the extension services in the region, training of more extension officers and improving the knowledge and skills of existing extension officers on climate change and adaptation strategies should be of high priority. Increasing the extension -farmer ratio and making extension services more accessible to farmers appear to be key components of the successful dissemination of adaptation strategies in this

Bahar ALarab locality, Sudan.

From Table 12, the results of multinomial logit regressions show that group of age, numbers of families, education levels, and social status are the main factors significantly influencing farmers' perception of climate change of the change rate in precipitation over the past 30 years in the study area. Similarly, the effect of climate on the growth of acacia trees and the productivity of acacia trees was highly significant in response to the change rate in precipitation over 30 years in the *Bahar Alarab* locality, East Darfur State, Sudan. Additionally, the results suggested that local farmers´ perceptions are shaped by both internal (i.e., experience in agriculture, male (gender), ethnic minority group (ethnicity), and poor household (household condition)) and external factors (i.e., distance to market, climate information, and agro-ecological zone). The results of multinomial logit regression show that age, sex, marital status, household size, and education level are the main factors significantly influencing farmers' perception of climate change in the study area. This result is consistent often with the fact that the sociodemographic characteristics influence farmers' perception of climate change as reported by whom, please indicate the authors who supported this argument.

This result is consistent with the fact that sociodemographic characteristics influence farmers' perception of climate change, as reported by previous authors (Kapoury *et al.* 2016; Ayanwuyi et al. 2010; Agwu *et al.* 2018; Olayemi 2012; Sahu and Mishra 2013). This result is, however, in contradiction to the findings of Odewumi *et al.* (2013), who found no influence of any of the explanatory variables (age, education level, and gender) on farmers' perception of climate change. The findings show that farmers are well aware of climate change and its effects, such as changes in rainfall patterns, frequent droughts and floods, increases in temperature, and stronger winds; the results validated those reported by Kapoury *et al.* (2016). They studied farmers' perception of climate change in southern Mali and reported increases in the frequency of strong wind, dust, drought, high temperatures, and number of hot days as the main climate change-related indicators and an early cessation of the rainy season, frequent drought, and wind as the factors impeding a better delivery of the ecosystem services from the parklands. Similar findings were reported by Limantol et al. (2016), Mihiretu et al. (2020), and Mainuddin et al. (2022) in Chana, Ethiopia, Bangladesh regions respectively. The results also agree with Arbuckle et al. (2015) in USA, who reported that high temperatures are often associated with drought, while an increase in temperature is expected to reduce crop yields and increase levels of food insecurity in Nigeria (Agwu, et al. 2018). A chi-square analysis showed no significant difference in farmers' perceptions about climate change between the study areas, indicating that their knowledge might be similar. This agrees with Odewumi et al. (2013) in Nigeria, who observed no significant difference in farmers' perceptions of climate change in the study area.

Conclusion

The perceptions of local communities on climate change and variability were consistent with the analysed historical climate data. The results highlighted that the high fluctuation in the rainfall patterns had an increasing uncertainty in rainfall. The results revealed that the perception of most farmers was the existence of an increasing pattern in temperature and a decreasing pattern in precipitation in the study area for the past 30 years. Furthermore, it had a great influence on collection practices and the total production yield of gum Talha in the *Bahar Alarab* locality, East Darfur State, Sudan. The study indicated that the increase in temperature had a positive effect on the growth and productivity of acacia gum and a negative effect on the growth of acacia trees. Finally, from these findings, we concluded that the impacts of climate change on gum production in *Bahar Alarab* Locality in East Darfur State are negatively affected. Based on the results, it is recommended that the empowerment of communities through information, technology skills, education and employment be the best way to address vulnerability. Furthermore, the creation of capacity building and awareness programmes will support the climate change adaptation process, especially in rural communities, as well as the establishment of structured climate change information and early warning systems to better support these vulnerable communities.

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Conflict of interest

The authors declare that they have no conflict of interest.

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