atmosphere

MDPI

Article

Dynamics and Determinants of Farmers' Perceptions about Causes and Impacts of Climate Change on Agriculture in Saudi Arabia: Implications for Adaptation, Mitigation, and Sustainability

Bader Alhafi Alotaibi [1,*], Azhar Abbas [2,*], Raza Ullah [2], Muhammad Imran Azeem [1], Abdus Samie [2], Muhammad Muddassir [1], Abduaziz Thabet Dabiah [1], Moodhi Raid [3] and Tahira Sadaf [2]

1 Department of Agricultural Extension and Rural Society, College of Food and Agriculture Sciences, King Saud University, Riyadh 11451, Saudi Arabia
2 Institute of Agricultural and Resource Economics, University of Agriculture, Faisalabad 38040, Pakistan
3 Faculty of Business Studies, Arab Open University, Riyadh 11681, Saudi Arabia
* Correspondence: balhafi@ksu.edu.sa (B.A.A.); azhar.abbas@uaf.edu.pk (A.A.); Tel.: +966-504240201 (B.A.A.)

Abstract: Concerns over the potential harmful impacts of changing climate are strongly echoing around the globe. With its wide range of hazards to human societies, climate change is posing serious threats to human survival and impacting every aspect of human life, including food production systems. It is, therefore, imperative to gauge the local knowledge, perceptions, and adaptation capacity for the effective mitigation of the ill impacts of climate change. In this backdrop, the present study has been designed to investigate the perceptions of farmers regarding causes and impacts of climate change on agriculture. Required data were collected from the Madinah region in Saudi Arabia and analyzed to answer the following study questions: How do farmers perceive impacts of climate change? What factors affect their perceived impacts of climate change? Additionally, what factors affect their perception about the causes of climate change? Individual logit models were used to assess the impacts of various factors on perceived causes and perceived impacts of climate change on agriculture. A multinomial logit model was also employed to figure out significant determinants of perceived causes of climate change on agriculture. Results indicated that the most dominant perceived impacts of climate change are its effects on crop production, followed by drying water sources. The results also revealed that the age of the farmers had a positive effect on their perception of natural processes being the cause of climate change. Similarly, farming experience had an inverse effect on their perceptions regarding causes of climate change. The majority of the farmers seemed clear about the possible drivers of climate change in the country. In particular, about 79 percent of the farmers believed that GHGs and pollution are causing climate change in the country. The findings provide useful insights into farmers' perceptions about causes and impacts of climate change and may be used by policymakers to strategically design extension and agricultural development initiatives for helping the farmers to implement sustainable agricultural practices to adapt to and lower the adverse impacts of climate change in the Kingdom.

Keywords: vulnerability; resilience; sustainable agriculture; rural development; Saudi Arabia

check for updates

Citation: Alotaibi, B.A.; Abbas, A.; Ullah, R.; Azeem, M.I.; Samie, A.; Muddassir, M.; Dabiah, A.T.; Raid, M.; Sadaf, T. Dynamics and Determinants of Farmers' Perceptions about Causes and Impacts of Climate Change on Agriculture in Saudi Arabia: Implications for Adaptation, Mitigation, and Sustainability. *Atmosphere* **2023**, *14*, 917. https://doi.org/10.3390/atmos14060917

Academic Editor: Muhammad Habib ur Rahman

Received: 23 April 2023
Revised: 18 May 2023
Accepted: 22 May 2023
Published: 24 May 2023

1. Introduction

With profound regional and global implications, climate change is affecting almost every country and every sector, particularly developing countries, having compromised coping capacity [1,2]. Every continent on the planet has already been witnessing its adverse impacts [3], and it is acknowledged as one of the biggest threats to the world economies and societies in the coming decades [4,5]. Since the beginning of the twentieth century, there has been a rise of 1.1 °C in the mean global surface temperature [6]. It is further anticipated that global mean surface temperature could go up by 1.4 to 5.8 °C at the end of the century, which may intensify suffering, as well as impacts thereafter [7,8]. Moreover, there is increased likelihood of wider shifts in the frequency, intensity, and impact severity of extreme climatic and weather events, viz., drought, flooding, storms, and heat waves [2,9–11]. The prime and foremost basis for the ongoing climate change is believed to be anthropogenic greenhouse gas emission, mainly due to fossil fuel burning, as well as agriculture and land-use changes [2,12–14]. Our ability to realize Sustainable Development Goals (SDGs) is also considerably affected by, *inter alia*, climatic variability. In addition, it has a great potential to seriously undermine various sustainable development goals. Out of the 17 SDGs, climate change can undermine around 16 of the goals. Therefore, combating climate change is not only a priority, but also one of the key United Nations' SDGs [2,15]. SDG 13 exclusively focuses on all the efforts to combat climate change and encourages all the nations to undertake practical measures in order to lower GHG emissions.

Agriculture is not only a prime sector affected by climate extremes, but, at the same time, it is a big contributor towards climate change [16,17]. Subsequently, food security at the global level is highly at stake due to disturbed and vulnerable agricultural production in a wide range of agro-ecological zones and regions [1,8,18–21]. Many regions of the world are anticipated to experience a decrease in crop productivity for both irrigated and rain-fed agriculture, owing to global warming and other extreme weather events, such as drought and intense rainfall [22–26]. All major staple food crops, such as wheat, rice, maize, and soybean, are negatively affected by increases in temperatures and rainfall extremes [27]. The potential impacts of both abiotic and biotic stresses may be escalated in the wake of climatic changes [28]. Similarly, soil erosion would likely increase, which will further reduce land productivity [29,30] and undermine the efforts to achieve the goals and targets set in SDG 2 (zero hunger).

Moreover, global warming can enhance the incidence of insects, pests, invasive species, weeds, and diseases [31]. An analysis of the agricultural data published by FAO (Food and Agriculture Organization) suggests a 20–30% decrease in the yields of major cereals crops, such as rice, wheat, and maize, by the end of 2100 if there is a persistently rising trend in GHG emissions and climatic variability, as has been observed in recent years and validated through historical data [32]. It would be difficult to sustain the current levels of farm and livestock productivity in the wake of excessive changes in weather and climate indicators, such as temperature, humidity, and precipitation [33]. Furthermore, water scarcity could become intensified in several parts of the world, causing significant losses to the national economies and ecosystems [34]. At a predicted increase in global temperature of 2 °C, a significant number of people in the world (around 540–590 million) will become undernourished [35]. Many vulnerable regions, facing increased levels of poverty and food insecurity, and where agriculture is an indispensable part of the economy, are likely to suffer severe losses [36,37]. On the other hand, agriculture, forestry, and other land uses collectively contribute about 24–30% of the total global Greenhouse Gas (GHG) emissions [38,39]. Therefore, adoption of sustainable agricultural practices that aim to reduce GHG emissions would be highly useful because of their role in climate change mitigation and adaptation.

Saudi Arabia has an arid climate [7,40–42]. In some parts of the country, temperature can rise even above 50 °C. The country receives extremely low precipitation, with a long-term mean annual rainfall of around 100 mm. In some western parts of the Kingdom, however, rainfall can sometimes rise above 500 mm per annum [7]. Intense rainfall events are also rare, and there are no permanent rivers [42,43]. The United Nations classifies it as a water-scarce nation [44], whereas, according to the Water Resources Institute, the Kingdom will be at the 9th position in the list of water-stressed nations by 2040 [45]. Climate-induced water scarcity makes the region more vulnerable to the harsh impacts of climatic changes [46]. The last five decades saw a significant variation in the climatic conditions, leaving adverse impacts on the countries in the region, particularly in water-deficient Saudi Arabia [47]. Studies reported a 1.9 °C increase in mean surface temperature during the last five decades [44,47], while Gosling [40] reported that the summer temperature in the Kingdom increased by 2.058 °C, whereas winter temperature increased by 0.88 °C. The rate of warming was 50% higher than the rest of the landmasses in the Northern Hemisphere [48]. This future scenario is also alarming. Several studies predict that, by the end of this century, there may be a 2–4 °C increase in mean surface temperature in Saudi Arabia [40,49,50]. Such an increase in temperature would challenge both the suitability and sustainability of agriculture in the Kingdom [42,51]. It will considerably increase irrigation water requirements, and around a 5–25% decrease in yields of various crops will be observed with just 1 °C increase in temperature [47,50,52]. In terms of precipitation, significant changes were not observed during the last 50 years [47]. However, a decline in rainfall in many parts of the country is predicted [40,53]. In the future, date palm production may significantly decline, which is a major crop in Saudi Arabia. Water scarcity will significantly affect agricultural crop production, as it is the largest consumer of water [47,51,54]. Decrease in local food production will not only increase domestic food prices, but it will also force the country towards increased food imports, ultimately making it dependent on other nations for its food security [55]. Keeping in view these future scenarios, the country has been striving hard to actively pursue various measures and strategies for the mitigation of climate changes and its effects, along with designing specific adaptation interventions [47]. In a similar vein, the Kingdom has made itself aware of the potential threats linked with excessive and rapid changes taking place in relation to weather and climate, whereby the country has a strong intent for engaging in the development of remedial actions. Moreover, there are concerted efforts going on with regards to the planning and policy front, in accordance with the Kingdom's efforts toward economic sustainability and diversification. Such an economic agenda, vis-à-vis, climate change mitigation, is highly instrumental in creating a window of opportunity to address the pressing issues of climate change vulnerability, coping capacity, and livelihood sustenance with potential co-benefits for economic resilience, political stability, employment generation, public health, and energy security [56].

The drive towards an overarching approach towards an effective adaptation mechanism among the farming community would emphasize awareness of the issue at the grass root level. Moreover, such an effort is also needed to sensitize other stakeholders, such as politicians, policy planners, extension agents, and scientists, for developing and promoting tools and strategies to ensure sustainable agriculture at the local and national levels for effectively addressing climate change issues. Nevertheless, there is a tendency of varying levels of perception about the prevailing issues, such as climate change, among farmers who would behave differently in similar situations, mainly due to variations in their respective socioeconomic characteristics, demographic profiles, and life experiences, that would, in turn, shape their ability to adopt and implement adaptation measures for building resilience against undesirable climatic events, such as drought, floods, heat waves, etc. [57]. Hence, it is highly important to anticipate and accordingly plan in relation to the nature of expected changes, based on the understanding of the stakeholders, such as farmers, as to how they perceive, experience, and interpret climatic changes and related impacts [58,59]. The perceptions of the local stakeholders would mainly stem from their daily interactions with and experiences of the environment [60]; henceforth, delving on the localized nature of issues [61], including the actual impacts of climate change and its related hazards on the lives of local people, is important for developing an understanding of the climate change phenomenon [58]. Owing to their high vulnerability to the adverse impacts of climate change and limited arable land and water resources, agricultural production and food security in the Kingdom will be seriously compromised if farmers and growers fail to implement appropriate adaptation measures for sustaining production and enhancing resilience of the local food production system [62]. Understanding farmers' views about the causes of ongoing climate change and their perceptions regarding impacts of climate change on agriculture are basic steps in assessing their level of knowledge about climate change and their efforts to address the issue. In the recent past, a study [63] was conducted in the Jazan region to identify farmers' beliefs about climate change and their concerns about its ill impacts on agriculture. The current study has been designed to analyze farmers' perception of the causes and impacts of climate change on the agriculture sector in the Madinah region of Saudi Arabia.

2. Methodology

2.1. Study Area

The universe of this study was the Madinah Region in Saudi Arabia, being a major hotspot, both in terms of religious tourism and commercial activism, but, at the same time, one of the highly vulnerable regions of the country to climate change [64]. The Madinah Region is situated on the western side of the country, along the Red Sea coast. As shown in Figure 1, this region lies between latitude 23°00′ to 26°00′ North and longitude 39°00′ to 44°00′ East. It covers an area of 151,990 km^2 [65]. Administratively, there are seven Governorates of the Madinah Region, namely, Madinah, Mahd Al Thahab, Al Hunakiyah, Badr, Al-'Ula, Khaybar, and Yanbu Al Bahar. The Madinah region contributed about 15% of total date production, with 4.7 million date palm trees that cover nearly 18,000 hectares and produced 1416.0 tons of grain crops, with a cultivated area of 3607.1 (1000 sq miles) [66]. It also produces barley, wheat, clover, open field vegetables, watermelons, tomatoes, potatoes, and greenhouse vegetables, including cucumber, tomatoes, cut flowers, olive, ever green trees, and grapes [66]. The average monthly temperature ranges between 16 °C to 33 °C, and the highest temperature of 49 °C is recorded in July, and the lowest temperature of 1 °C is recorded in January. Relative humidity in the region in summer has been observed to be below 20%, while it is above 40% during winter [65]. Groundwater is the major source of water in Madinah. Agricultural activities around the Madinah region are thought to be a cause of water scarcity in the area due to extensive groundwater pumping [67].

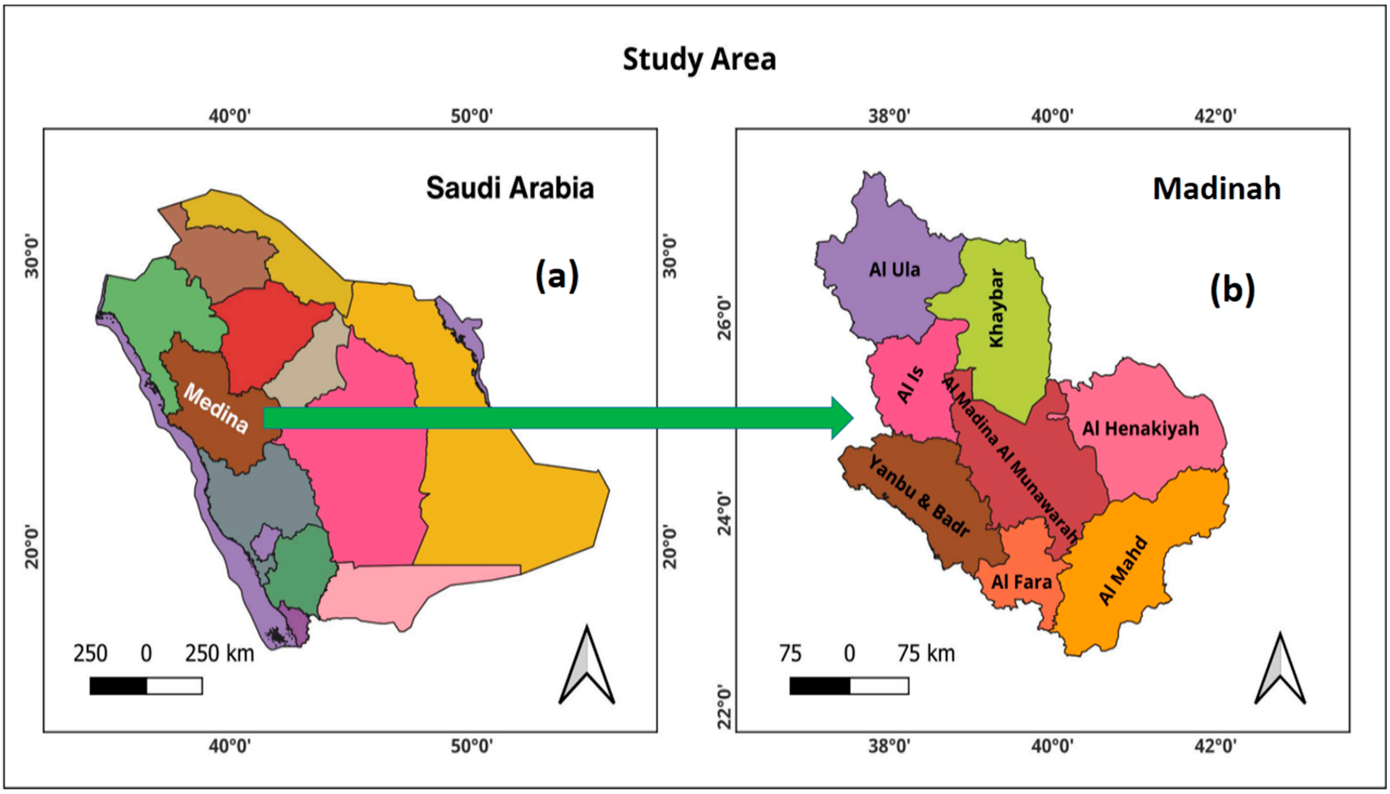

Figure 1. Map of the study area (**a**) Map of Saudi Arabia (**b**) Map of Madinah Region with different Governorates.

Looking at the long-term environmental data, the mean annual temperature of Madinah during the period 1959–2011 was 28.3 °C, while the mean annual precipitation during the same period has been recorded at 36.2 mm/year. The mean maximum temperature of the region is around 34 °C, while the mean minimum is 21 °C. In addition, there has been an increase of 1.7 °C mean monthly temperature, with a 1.2 °C increase in maximum temperature and decrease of −1.9 °C in minimum temperature [68].

2.2. Survey Method and Data Collection

Farmers' perceptions on causes and potential impacts of climate change on agricultural productivity were recorded from sampled farmers in the Madinah Region using a structured questionnaire. Five governorates (Madinah, Badr, Mahd Al Hunakiyah, Khaybar, and Al-'Ula), with a total population of 3491 farmers, were randomly selected to represent the region.

A sample of 150 respondents was selected for participation in the study. However, only 123 farmers completed the questionnaires, resulting in an 82% response rate. Face-to-face interviews, using a structured questionnaire, were conducted with the farmers. The entire data collection lasted for around 10 weeks, from April to June 2022. The farmers' data within each governorate in the Madinah region were purposively selected with the help of the National Center for Vegetation Cover Development and Combating Desertification and governorate representatives. The sample consists of 45% of the farmers in the Madinah and Badr governorates; 17% from the governorate of Mahd Al Thahab; 13% from the governorate of Al Hunakiyah; 16% from the governorate of Khaybar; and 5% from the governorate of Al-'Ula.

The questionnaire contained four different sections. The first section was comprised of farmers' personal socioeconomic and demographic characteristics, such as age, household income, farm size, land ownership (rented or owned), farming experience, household head's educational level, and soil fertility of the farm. The second section contained questions about the elicitation of the farmers' response towards statements documenting their perceptions/beliefs about the farm-level impacts of climate change. In a similar vein, the third section documented the respondent farmers' response on the causes of climate change, while the final section was about adaptation practices employed by the farmers to combat the adverse impacts of climate change in agriculture.

2.3. Data Analysis

2.3.1. Logit Model

The collected data were analyzed using logit models for the three prominent perceived causes of climate change identified during surveys. A separate logit model was employed for each of the selected perceived causes of climate change (natural process, deforestation, and urbanization), using a set of independent variables (age, farming experience, education, income, farm size, and land ownership). The individual logit models were also estimated in case of the factors affecting the perceived impacts of climate change. A general form of the logit model is provided as follow:

$$\log of\ Odds\ (Y_i) = \beta_0 + \sum \beta_i X_i + \varepsilon_i \quad (1)$$

where; Y_i is the dependent variable for the ith respondent (where i = 1, 2, 3 ... 123); β_0 is a constant term; ΣX_i is the set of observed variables; β_i are the parameters to be estimated; and ε_i are the error terms. The term log of odds is the log of probability of an event happening. Here, this is the presence of a cause of climate change to the corresponding odds, i.e.,

$$logit\ (p) = log\left(\frac{p}{1-p}\right) \quad (2)$$

2.3.2. Multinomial Logit Model

A multinomial logit model is also used to assess the impacts of a set of observed variables on various combinations of the perceived causes of climate change. In the case of the multinomial logit model, the choice set is the possible combination of mutually exclusive and collected exhaustive categories of perceived causes of climate change [69]. In the present study, there are three selected perceived causes of climate change, which make eight possible combinations (2^3) that a respondent can choose from: (1) no cause of climate change (select none of the combination of perceived climate change causes), (2) natural process only, (3) deforestation only, (4) urbanization only, (5) natural process, as well as deforestation, (6) natural process and urbanization, (7) deforestation and urbanization, and (8) all three causes. Given this choice set, a multinomial logit model can be specified as follows:

$$Y_i = x_i'\beta + \varepsilon_i, \qquad \varepsilon_i \simeq MVN\ (0,\ \Sigma) \tag{3}$$

Y_i in Equation (3) represents the combinations of perceived causes of climate change (Y_i = 1, . . . , m, in this case m = 8) that the ith respondent (i = 1, . . . , n, where n represents the total number of respondents which is 123) chooses; x_i' is a 1 × K vector of observed variables that affects their choices of combination; β is a k × 1 vector of unknown parameters (to be estimated); and ε_i is the unobserved error term. The unobserved error term in this case is assumed to be multivariate normally distributed (MVN), with zero mean and possessing a variance–covariance matrix (also known as a covariance matrix) equal to Σ, which is obtained by associating the variances and covariances of the observed variables in a square matrix.

3. Findings

This section provides results of the data analysis, based on descriptive, as well as inferential analysis. The general findings related to trends and tendency among farmers compare various dynamics of socioeconomic features in relation to causes and impacts of climate change in the Madinah Region. A complete report on the statistical findings, vis-à-vis, perceived causes and perceived impacts of climate change, have been provided for the intuitive understanding and policy implications for development and research.

3.1. Perceived Impacts of Climate Change

The findings in Table 1 reveal that the most dominant perceived impacts of climate change are its effect on crop production and increasing temperature, followed by drying of the water resources. Changes in the rainfall pattern have been ranked as the 3rd most dominant perceived consequence of climate change, while the drought, as a result of changes in the rainfall pattern, has been ranked as the 4th most dominant perceived consequence of climate change in the study area. A similar pattern of perception has been reported by previous studies performed in the region by [42,63]. The dominant perceived consequences of climate change, namely, climate change effect on crop production, increase in temperature, drying of the water resources, and changes in rainfall pattern changes, are considered for further analysis, and individual logit models are employed to assess the impacts of various farm and farmers' characteristics on their perceptions of climate change.

Several studies have reported negative impacts of climate change on agricultural production and water supplies in the Kingdom [51,70,71]. The analysis of meteorological data suggests that no considerable changes in precipitation have been observed over the period of the last five decades [47]. However, significant changes in temperature have been observed for the same time period; there has been a 1.9 °C increase in average temperature [44,47]. Farmers' worries may seem right, as future projections suggest a further increase in temperature and a decrease in rainfall. Several studies predict that, by the end of 2100, there will be a 2–4 °C increase in temperature in the Kingdom due to ongoing climate change [40,49,50]. There will also be a decline in rainfall across many parts of Saudi Arabia (Gosling [40,53]). An increase in temperature will significantly affect agricultural production by increasing irrigation water requirements for different crops grown in the Kingdom [52], and the problem would be further exacerbated amid water scarcity [46].

Table 1. Perceived Impacts of Climate Change.

Variables	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Cumulative Frequency	Ranking
Climate change affecting crop production	0	0	2	70	51	541	1
Drying water sources	0	0	3	70	50	539	2
Temperature is increasing	0	0	2	70	51	541	1
Rainfall pattern changes	0	0	11	61	51	532	3
New crop diseases appeared	40	7	34	14	28	352	10
Climate change increases seasonal flood	40	8	46	20	9	319	12
Climate change cause drought	0	0	11	64	48	529	4
Delay seeding	0	0	11	81	31	512	6
Delay crop maturity	0	0	19	94	10	483	9
Increasing windstorm	0	1	15	63	44	519	5
Risky for human health	0	8	12	72	31	495	7
Risky for animal health	0	8	15	75	25	486	8
Increase in sea level	11	15	89	2	6	346	11

The other consequences of climate change, as perceived by the respondents, do have their intensity, but they are regarded to be less severe in comparison with the first four ranked consequences. More interestingly, there is a greater scope of in-depth analysis regarding the consequences of impacts on health, both for animals and humans. These consequences, being down the ladder, are indicative of better health infrastructure for human health, while animal health is definitely at stake. However, livestock are not a major source of farm earnings in the country [47]. The intensity of increased windstorms lies in the fifth position, having some weaker to mild consequences for agricultural growth in the country [72–74].

The findings of the logit models related to various factors, affecting perceived impacts of climate change in the study area, are provided in Table 2. Based on the nature of collected data on the perceived impacts of climate change, the study selected the four top-ranked impacts out of the total 12 various types of such impacts, as given in Table 1. In the case of factors affecting farmers' perceptions of climate change affecting crop production, various factors have a varying level of impact, as given in the second column of Table 2. The major factors affecting perceived impacts of climate change on crop production include education of the sampled respondents, which has a significant inverse relationship with the farmers' perceptions of climate change, affecting crop production. The negative sign shows that farmers with lower levels of education tend to perceive climate change as a higher threat to their crop production compared to farmers with a higher level of education. Such a type of relation of education with perceived impacts of climate change on crop production is widely reported both in case of the selected region and elsewhere in the world, such as the results highlighted by [57,75–77].

The negative and significant impact of education on perceived climate change impacts has a very practical intuition regarding the manner in which farmers that have higher education can strive to keep themselves abreast of the current dynamics of climate change and, hence, would be highly prepared to face it instead of panicking or resorting to wait-and-see [78,79]. Similarly, income of the sampled respondents also showed a significant and negative effect on farmers' perceptions of climate change affecting crop production. The finding on income has a greater support from the literature and is intuitively relevant, as farmers with lower incomes would consider climate change as a threat to their farm production compared to farmers with higher incomes, and, hence, they would be under a greater risk of damage from any climatic extreme or disaster [80,81]. Higher income represents a bigger asset base to draw resources in times of need and, consequently, lowers the risks of crop failure. On the other hand, loans have a positive and significant effect on farmers' perceptions of climate change affecting crop production. The need for higher loan acquisition reflects lower resources owned by the farmers to cope with the adverse impacts of climate change at the farm level.

Table 2. Factors affecting perceived impacts of climate change.

Variables	Climate Change Affecting Crop Production	Temperature Is Increasing	Drying Water Sources	Rainfall Pattern Changes
	Coeff. (S.E)	Coeff. (S.E)	Coeff. (S.E)	Coeff. (S.E)
Age	0.029 (0.032)	0.023 (0.031)	0.018 (0.030)	0.028 (0.027)
Experience	0.069 (0.044)	0.091 ** (0.043)	0.050 (0.041)	0.033 (0.036)
Education	−0.403 * (0.238)	−0.669 *** (0.242)	−0.416 * (0.224)	0.097 (0.204)
Income	−0.782 *** (0.262)	−0.681 ** (0.263)	−0.616 ** (0.245)	−0.666 *** (0.233)
Farm Size	0.070 (0.053)	0.066 (0.051)	0.075 (0.056)	0.090 (0.058)
Land Ownership	−0.555 (1.474)	0.043 (1.269)	−0.362 (1.296)	1.787 * (0.995)
Loan	2.695 *** (0.859)	1.806 ** (0.704)	2.227 *** (0.733)	2.411 *** (0.659)
Soil Fertility	−0.392 (0.275)	−0.544 ** (0.273)	−0.430 * (0.258)	−0.492 ** (0.231)
Cut 1	−5.782 (2.525)	−6.599 (2.405)	−5.631 (2.302)	0.109 (1.874)
Cut 2	1.151 (2.374)	−0.064 (2.190)	0.314 (2.186)	4.452 (1.975)
Log Likelihood	−56.895	−59.519	−63.989	−78.847
LR Chi2 (8)	71.40 ***	66.15 ***	63.23 ***	70.78 ***
Pseudo R^2	0.385	0.357	0.331	0.310

Note: Standard errors are in parenthesis. *, **, and *** represent statistical significance at 10%, 5%, and 1%, respectively.

In the equation for perceived impacts of climate change related to rise in temperature, the variable on farming experience and loans has a significant positive relationship, while education, income, and soil fertility have a significant negative relationship. Farmers with more farming experience can observe an increase in temperature over the years, which is reflected in their perceptions regarding climate change. Similarly, loan acquisition reflects that the farm owner has a lower resource base of their own and tends to rely on external sources to finance their farming activities. The lack of resources makes them vulnerable to uncertain events arising from climate change, and, therefore, their perceptions regarding climatic parameters, such as temperature, are high [82,83]. On the contrary, the impacts of education on respondents' perceptions regarding increase in temperature due to climate change reveal that farmers with higher levels of education are less threatened by the vagaries of nature and put in place necessary mitigation measures to avoid adverse impacts arising from climate-induced adverse events. Higher incomes also facilitate farmers to adopt adequate protective measures to combat climate shocks and to avoid uncertain and adverse events.

The findings presented in the 3rd and 4th columns of Table 2 portray covariates of perceived impacts of climate change related to 'drying water sources' and 'changes in rainfall patterns', respectively. The factors influencing such perception of impacts brought about by climate change are well-supported by theory, as well as the previous literature on the subject. In particular, the role of education, income, loan availability, and soil fertility are highly intuitive and worth considering for future research and policy. Education has shown a significantly negative impact on the perceived impact of drying water sources in the study area, as in the case of the first two impacts, viz., impacts on crop production and temperature increases. However, its impact on changing rainfall pattern is less conspicuous and can be justified, as the farmers may believe it to be a natural process, and even a highly qualified farmer would be in a difficult position to judge changes in rainfall pattern. Whereas, farmers can observe the level of water resources, crop production impacts, and temperature increases [41,57].

The variable of land ownership has shown a significant impact on changing rainfall pattern due to climate change. This variable had a non-significant impact for the other three aspects of climate change. The reason for such an outcome can be because the people having ownership of land, instead of lease arrangement, would have greater proximity to land and surrounding area, placing them in a better position to perceive abrupt changes in rainfall pattern. The variable on availing of loan positively affects both impacts, while the level of soil fertility has a significantly negative impact both for drying of water sources and changing rainfall pattern. These findings provide valuable insights related to future policy and planning, as the people having access to easy loans will be investing heavily on their farms and would early perceive the ensuing impacts of climate change. Similarly, a negative sign on level of soil fertility indicates farmers would be less disturbed by the changing climate, as they have a greater confidence in the quality of their land and its ability to adjust to changing climate [81,84].

3.2. *Perceived Causes of Climate Change*

Along with eliciting farmers' responses about the perceived impacts of climate change on agricultural production in Saudi Arabia, they were also enquired about their viewpoint as to what are the major causes of climate change in the country. As given in Figure 2, the majority of the respondents seemed clear about the possible drivers of climate change in the country. In particular, about 79 percent of the farmers believed that GHGs and pollution are causing climate change in the country. Other major perceived/reported causes of climatic variation include excessive exploitation of natural resources (94%), deforestation (93.5%), urbanization (92%), infrastructural development and transportation activities (71.5% for each), natural processes (64.2%), and technologies (42.3%). These perceived causes have varying levels of impacts on the surge of climatic anomalies worldwide, as reported by [7,85–91]. Conversely, the majority of farmers had little knowledge in ascribing climate change to an increase in dairy and goat farming, as well as cattle farming (72–80%). A greater proportion of the farmers also did not attribute climate change to agriculture as a profession.

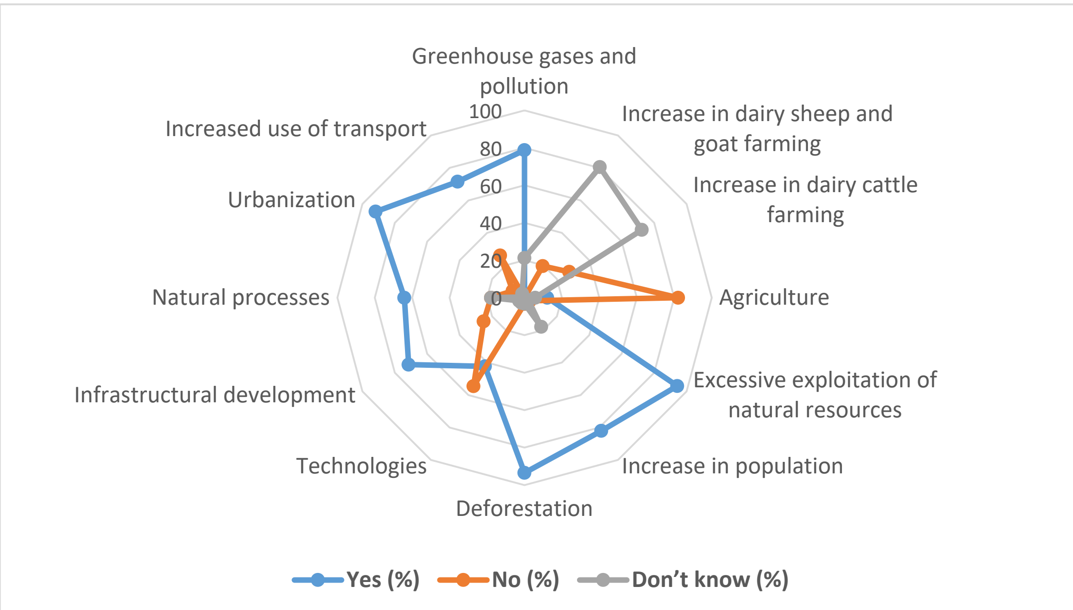

Figure 2. Perceived Causes of Climate Change.

3.2.1. Factors Affecting Perceptions of Natural Process as Being a Cause of Climate Change

Table 3 presents the parameter estimates of the three logit models used to estimate the effects of various farm and farmers' characteristics on their perceived causes of climate change. We selected the top three climate change causes for evaluating influencing factors in perceiving them as causes of climate change. They include 'natural processes', 'deforestation', and 'urbanization', as depicted in Figure 2.

Table 3. Parameter estimates of the logit models for perceived causes of climate change.

Variables	Natural Process	Deforestation	Urbanization
Age	0.052 (0.037)	−0.030 (0.034)	0.004 (0.034)
Farming Experience	−0.088 * (0.046)	−0.005 (0.044)	−0.001 (0.045)
Education	1.033 *** (0.229)	0.722 *** (0.216)	−0.129 (0.228)
Income	0.417 * (0.229)	0.584 ** (0.235)	0.573 ** (0.255)
Farm Size	−0.007 (0.023)	−0.004 (0.023)	0.623 *** (0.194)
Land Ownership	2.223 *** (0.722)	2.502 *** (0.744)	−0.301 (0.788)
Log Likelihood	−50.471	−46.559	−46.918
LR chi2(6)	45.97 ***	43.54 ***	38.12 ***
Pseudo R^2	0.313	0.319	0.289

Note: Figures in parenthesis are standard errors. *, **, and *** represent significance at 10%, 5% and 1% probability levels, respectively.

The findings presented in Table 3 reveal that the age of the sampled respondents has a positive effect on their perception of natural processes being the causes of climate change. Similarly, farming experience has an inverse effect on respondents' perceptions regarding causes of climate change. The relationship is statistically significant, at 10 percent probability level. This outcome is justifiable, as increased level of farming experience can provide farmers with better understanding related to the causes of climate change. This is because they learn and practice under varying natures of environmental conditions and have a proper historical backing in their perceptions and decisions [41,84]. Similarly, education of the sampled respondents showed a positive and significant effect on farmers' perceptions of natural processes being a cause of climate change. Educated farmers tend to see natural processes being the major contributor towards the changing climate compared to farmers with lower or no formal education. Iqbal et al. [75,77] have shown similar findings related to the role of education on the perceived causes of climatic variation.

In a similar vein, income is found to exert a significant positive impact in perceiving natural processes as being a cause of climate change. This finding is supported by the fact that people with increased income levels may attribute the changes in climate to the natural processes taking place locally or regionally. The probability of attributing natural processes to climate change increases significantly with either the size of owned land or having ownership rights. Van der Linden et al. [77] has advocated similar arguments in favor of many socio-demographic variables in influencing the perceived causes of climate change.

3.2.2. Factors Affecting Perceptions of Deforestation Being a Cause of Climate Change

Findings given in the third column of Table 3 portray parameter estimates on deforestation as a perceived cause of climate change in the Madinah region. The pattern and coefficient signs are similar to those for natural processes as being causes of climate change. The only variation is observed in the farming experience being statistically significant. It is highly intuitive, and deforestation has nothing to do with a farmer's farm level experience. However, the sign, being negative, of course indicates a weaker role of farming experience in perceiving deforestation as a cause of climate change.

3.2.3. Factors Affecting Perceptions of Urbanization as Being a Cause of Climate Change

The third top-most perceived cause of climate change was reported to be urbanization. The parameter estimates influencing farmers' perception of urbanization as being a cause of climate change are given in the 4th column of Table 3. As in the case of natural processes and deforestation as the perceived causes of climate change, a similar pattern and signs are depicted in the case of urbanization, except for non-significant coefficients of farming experience, education, and land ownership. Coefficients on farm size, however, have a significant and positive impact on perceiving urbanization as a cause of climate change. Milfont et al. [82,83,92,93] have reported similar findings related to income, education, farm experience in relation to climate change perceptions, and influencing factors therein.

3.3. Parameter Estimates of the Multinomial Logit Model

A multinomial logit model—an alternative approach to the individual logit models—is applied to estimate the effects of the socio-economic and farm characteristics on respondents' perceptions of the causes of climate change. The dependent variable in this case is comprised of the combinations of the perceived causes of climate change. The findings of the multinomial logit model are provided in Table 4.

The findings depict that age has a positive, but non-significant effect, on the perceptions of farmers who perceived natural process as the only major cause of climate change. The finding is in line with the findings in case of an individual logit model, where age was positively related to perceptions of natural processes being the causes of climate change and is also consistent with [41,85]. Education, on the other hand, has a significant impact on farmers' perceptions related to natural processes being the only causes of climate changes. However, it is significant at a 10 percent level of significance. The parameter estimates of the coefficients of perception of deforestation as the only causes of climate change show that education and farm size have significantly positive (10% significance level) effects. For the farmers perceiving urbanization as the only cause of climate change, farm size and land ownership are the significant factors having a positive impact on those farmers who only attribute climate change to urbanization. When considering farmers who reported two types of causes of climate change, the results give interesting insights, as the nature of parameters change with the combination of perceived causes of climate change in relation to the single cause of climate change in isolation. Previous studies, such as those by [42,43,71], do conform to these finding to a great extent. Natural processes and deforestation, for instance, were reported to be the causes of climate change by 14 farm households (see Table 4).

The covariates for this combined cause of climate change have significant impact, including education and land ownership, although at a 10 percent level of significance. The results are intuitive in the sense that they portray a different picture when individual categories of causes are analyzed (see Table 4). The significance level and signs would change when changes in combination of causes of climate change are considered. Similarly, 11 farmers reported natural processes and urbanization as joint causes of climate change, and the significant factor for this option includes only the farm size. In a similar vein, the factors influencing the perception of declaring deforestation and urbanization as joint causes of climate change include income and farm size, while this option is reported/perceived by 14 farmers. These findings are in conformity with those by [41,47,57], showing different magnitudes of factors causing climate change in Saudi Arabia and elsewhere in the world.

The results from the analysis of factors affecting the perceptions of farmers regarding all three climate change causes (natural process, deforestation, and urbanization) merit further discussion here, since this is the combination most frequently reported by the farmers in the sample. The significant variables in this case are education level of the respondent, household income, and total farm size of the farming household. These variables positively and significantly affect farmers' perceptions when considering all the three dominant perceived causes of climate change. The age of the sampled respondents has a positive and significant effect on farmers' perceptions of all three causes of climate change. Farming experience, on other hand, has a negative relationship with farmers' perceived causes of climate change in this category. The impacts of these variables are, however, insignificant.

Table 4. Parameter estimates of the multinomial logit model.

Variables	Coefficient	Standard Errors	Significance
No Cause among the Selected Causes (Base Category)			
Natural Process Only (N = 3)			
Age	0.085	0.173	0.622
Farming Experience	0.047	0.246	0.847
Education	2.129	1.202	0.077 *
Income	1.561	1.396	0.263
Farm Size	0.782	1.138	0.492
Land Ownership	−1.550	2.681	0.563
Deforestation Only (N = 5)			
Age	0.056	0.126	0.658
Farming Experience	−0.042	0.145	0.771
Education	1.511	0.881	0.08 *
Income	1.704	1.259	0.176
Farm Size	1.726	0.899	0.055 *
Land Ownership	−0.865	2.338	0.711
Urbanization Only (N = 10)			
Age	−0.043	0.117	0.713
Farming Experience	0.012	0.132	0.927
Education	0.494	0.808	0.541
Income	0.017	1.217	0.989
Farm Size	2.074	0.872	0.017 **
Land Ownership	−3.734	2.129	0.080 *
Natural Process and Deforestation (N = 14)			
Age	0.055	0.114	0.625
Farming Experience	−0.209	0.133	0.117
Education	2.420	0.968	0.012 **
Income	1.132	1.239	0.361
Farm Size	1.321	0.902	0.143
Land Ownership	1.892	5.0546	0.98 *
Natural Process and Urbanization (N = 11)			
Age	0.108	0.113	0.341
Farming Experience	−0.148	0.126	0.241
Education	1.311	0.818	0.109
Income	2.007	1.219	0.100
Farm Size	1.786	0.879	0.042 *
Land Ownership	0.269	2.228	0.904
Deforestation and Urbanization (N = 14)			
Age	0.005	0.117	0.965
Farming Experience	−0.047	0.133	0.723
Education	1.163	0.813	0.152
Income	2.089	1.222	0.087 *
Farm Size	1.879	0.876	0.032 **
Land Ownership	−0.509	2.185	0.816
Natural Process, Deforestation and Urbanization (N = 60)			
Age	0.063	0.111	0.572
Farming Experience	−0.128	0.125	0.309
Education	2.259	0.829	0.006 ***
Income	2.054	1.209	0.089 *
Farm Size	2.027	0.871	0.020 **
Land Ownership	1.489	2.301	0.517
Log likelihood		−123.126	
LR Chi (Sqr)		155.44	
Pseudo R^2		0.387	

Note: Values with *, **, and *** represent significance at 10%, 5% and 1% probability levels, respectively.

4. Discussion and Conclusions

Documenting the understanding of farmers' perceptions, behaviors, and their responses to climate change impacts is crucial for designing site-specific and community-based adaptation plans, particularly in rural areas. The current study provides a solid indication of climate change in the study area, which is also perceived by the farmers. The location-specific survey explored the factors that affect farmers' perceptions of causes and impacts of climate change in Saudi Arabia. According to the results, farmers' socioeconomic characteristics, such as land ownership, farm size, access to loans, education and household income significantly influenced their perception about climate change impacts and the causes of climate change. These findings imply that farmers' perceived impacts of climate change are significantly affected by their education level, which is considered to affect their level of understanding, income level, farming experience, land ownership, type of land, and soil fertility in different directions. Furthermore, farmers' socioeconomic characteristics show differential impacts on their perceived causes of climate change. There is great scope of these findings to manage climate change in the country, which has predominantly an arid to semi-arid climate for sustainable agriculture through various practices, such as improving input use efficiency, particularly water, land, fertilizer, and seeds, along with crop diversification. Such interventions have been proven to be highly useful under similar environmental conditions elsewhere in the world [94–96].

Findings on the influence of educational level in early perception about the causes and impacts of climate change can provide valuable insights while planning for mitigation and adaptation strategies, as well as benchmarking the extension system in rural areas. One option to facilitate early and effective adaptation and mitigation strategy can be the uplifting of existing extension programs to address areas and issues, which remain unclear for the farmers.

There is also a need to further assess climate change stimuli in the real world that would need to be corroborated with the perceived causes by the farmers and households. This would build a sense of clarity both in the minds of policy planners and ultimate beneficiaries. Once farmers are conveyed authentic information on the causes and impacts of climate change, they would be in a better position to simulate and/or match mitigation/adaptation options with little chances of failure and mismatch between perceived actual causes and effects. This conclusion has far-reaching implications both for the studied country and many other countries in the world, where causes and subsequent mitigation measures related to climate change are merely developed on hearsay, imitation, and perceptions.

Innovative climate adaptation technologies, adopted in developed countries to mitigate climate effects, need not be suited elsewhere, but, having a thorough analysis on their efficacy could lead to better customization potential and scope in a varied environment and location. Similarly, for rural areas, informal extension training and awareness campaigns need to be a regular focus for boosting farmers' understanding of adaptive climate technologies. Based on findings, timely and appropriate weather information should be provided to the farming community. The farmers would be in a good position to take measures rightly and accordingly if they have access to information, as well as guidance related to future climate-related events/threats. Each group of farmers should be educated, advised, or trained according to their education level. The focus of extension services and training should be on reducing the adverse impacts of climate change through applicable adaptation measures in the region.

The study is limited only to the perceived causes and impacts of climate change in the Madinah Region of KSA. The findings are based on sample data from this region, and caution is warranted when generalizing findings for a whole country, although a similar pattern has been reported by select studies. Future research studies may also consider the impacts of farmers' perceptions of the causes of climate change on their capacity of adaptation to climate change. Looking further into the limitations of the current work, the real-time data on crop losses, public health, as well as tourism, can be integrated for comprehensive estimation of effects of climate change in the region. In addition, the study did not consider time series data on climate trends and impacts that could yield some interesting insights, which are left for future work. Moreover, future research should focus on factors affecting the adoption of climate-smart technologies among farmers in the study area, along with knowing the efficacy of existing practices in terms of their uptake, mitigation potential, and ease of installation/establishment. Similarly, because study was limited to the Madinah Region, the findings may not be generalized in other regions of Saudi Arabia. Therefore, it is suggested that similar research can be designed to test adaptation to climate change in other regions of Saudi Arabia that are highly susceptible to climate change. For making adaptation to climate change more popular, an integrated campaign needs to be started, involving the community and other stakeholders, such as local leaders and large/commercial farmers. In this regard, organizing community for joint efforts of climate change mitigation would yield better outcomes, especially faster adaptation mechanisms and information sharing. There can be a system of incentivizing those farmers who go for early adoption of measures identified to be climate-smart. In this regard, an effort is needed to identify and promote options that are climate-smart and effective for management of issues affecting agricultural productivity and rural livelihoods.

Author Contributions: Conceptualization B.A.A. and A.A.; methodology B.A.A. and T.S.; data curation M.M. and M.I.A.; validation M.M., R.U., M.R. and T.S.; formal analysis R.U. and A.A.; investigation B.A.A., A.A., M.I.A. and R.U.; resources B.A.A., M.R., and A.S.; writing—original draft preparation B.A.A., A.A. and A.T.D.; writing—review and editing B.A.A., R.U., A.S., M.R. and T.S.; project administration A.S., A.T.D., M.M., R.U. and T.S.; funding acquisition A.T.D. and M.R. All authors have read and agreed to the published version of the manuscript.

Funding: The authors extend their appreciation to the Deputyship for Research & Innovation, Ministry of Education in Saudi Arabia for funding this research through the project no. (IFKSUOR3-141-1).

Institutional Review Board Statement: The study was approved by King Saud University.

Informed Consent Statement: Informed consent was obtained from all the respondents involved in the study.

Data Availability Statement: Data used in this study will be made available on request.

Acknowledgments: The authors extend their appreciation to the Deputyship for Research and Innovation Ministry of Education in Saudi Arabia for funding this Research (IFKSUOR3-141-1).

Conflicts of Interest: The authors declare no conflict of interest.

References

1. UNESCO; UN-Water; World Water Assessment Programme. *United Nations World Water Development Report 2020: Water and Climate Change*; UN: New York, NY, USA, 2020.
2. IPCC. *Climate Change 2022: Impacts, Adaptation, and Vulnerability*; Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change; IPCC: Geneva, Switzerland, 2022.
3. Romm, J. *Climate Change: What Everyone Needs to Know*; Oxford University Press: Oxford, UK, 2022.
4. Reckien, D.; Creutzig, F.; Fernandez, B.; Lwasa, S.; Tovar-Restrepo, M.; McEvoy, D.; Satterthwaite, D. Climate change, equity and the Sustainable Development Goals: An urban perspective. *Environ. Urban.* **2017**, *29*, 159–182. [CrossRef]
5. Bator, A.; Borek, A. Adaptation to Climate Change under Climate Change Treaties. *Int. Community Law Rev.* **2021**, *23*, 158–167. [CrossRef]
6. Stern, N. A Time for Action on Climate Change and a Time for Change in Economics. *Econ. J.* **2022**, *132*, 1259–1289. [CrossRef]
7. DeNicola, E.; Aburizaiza, O.S.; Siddique, A.; Khwaja, H.; Carpenter, D.O. Climate Change and Water Scarcity: The Case of Saudi Arabia. *Ann. Glob. Health* **2015**, *81*, 342–353. [CrossRef] [PubMed]
8. Malhi, G.S.; Kaur, M.; Kaushik, P. Impact of Climate Change on Agriculture and Its Mitigation Strategies: A Review. *Sustainability* **2021**, *13*, 1318. [CrossRef]
9. Olsson, L.; Barbosa, H.; Bhadwal, S.; Cowie, A.; Delusca, K.; Flores-Renteria, D.; Hermans, K.; Jobbagy, E.; Kurz, W.; Li, D. Land degradation: IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. In *IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems*; Intergovernmental Panel on Climate Change (IPCC): Geneva, Switzerland, 2019; pp. 345–436.
10. Hermans, K.; McLeman, R. Climate change, drought, land degradation and migration: Exploring the linkages. *Curr. Opin. Environ. Sustain.* **2021**, *50*, 236–244. [CrossRef]
11. Asadieh, B.; Krakauer, N.Y. Global change in streamflow extremes under climate change over the 21st century. *Hydrol. Earth Syst. Sci.* **2017**, *21*, 5863–5874. [CrossRef]

12. Yoro, K.O.; Daramola, M.O. Chapter 1—CO_2 emission sources, greenhouse gases, and the global warming effect. In *Advances in Carbon Capture*; Rahimpour, M.R., Farsi, M., Makarem, M.A., Eds.; Woodhead Publishing: Sawston, UK, 2020; pp. 3–28.
13. Shen, X.; Liu, B.; Jiang, M.; Lu, X. Marshland Loss Warms Local Land Surface Temperature in China. *Geo. Res. Lett.* **2020**, *47*, e2020GL087648. [CrossRef]
14. Hong, C.; Burney, J.A.; Pongratz, J.; Nabel, J.E.; Mueller, N.D.; Jackson, R.B.; Davis, S.J. Global and regional drivers of land-use emissions in 1961–2017. *Nature* **2021**, *589*, 554–561. [CrossRef]
15. Nerini, F.F.; Sovacool, B.; Hughes, N.; Cozzi, L.; Cosgrave, E.; Howells, M.; Tavoni, M.; Tomei, J.; Zerriffi, H.; Milligan, B. Connecting climate action with other Sustainable Development Goals. *Nat. Sustain.* **2019**, *2*, 674–680. [CrossRef]
16. Lynch, J.; Cain, M.; Frame, D.; Pierrehumbert, R. Agriculture's Contribution to Climate Change and Role in Mitigation Is Distinct From Predominantly Fossil CO_2-Emitting Sectors. *Front. Sustain. Food Syst.* **2021**, *4*, 518039. [CrossRef]
17. Shrestha, R.; Rakhal, B.; Adhikari, T.R.; Ghimire, G.R.; Talchabhadel, R.; Tamang, D.; Kc, R.; Sharma, S. Farmers' Perception of Climate Change and Its Impacts on Agriculture. *Hydrology* **2022**, *9*, 212. [CrossRef]
18. Sillmann, J.; Roeckner, E. Indices for extreme events in projections of anthropogenic climate change. *Clim. Chang.* **2008**, *86*, 83–104. [CrossRef]
19. Zhang, Y.; Zhang, Y.; Shi, K.; Yao, X. Research development, current hotspots, and future directions of water research based on MODIS images: A critical review with a bibliometric analysis. *Environ. Sci. Pollut. Res.* **2017**, *24*, 15226–15239. [CrossRef]
20. Das, U.; Ansari, M.A. The nexus of climate change, sustainable agriculture and farm livelihood: Contextualizing climate smart agriculture. *Clim. Res.* **2021**, *84*, 23–40. [CrossRef]
21. Karavolias, N.G.; Horner, W.; Abugu, M.N.; Evanega, S.N. Application of gene editing for climate change in agriculture. *Front. Sustain. Food Syst.* **2021**, *5*, 685801. [CrossRef]
22. Du, T.; Kang, S.; Zhang, J.; Davies, W.J. Deficit irrigation and sustainable water-resource strategies in agriculture for China's food security. *J. Exp. Bot.* **2015**, *66*, 2253–2269. [CrossRef]
23. Gosling, S.N.; Arnell, N.W. A global assessment of the impact of climate change on water scarcity. *Clim. Chang.* **2016**, *134*, 371–385. [CrossRef]
24. Zampieri, M.; Ceglar, A.; Dentener, F.; Toreti, A. Wheat yield loss attributable to heat waves, drought and water excess at the global, national and subnational scales. *Environ. Res. Lett.* **2017**, *12*, 064008. [CrossRef]
25. Cogato, A.; Meggio, F.; De Antoni Migliorati, M.; Marinello, F. Extreme Weather Events in Agriculture: A Systematic Review. *Sustainability* **2019**, *11*, 2547. [CrossRef]
26. Mancosu, N.; Snyder, R.L.; Kyriakakis, G.; Spano, D. Water Scarcity and Future Challenges for Food Production. *Water* **2015**, *7*, 975–992. [CrossRef]
27. Haile, M.G.; Wossen, T.; Tesfaye, K.; von Braun, J. Impact of Climate Change, Weather Extremes, and Price Risk on Global Food Supply. *Econ. Disasters Clim. Chang.* **2017**, *1*, 55–75. [CrossRef]
28. Shahzad, A.; Ullah, S.; Dar, A.A.; Sardar, M.F.; Mehmood, T.; Tufail, M.A.; Shakoor, A.; Haris, M. Nexus on climate change: Agriculture and possible solution to cope future climate change stresses. *Environ. Sci. Pollut. Res.* **2021**, *28*, 14211–14232. [CrossRef] [PubMed]
29. Borrelli, P.; Robinson, D.A.; Fleischer, L.R.; Lugato, E.; Ballabio, C.; Alewell, C.; Meusburger, K.; Modugno, S.; Schütt, B.; Ferro, V.; et al. An assessment of the global impact of 21st century land use change on soil erosion. *Nat. Commun.* **2017**, *8*, 2013. [CrossRef] [PubMed]
30. Kulkarni, S. Climate Change, Soil Erosion Risks, and Nutritional Security. In *Climate Change and Resilient Food Systems: Issues, Challenges, and Way Forward*; Hebsale Mallappa, V.K., Shirur, M., Eds.; Springer: Singapore, 2021; pp. 219–244.
31. Skendžić, S.; Zovko, M.; Živković, I.P.; Lešić, V.; Lemić, D. The Impact of Climate Change on Agricultural Insect Pests. *Insects* **2021**, *12*, 440. [CrossRef]
32. Arora, N.K. Impact of climate change on agriculture production and its sustainable solutions. *Environ. Sustain.* **2019**, *2*, 95–96. [CrossRef]
33. Fuglie, K. Climate change upsets agriculture. *Nat. Clim. Chang.* **2021**, *11*, 294–295. [CrossRef]
34. FAO; Weltbankgruppe. *Water Management in Fragile Systems: Building Resilience to Shocks and Protracted Crises in the Middle East and North Africa*; FAO: Rome, Italy; World Bank: Washington, DC, USA, 2018.
35. WHO. *COP24 Special Report: Health and Climate Change*; WHO: Geneva, Switzerland, 2018.
36. Abbass, K.; Qasim, M.Z.; Song, H.; Murshed, M.; Mahmood, H.; Younis, I. A review of the global climate change impacts, adaptation, and sustainable mitigation measures. *Environ. Sci. Pollut. Res.* **2022**, *29*, 42539–42559. [CrossRef]
37. Vermeulen, S.J.; Aggarwal, P.K.; Ainslie, A.; Angelone, C.; Campbell, B.M.; Challinor, A.J.; Hansen, J.W.; Ingram, J.S.I.; Jarvis, A.; Kristjanson, P.; et al. Options for support to agriculture and food security under climate change. *Environ. Sci. Policy* **2012**, *15*, 136–144. [CrossRef]
38. Mishra, A.; Bruno, E.; Zilberman, D. Compound natural and human disasters: Managing drought and COVID-19 to sustain global agriculture and food sectors. *Sci. Total Environ.* **2021**, *754*, 142210. [CrossRef]
39. Ortiz, A.M.D.; Outhwaite, C.L.; Dalin, C.; Newbold, T. A review of the interactions between biodiversity, agriculture, climate change, and international trade: Research and policy priorities. *One Earth* **2021**, *4*, 88–101. [CrossRef]
40. Gosling, S.N.; Dunn, R.; Carrol, F.; Christidis, N.; Fullwood, J.; Gusmao, D.d.; Golding, N.; Good, L.; Hall, T.; Kendon, L. *Climate: Observations, Projections and Impacts*; Met Office: Exeter Devon, UK, 2011.

41. Faisal, M.; Chunping, X.; Abbas, A.; Raza, M.H.; Akhtar, S.; Ajmal, M.A.; Ali, A. Do risk perceptions and constraints influence the adoption of climate change practices among small livestock herders in Punjab, Pakistan? *Environ. Sci. Pollut. Res.* **2021**, *28*, 43777–43791. [CrossRef]
42. Al Zawad, F.M.; Aksakal, A. Impacts of Climate Change on Water Resources in Saudi Arabia. In *Global Warming: Engineering Solutions*; Dincer, I., Hepbasli, A., Midilli, A., Karakoc, T.H., Eds.; Springer: Boston, MA, USA, 2010; pp. 511–523.
43. Almazroui, M.; Islam, M.N.; Balkhair, K.S.; Şen, Z.; Masood, A. Rainwater harvesting possibility under climate change: A basin-scale case study over western province of Saudi Arabia. *Atmos. Res.* **2017**, *189*, 11–23. [CrossRef]
44. Relief Web. Aqueduct Projected Water Stress Country Rankings. OCHA, New York, USA, 2015. Available online: https://www.wri.org/insights/ranking-worlds-most-water-stressed-countries-2040 (accessed on 15 March 2023).
45. Samad, N.; Bruno, V. The urgency of preserving water resources. *Environ. News* **2013**, *21*, 3–6.
46. Sowers, J.; Vengosh, A.; Weinthal, E. Climate change, water resources, and the politics of adaptation in the Middle East and North Africa. *Clim. Chang.* **2011**, *104*, 599–627. [CrossRef]
47. Haque, M.I.; Khan, M.R. Impact of climate change on food security in Saudi Arabia: A roadmap to agriculture-water sustainability. *J. Agribus. Dev. Emerg. Econ.* **2022**, *12*, 1–18. [CrossRef]
48. Odnoletkova, N.; Patzek, T.W. Data-Driven Analysis of Climate Change in Saudi Arabia: Trends in Temperature Extremes and Human Comfort Indicators. *J. Appl. Meteorol. Climatol.* **2021**, *60*, 1055–1070. [CrossRef]
49. Williams, J.B.; Shobrak, M.; Wilms, T.M.; Arif, I.A.; Khan, H.A. Climate change and animals in Saudi Arabia. *Saudi J. Biol. Sci.* **2012**, *19*, 121–130. [CrossRef]
50. Chowdhury, S.; Al-Zahrani, M. Implications of Climate Change on Water Resources in Saudi Arabia. *Arab. J. Sci. Eng.* **2013**, *38*, 1959–1971. [CrossRef]
51. Allbed, A.; Kumar, L.; Shabani, F. Climate change impacts on date palm cultivation in Saudi Arabia. *J. Agric. Sci.* **2017**, *155*, 1203–1218. [CrossRef]
52. Zatari, T. *Second National Communication: Kingdom of Saudi Arabia*; UN: New York, NY, USA, 2011.
53. Tarawneh, Q.Y.; Chowdhury, S. Trends of Climate Change in Saudi Arabia: Implications on Water Resources. *Climate* **2018**, *6*, 8. [CrossRef]
54. MEWA. *National Environmental Strategy: Executive Summary for the Council of Economic and Development Affairs*; MEWA: Dammam, Saudi Arabia, 2017.
55. Nelson, G.C.; Rosegrant, M.W.; Koo, J.; Robertson, R.; Sulser, T.; Zhu, T.; Ringler, C.; Msangi, S.; Palazzo, A.; Batka, M. *Climate Change: Impact on Agriculture and Costs of Adaptation*; International Food Policy Research Institute: Washington, DC, USA, 2009; Volume 21.
56. Al-Sarihi, A. *Prospects for Climate Change Integration into GCC Economic Diversification Strategies*; LSE Middle East Centre, Kuwait Programme: London, UK, 2018.
57. Alotaibi, B.A.; Abbas, A.; Ullah, R.; Nayak, R.K.; Azeem, M.I.; Kassem, H.S. Climate Change Concerns of Saudi Arabian Farmers: The Drivers and Their Role in Perceived Capacity Building Needs for Adaptation. *Sustainability* **2021**, *13*, 12677. [CrossRef]
58. Manandhar, S.; Pratoomchai, W.; Ono, K.; Kazama, S.; Komori, D. Local people's perceptions of climate change and related hazards in mountainous areas of northern Thailand. *Int. J. Disaster Risk Reduct.* **2015**, *11*, 47–59. [CrossRef]
59. Ono, K.; Kazama, S.; Kawagoe, S. Analysis of the risk distribution of slope failure in Thailand by the use of GIS data. In *Environmental hydraulics*; CRC Press: Boca Raton, FL, USA, 2010; pp. 1189–1194.
60. Laidler, G.J. Inuit and scientific perspectives on the relationship between sea ice and climate change: The ideal complement? *Clim. Chang.* **2006**, *78*, 407. [CrossRef]
61. Danielsen, F.; Burgess, N.D.; Balmford, A. Monitoring matters: Examining the potential of locally-based approaches. *Biodivers. Conserv.* **2005**, *14*, 2507–2542. [CrossRef]
62. Azeem, M.I.; Alhafi Alotaibi, B. Farmers' beliefs and concerns about climate change, and their adaptation behavior to combat climate change in Saudi Arabia. *PLoS ONE* **2023**, *18*, e0280838. [CrossRef]
63. Alotaibi, B.A.; Kassem, H.S.; Nayak, R.K.; Muddassir, M. Farmers' Beliefs and Concerns about Climate Change: An Assessment from Southern Saudi Arabia. *Agriculture* **2020**, *10*, 253. [CrossRef]
64. Jägerskog, A.; Barghouti, S. *Advancing Knowledge of the Water-Energy Nexus in the GCC Countries*; World Bank: Washington, DC, USA, 2022.
65. Khomsi, S.; Roure, F.; Al Garni, M.; Amin, A. *Arabian Plate and Surroundings: Geology, Sedimentary Basins and Georesources*; Springer: Berlin/Heidelberg, Germany, 2020.
66. GASTAT. *Agricultural Production Survey Bulletin*; GASTAT: Riyadh, Saudi Arabia, 2019.
67. Sharaf, M.A.M. Major elements hydrochemistry and groundwater quality of Wadi Fatimah, West Central Arabian Shield, Saudi Arabia. *Arab. J. Geosci.* **2013**, *6*, 2633–2653. [CrossRef]
68. Khan, S.; Alghafari, Y. Temperature and Precipitation Fluctuation of Madinah-Al-Munawara, Kingdom of Saudi Arabia (1959–2011). *Atmos. Clim. Sci.* **2016**, *6*, 402. [CrossRef]
69. Velandia, M.; Rejesus, R.M.; Knight, T.O.; Sherrick, B.J. Factors Affecting Farmers' Utilization of Agricultural Risk Management Tools: The Case of Crop Insurance, Forward Contracting, and Spreading Sales. *J. Agric. Appl. Econ.* **2009**, *41*, 107–123. [CrossRef]
70. Alkolibi, F.M. Possible effects of global warming on agriculture and water resources in Saudi Arabia: Impacts and responses. *Clim. Chang.* **2002**, *54*, 225–245. [CrossRef]

71. Alam, J.B.; Hussein, M.H.; Magram, S.F.; Barua, R. Impact of climate parameters on agriculture in Saudi Arabia: Case study of selected crops. *Int. J. Clim. Chang.* **2011**, *2*, 41–50. [CrossRef]
72. Frank, E.; Eakin, H.; López-Carr, D. Social identity, perception and motivation in adaptation to climate risk in the coffee sector of Chiapas, Mexico. *Glob. Environ. Chang.* **2011**, *21*, 66–76. [CrossRef]
73. Ahmed, Z.; Guha, G.S.; Shew, A.M.; Alam, G.M.M. Climate change risk perceptions and agricultural adaptation strategies in vulnerable riverine char islands of Bangladesh. *Land Use Policy* **2021**, *103*, 105295. [CrossRef]
74. Maurya, R.K. *Alternate Dairy Management Practices in Drought Prone Areas of Bundelkhand Region of UP*; IVRI Izatnagar: Bareilly, India, 2010.
75. Iqbal, M.A.; Abbas, A.; Naqvi, S.A.; Rizwan, M.; Samie, A.; Ahmed, U.I. Drivers of Farm Households' Perceived Risk Sources and Factors Affecting Uptake of Mitigation Strategies in Punjab Pakistan: Implications for Sustainable Agriculture. *Sustainability* **2020**, *12*, 9895. [CrossRef]
76. Malka, A.; Krosnick, J.A.; Langer, G. The Association of Knowledge with Concern About Global Warming: Trusted Information Sources Shape Public Thinking. *Risk Anal.* **2009**, *29*, 633–647. [CrossRef]
77. Van der Linden, S.L.; Leiserowitz, A.A.; Feinberg, G.D.; Maibach, E.W. The scientific consensus on climate change as a gateway belief: Experimental evidence. *PLoS ONE* **2015**, *10*, e0118489. [CrossRef]
78. Adger, W.N.; Huq, S.; Brown, K.; Conway, D.; Hulme, M. Adaptation to climate change in the developing world. *Prog. Dev. Stud.* **2003**, *3*, 179–195. [CrossRef]
79. Aryal, J.P.; Sapkota, T.B.; Rahut, D.B.; Krupnik, T.J.; Shahrin, S.; Jat, M.L.; Stirling, C.M. Major Climate risks and Adaptation Strategies of Smallholder Farmers in Coastal Bangladesh. *Environ. Manag.* **2020**, *66*, 105–120. [CrossRef]
80. Hornsey, M.J.; Harris, E.A.; Bain, P.G.; Fielding, K.S. Meta-analyses of the determinants and outcomes of belief in climate change. *Nat. Clim. Chang.* **2016**, *6*, 622–626. [CrossRef]
81. Slimak, M.W.; Dietz, T. Personal Values, Beliefs, and Ecological Risk Perception. *Risk Anal.* **2006**, *26*, 1689–1705. [CrossRef] [PubMed]
82. Akbar, M.S.; Aldrich, D.P. Social capital's role in recovery: Evidence from communities affected by the 2010 Pakistan floods. *Disasters* **2018**, *42*, 475–497. [CrossRef] [PubMed]
83. Hansen, J.; Hellin, J.; Rosenstock, T.; Fisher, E.; Cairns, J.; Stirling, C.; Lamanna, C.; van Etten, J.; Rose, A.; Campbell, B. Climate risk management and rural poverty reduction. *Agric. Syst.* **2019**, *172*, 28–46. [CrossRef]
84. Ali, A.; Erenstein, O. Assessing farmer use of climate change adaptation practices and impacts on food security and poverty in Pakistan. *Clim. Risk Manag.* **2017**, *16*, 183–194. [CrossRef]
85. Milfont, T.L. The Interplay Between Knowledge, Perceived Efficacy, and Concern About Global Warming and Climate Change: A One-Year Longitudinal Study. *Risk Anal.* **2012**, *32*, 1003–1020. [CrossRef]
86. Smith, N.; Leiserowitz, A. The Rise of Global Warming Skepticism: Exploring Affective Image Associations in the United States Over Time. *Risk Anal.* **2012**, *32*, 1021–1032. [CrossRef]
87. Arbuckle, J.G.; Morton, L.W.; Hobbs, J. Farmer beliefs and concerns about climate change and attitudes toward adaptation and mitigation: Evidence from Iowa. *Clim. Chang.* **2013**, *118*, 551–563. [CrossRef]
88. Metag, J.; Füchslin, T.; Schäfer, M.S. Global warming's five Germanys: A typology of Germans' views on climate change and patterns of media use and information. *Public Underst. Sci.* **2015**, *26*, 434–451. [CrossRef]
89. Capstick, S.; Whitmarsh, L.; Poortinga, W.; Pidgeon, N.; Upham, P. International trends in public perceptions of climate change over the past quarter century. *WIREs Clim. Chang.* **2015**, *6*, 35–61. [CrossRef]
90. Abbas, A.; Amjath-Babu, T.S.; Kächele, H.; Müller, K. Participatory adaptation to climate extremes: An assessment of households' willingness to contribute labor for flood risk mitigation in Pakistan. *J. Water Clim. Chang.* **2016**, *7*, 621–636. [CrossRef]
91. Hirabayashi, Y.; Mahendran, R.; Koirala, S.; Konoshima, L.; Yamazaki, D.; Watanabe, S.; Kim, H.; Kanae, S. Global flood risk under climate change. *Nat. Clim. Chang.* **2013**, *3*, 816–821. [CrossRef]
92. Chekima, B.; Chekima, S.; Syed Khalid Wafa, S.A.W.; Igau, O.A.; Sondoh, S.L. Sustainable consumption: The effects of knowledge, cultural values, environmental advertising, and demographics. *Int. J. Sustain. Dev. World Ecol.* **2016**, *23*, 210–220. [CrossRef]
93. Ding, N.; Liu, J.; Kong, Z.; Yan, L.; Yang, J. Life cycle greenhouse gas emissions of Chinese urban household consumption based on process life cycle assessment: Exploring the critical influencing factors. *J. Clean. Prod.* **2019**, *210*, 898–906. [CrossRef]
94. Habib-ur-Rahman, M.H.; Ahmad, I.; Wang, D.; Fahd, S.; Afzal, M.; Ghaffar, A.; Saddique, Q.; Khan, M.A.; Saud, S.; Hassan, S.; et al. Influence of semi-arid environment on radiation use efficiency and other growth attributes of lentil crop. *Environ. Sci. Pollut. Res.* **2021**, *28*, 13697–13711. [CrossRef]
95. Hussain, S.; Habib-Ur-Rehman, M.; Khanam, T.; Sheer, A.; Kebin, Z.; Jianjun, Y. Health Risk Assessment of Different Heavy Metals Dissolved in Drinking Water. *Int. J. Environ. Res. Public Health* **2019**, *16*, 1737. [CrossRef]
96. Raza, A.; Ahrends, H.; Habib-Ur-Rahman, M.; Gaiser, T. Modeling Approaches to Assess Soil Erosion by Water at the Field Scale with Special Emphasis on Heterogeneity of Soils and Crops. *Land* **2021**, *10*, 422. [CrossRef]