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Authors: Ali H. Khalil & Shirley Thompson

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Ali H. Khalil
University of Manitoba
Winnipeg, Manitoba, Canada
alikhalil2@gmail.com

Shirley Thompson
University of Manitoba
Winnipeg, Manitoba, Canada
s.thompson@umanitoba.ca

Abstract

Climate change is challenging the agricultural sector globally and has undermined food security in some countries. Yemen is suffering catastrophic food insecurity attributed to climate change and war. To reduce this food insecurity, agriculture extension workers must facilitate climate-smart agriculture. Of 52 agricultural extension workers who took a climate-smart survey, most (97%) extension workers had observed climatic shifts, including rising temperatures and droughts, with 81% finding climate change a major threat to agriculture. A high percentage of (77%) agricultural extension workers surveyed reported never attending training workshops on climate change issues, receiving their information from different media, including agriculture research centers (72%), subject matter specialists (67%), and social media (60%). Major barriers to climate-smart extension programs that support sustainable food production for food security in Yemen include a lack of training of programs for extension workers concerning climate change issues, low competence regarding climate change adaptation issues, insufficient number of extension workers to serve farmers, and lack of coordination between extension services and agricultural research centers. Adaptation extension work was undertaken at a moderate level by 61% of respondents, with over half (67%) complaining about having few resources for climate change adaptation programming (67%). Further programming and resources are needed for agricultural extension workers to help farmers combat climate change, food security and malnutrition in Yemen.

Keywords: agriculture extension, climate change, food security, Yemen, climate-smart agriculture, adaptation

Changement climatique, sécurité alimentaire et vulgarisation agricole au Yémen

Ali H. Khalil
University of Manitoba
Winnipeg, Manitoba, Canada
alikhalil2@gmail.com

Shirley Thompson
University of Manitoba
Winnipeg, Manitoba, Canada
s.thompson@umanitoba.ca

Résumé

Le changement climatique met à rude épreuve le secteur agricole à l'échelle mondiale, mais pour certains pays, il a des effets dévastateurs sur leur sécurité alimentaire. Le Yémen souffre d'une insécurité alimentaire catastrophique attribuée au changement climatique et à la guerre. Pour réduire cette insécurité alimentaire, les vulgarisateurs agricoles doivent faciliter une agriculture intelligente face au climat. Sur les 52 vulgarisateurs agricoles qui ont répondu à une enquête intelligente sur le climat, la plupart (97 %) des agents de vulgarisation agricole avaient observé des changements climatiques, notamment une hausse des températures et des sécheresses, et 81 % d'entre eux estimaient que le changement climatique constituait une menace majeure pour l'agriculture. Un pourcentage élevé (77 %) des vulgarisateurs agricoles interrogés ont déclaré n'avoir jamais assisté à des ateliers de formation sur les questions de changement climatique, mais avoir reçu leurs informations de différents médias, notamment des centres de recherche agricole (72 %), des spécialistes en la matière (67 %) et des médias sociaux (60 %). Les principaux obstacles aux programmes intelligents de vulgarisation face au climat qui soutiennent la production alimentaire durable pour la sécurité alimentaire au Yémen comprennent le manque de programmes de formation des agents de vulgarisation sur les questions de changement climatique, la faible compétence en matière d'adaptation au changement climatique, le nombre insuffisant d'agents de vulgarisation pour servir les agriculteurs, et le manque de coordination entre les services de vulgarisation et les centres de recherche agricole. Les travaux de vulgarisation en matière d'adaptation ont été entrepris à un niveau modéré par 61 % des personnes interrogées, dont plus de la moitié (67 %) se plaignent du manque de ressources pour les programmes d'adaptation au changement climatique (67 %). Des programmes et des ressources supplémentaires sont nécessaires pour que les agents de vulgarisation agricole puissent aider les agriculteurs à lutter contre le changement climatique, la sécurité alimentaire et la malnutrition au Yémen.

Mots-clés : vulgarisation agricole, changement climatique, sécurité alimentaire, Yémen, agriculture intelligente face au climat, adaptation

1.0 Introduction

Climate change is challenging the agricultural sector globally. Poorer countries are especially vulnerable to climate change because of their geographic exposure, low incomes, and heavy reliance on agriculture (Davies et al., 2009). Agricultural vulnerability to climate change challenges the sustainability of the global food system and the livelihoods of farmers in Yemen (Intergovernmental Panel on Climate Change [IPCC], 2022; McCarthy et al., 2022; Food and Agriculture Organization [FAO], 2021; Rouabhi et al., 2019; Abah, 2014; Walthall, 2012). In Yemen, climate change is contributing to food insecurity and starvation (Thomas, 2022) in a country besieged by civil war from 2015 to the present. Rising temperatures and changes in rainfall in Yemen, along with more cyclones and floods, are reducing crop yields and leading to malnutrition (Schulman, 2021), requiring climate-smart agriculture. Yemen's agriculture extension workers' awareness, actions, and barriers to climate change in agriculture are explored in this study.

Yemen's agriculture has been negatively impacted by climate change because of its geographical position, climatic characteristics, and climate-sensitive agriculture. The agricultural yield of many Yemeni crops has declined over the past 30 years (Food and Agriculture Organization Statistics [FAOSTAT], 2021). Between 1989 and 2011, lentil yield were halved from 1.5 to 0.7 tons per hectare. Sorghum and tomato yield declined from 1 to 0.7 tons per hectare and 15.9 to 13.5 tons per hectare, respectively (FAOSTAT, 2021).

This paper focuses on the role of agricultural extension workers in climate change adaptation. In the introduction, we discuss the high rates of food insecurity in Yemen. We seek to understand the extension workers' perceptions of climate change and their efforts to build climate-smart agriculture to increase adaptive capacity (Azadi et al., 2021). We explore the need to build the climate-adaptive capacity of rural communities in Yemen to mitigate the negative impacts of climate change on agriculture and food security (Habib-ur-Rahman et al., 2022).

Climate-smart agriculture (CSA) refers to agriculture that provides sustainable increases in food security, availability and productivity by increasing resilience to climate change, growing the adaptive capacity of farmers and reducing greenhouse emissions (Lipper & Zilberman, 2018). Moreover, climate-smart agriculture is considered an approach to guide actions to transform and reorient agricultural systems to effectively and sustainably support development and food security under a changing climate (Turyasingura et al., 2023). Adaptive capacity in Yemen's farming communities is needed to face severe water scarcity, ecosystem fragility, continued land degradation, and declining agricultural productivity (Debela et al., 2015).

An understanding of extension workers' beliefs about climate change is required to inform effective extension adaptive and mitigation programs that are designed to be climate smart. Globally, most research articles focus on farmers' perceptions of climate change (Dagmawi & Wims, 2015), but there is a gap regarding the role of agricultural extension workers. This study addresses the role of agricultural extension workers in informing farmers about climate change adaptation.

1.1 Impact of Climate Change Worldwide

Climate change is impacting agriculture production around the world. Climate change increases extreme weather events like storms, erratic rainfall, floods, cyclones, droughts, and pests, which reduce agricultural yields (Habib-ur-

Rahman et al., 2022). When global average surface temperatures rise by 2°C, the expected yield losses due to pest pressure are expected to worsen by 46%, 19%, and 31% for wheat, rice, and maize, respectively, resulting in hundreds of metric megatons per year lost (Deutsch, et al. 2018).

The impact of climate change is reducing crop yield in many areas. A single day at 30°C instead of the optimal 29°C was found to reduce end-of-season yields by about half a percent, which is a large effect (Burke & Emerick, 2016). The Intergovernmental Panel on Climate Change's sixth assessment report warns that climate change impacts in Asia threaten agricultural productivity (IPCC, 2022). Higher temperatures due to climate change result in increased rates of evapotranspiration, leading to soil dryness, water scarcity, and reduced crop yield (Yuan, et al. 2024). For example, the heatwaves in India decimated India's wheat harvest, adding to the global wheat shortage caused by the war in Ukraine (Yuan et al, 2024). Elevated temperatures and reduced precipitation during the reproductive phase in the Indus, Ganges, and Brahmaputra River basins of South Asia, if increased irrigation does not occur, will reduce rice productivity (Ahmad, et al. 2023). Also, climate change is expected to decrease yields in the Middle East and sub-Saharan Africa. Thiombiano et al. (2018) reported that the yields of the main staple crops in Sub-Saharan Africa (maize, millet, and sorghum) will decrease by approximately one-quarter due to climate change. The negative impacts of climate change on Iranian rainfed wheat are expected to decrease by 18% and 24% by 2025 and 2050, respectively (Karimi et al., 2018). Climate change's negative impact on the global food system are expected to increase in the future.

Climate change is projected to decrease livelihoods and food security (El-Mokhtar, et al. 2019; FAO, 2020). Climate change is exacerbating food insecurity in areas currently vulnerable to hunger and undernutrition (FAO, 2020). In Western and Eastern Africa, incomes are predicted to drop by more than 10% from 2015 to 2050 in high-warming scenarios (Philip, 2024).

Climate change is a global problem that is intensively impacting Yemeni people's food security, livelihoods, and national economic development. Agriculture depends on climate patterns and variations, placing food security at high risk. Climate change is expected to profoundly influence the agroecological conditions under which farmers and rural populations live.

1.2 Yemen

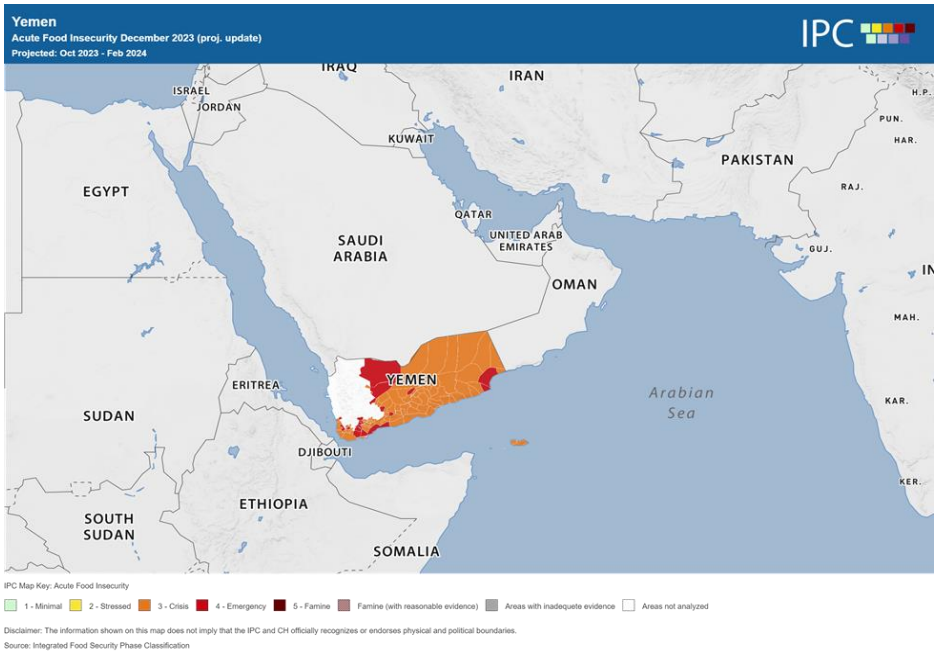
Yemen is a country located in the Southeast Arabian Peninsula. Yemen occupies an area of 555,000 square kilometers (km^2) between the latitude of 13° and 16°N and longitude of 43.2° and 53.2°E. Yemen is bordered by Saudi Arabia to the North, the Red Sea to the West, Oman to the East, and the Arabian Sea and Gulf of Aden to the South (World Bank, 2023).

According to the United Nations Population Fund (UNPF, 2023), 34.4 million people live in Yemen. More than 70% of the population lives in rural areas, where poverty and food insecurity are higher than in urban areas (Breisinger et al., 2020). Yemen's annual population growth rate is approximately 2.1% per year, placing pressure on the limited basic infrastructure and services, including water, education, health, and access roads (World Bank, 2023; UNPF, 2023; World Bank, 2010). Poverty and conflict limit and undermine development.

Yemen's conflict began in 2015 as a result of clashes between Yemeni government forces and the Houthis—also known as *Ansar Allah* (UNHCR, 2024). Yemen experiences poverty, food security, conflict, high population growth, inadequate access to basic social services, limited infrastructure, high

illiteracy rates, low per capita income, slow economic growth, and environmental degradation (UNHCR, 2024). Furthermore, climate change is associated with increased drought, temperature variability, and precipitation changes, which are impacting agriculture and food security.

Figure 1: Map of Yemen.



Source : Integrated Food Insecurity Phase Classification (IPC, 2024).

1.3 Climate Change in Yemen

Yemen faces extreme climatic events due to increasing temperatures, including intense drought and flood (UNDP, 2023). Temperatures have increased by 1.8 °C in Yemen and precipitation has decreased by 9% (Schulman, 2021). Between 1971 and 2020, Yemen's mean annual temperature increased by 0.42°C per decade, with more hot and humid days and nights (World Bank, 2023). Temperatures exceed 40°C in summer and 35°C in spring and autumn at an earlier date (International Committee of the Red Cross [ICRC], 2023). Table 1 lists the climate change issues in Yemen (ICRC, 2023).

Table 1. *Summary of Projected Impacts of Climate Change in Yemen*

Climate change issues	**Climate projections in Yemen**
Sea level rise and storms	Sea levels are expected to rise in the Gulfs of Aden and Oman, and in the Arabian Sea, with more intense storms.
Temperature change	Significant warming has already occurred. Maximum temperatures can exceed 40°C during most summers. Annual average temperatures are expected to be 2–4°C higher by the 2050s with the daily maximum temperatures exceeding 35°C to start earlier in spring and continue into autumn.
Impacts	Water stress, food insecurity, and impacts on marine ecosystems and fisheries.

Source: Adapted from the ICRC (2023).

Drought's impact in Yemen is increasing (UNDP, 2023). Yemen experienced significant declines in annual precipitation over the 50 years from 1971 to 2020 along the western and southwestern coasts (World Bank, 2023). Yemen's mean annual precipitation slightly declined (by 6.25 mm per decade) between 1971 and 2020 (World Bank, 2023). However, Al Hudaydah, on the Red Sea, had a decrease in precipitation by 38.25 mm between 1971–2020. These droughts are causing desertification with Yemen losing 20% of its arable land to sandstorms each year (Mulhern, 2021). The degradation of arable land undermines the sustainability of agriculture and livelihoods and worsens food insecurity (Fevari et al., 2022).

Climate change is amplifying flooding disasters from cyclones and hurricanes. In 2019, the Arabian Peninsula experienced its strongest storm in 12 years, with three cyclones. The Kyarr cyclone devastated Yemen in October 2019, followed by Maha in November 2019 and Pawan in December 2019. At least 130,000 people were affected by floods in the summer of 2019, and another 17,000 in autumn of the same year. These floods caused displacement, and destruction of homes, farmland, fishing equipment, and infrastructure. In 2022, the period between June and August was characterized by heavy rain and widespread flooding across Yemen, damaging critical infrastructure such as roads and bridges in some areas. Approximately 72 people died, and 73,854 families were affected throughout the country.

The majority of those affected by flood live in displaced sites and settlements, due to shelters, livelihoods, and water sourcesbeing damaged (UNDP, 2023). In addition to deaths and injuries, there has been damage to infrastructure and livelihoods, worsening deadly diseases already transmitted among vulnerable populations (Homaid, 2023). Floods and heavy rains in Yemen typically affect the poor, women, and marginal communities the hardest, especially internally displaced persons and small-scale farmers (Baig et al., 2018).

Floods reduce crop production when most farms engage in early planting (FAO, 2024). Flooding causes cropland losses, uprooting of fruit trees, death of animals, and destruction of infrastructure, such as irrigation facilities and rural roads (Red Cross Red Crescent Climate Centre [RCRCCC], 2024). A farmer from the Dhamar governorate in the central highlands of Yemen described flooding as devastating to his home and farm: "Floods took our farms and our homes. I feel life is over. I don't have land or a house anymore. It's all over" (ICRC, 2022, para. 2).

The impacts of climate change on Yemen include the degradation of agricultural land, soils, terraces, and desertification. Adaptation is needed to reduce the impact on food production, agricultural income, and national food insecurity rates (Antwi-Agyei & Stringer, 2021).

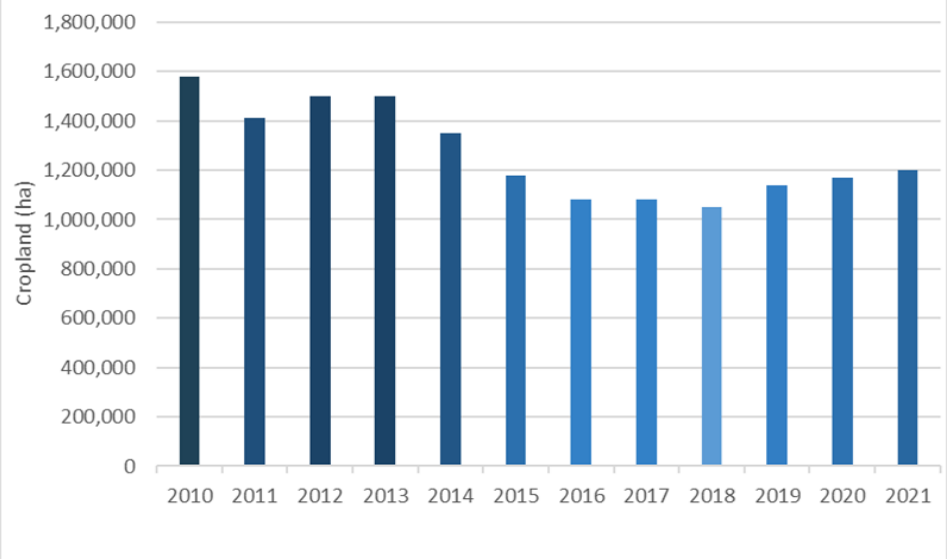
1.4 Food Insecurity in Yemen

Climate change in Yemen has negatively impacted its agriculture production. Climate change increases droughts, rain variability, draws down underground water tables and degrades soil. Desertification, animal diseases, and desert locust infestation are expected to worsen with climate change in Yemen (Mulhern, 2021).

The arable land in Yemen is decreasing. Figure 2 shows the decrease in cropland from 2010 to 2021, which is largely blamed on climate change. The arable land has decreased from approximately 1.6 million hectares in 2010 to its lowest level in 2018 of 1.1, rebounding slightly in 2021 to 1.2. Most Yemenis are subsistence

farmers, with only 3% arable land (mostly in the west) and one-third of farms suitable for grazing (Ministry of Agriculture and Irrigation [MAI], 2020).

Figure 2: Decrease in cropland in Yemen from 2010 to 2021.



Source: Ministry of Agriculture & Irrigation Statistics Annual Book (2010 to 2021).

Two-thirds of internally displaced populations are from rural communities, including 50% of all agricultural workers. In total, the civil war has displaced 4.5 million people and pushed 17 million people into acute hunger (ICRC, 2023). In 2017, many Yemenis were deprived of access to potable water due to the civil war destroying water infrastructure and sewage systems. These stresses add to environmental deterioration, agricultural decline and quality of life. Communities and individuals cannot meet their basic needs and live with dignity (ICRC, 2023).

The negative impacts of climate change on agriculture worsen Yemen's food security. Agriculture is crucial for food security and rural economic development in Yemen. Approximately 78% of rural household farms contribute about 17% of the country's Gross Domestic Product (GDP) (United Nations [UN], 2022). In 2023, 73% of farmers blamed climate change for their food insecurity (Tamdeen Youth Foundation & Oxfam, 2023).

Agriculture, food security and rural livelihoods have been decimated by the combined effects of conflict and climate change on agriculture in Yemen. Agricultural and food security systems in Yemen were poor before the 2015 conflict but collapsed shortly thereafter. Famine and malnutrition result from the disruption caused by the ongoing conflict, which obliterated domestic food production and the food ecosystem (Mundy, 2017). Reduced agricultural productivity resulted in food shortages, price inflation and increased food insecurity, exacerbating the humanitarian crisis in the country (Yemen Family Care Association [YFCA], 2023; Mundy, 2017). Yemen relies on imports for 70% of its food needs, which most people cannot afford. Yemen imports its main staples - 90% of the wheat and 100% of its rice (Giovetti, 2024).

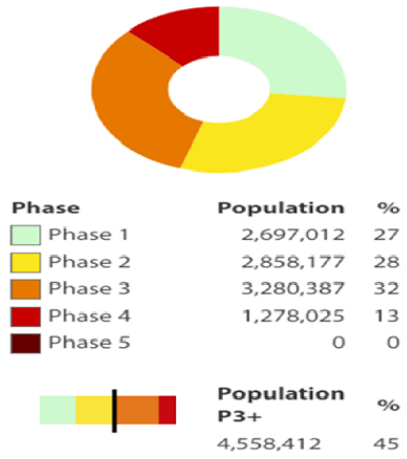
Yemen was ranked the worst severe humanitarian crisis in the world by the UN (2019). People's livelihoods and food supply are diminished by reductions in already scarce vegetation, increased soil erosion, desertification, and destroyed biodiversity. In 2024, after nine years of conflict, an estimated 4.5

million people (14% of the population) are displaced, with many displaced multiple times since 2015 (UNHCR, 2024). Yemen has an acute need for humanitarian assistance (United Nations Office for the Coordination of Humanitarian Affairs [OCHA], 2019).

1.5 Food Insecurity High and Acute

Yemen's food insecurity is escalating from acute to catastrophic levels (FAOSTAT, 2021). The Integrated Food Insecurity Phase Classification (IPC) defines food insecurity level three as acute or crisis, level four as an emergency, and level five as catastrophic famine. Figure 3 shows that over the period of October 2023 to February 2024, approximately 4.56 million people or 45 percent of the population analyzed in Government of Yemen controlled areas will experience high levels of acute food insecurity (AFI), classified as Crisis (IPC Phase 3) and Emergency (IPC Phase 4). More than 1.3 million people are estimated to have Emergency level food insecurity (IPC Phase 4). Compared to the initial projection analysis for June to December 2023, an overall four percentage point increase from 41 percent to 45 percent shows food insecurity in Yemen is worsening (IPC, 2024) but down from 2022 levels. From October 2022 to December 2022, 6.1 million people at IPC level 4 (emergency) and 3.5 million were acutely malnourished at catastrophic level 5 (WFP, 2023a).

Figure 3: Yemen's Acute food insecurity (October 2023- February 2024).



Source: IPC (2024).

The impact on Yemen's children's survival and development is devastating. Approximately 2.2 million children under five years old, including 538,000 severely malnourished children and approximately 1.3 million pregnant and lactating women, were projected to suffer acute malnutrition in 2022 (WFP, 2023). The humanitarian situation in Yemen is extremely fragile. Any disruption of critical food supplies brings millions of people closer to starvation and death. Yet, imports are highly restricted. Ongoing conflict, population pressures, water scarcity, low agricultural productivity, and degraded natural resources fuel famine in Yemen.

The conflict has affected the nation's agricultural industry. The turmoil has disrupted farming operations due to farmers being displaced and unable to cultivate crops or reach markets. Furthermore, the conflict has deteriorated

critical services such as irrigation systems, agricultural and residential properties, critical infrastructure such as storage facilities, and costly agricultural machinery, thereby impeding crop cultivation and compromising essential water and electricity resources relied upon by farmers.

Climate change is predicted to increase the variability of weather, causing more frequent and intense droughts and rainfall events, and crop damage (Baig et al., 2018). Desertification is spreading, water in wells is drying up, and the growing seasons are shrinking in Yemen (Price, 2022). Droughts have also been extended in frequency and length. The World Bank (2023, para. 1) ranks Yemen as one of the worst water-stressed countries, made worse by agricultural demands: "Yemen is among the most water-stressed countries in the world, experiencing high rates of groundwater extraction further exacerbated by agricultural demands and ongoing conflict."

1.6 Climate Change Adaptation

Climate change adaptation is defined as the "measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects" (Metz et al., 2007, p. 809). Adjusting farming activities to changing climatic conditions minimizes potential damages. Climate change adaptation and new livelihood strategies are required to manage natural resources and achieve food security. Therefore, adaptation should be a top priority in Yemen, as agriculture remains the most important sector to livelihoods. Agricultural extension must help farmers adapt to climate change. The current focus of extension on improving agricultural production performance without climate change adaptation cannot be achieved. Agricultural extension services provide information and guidance to farmers to enhance their understanding of climate change and implement appropriate adaptation measures.

Few studies and tools are available to address climate change in Yemen. The lack of recent, reliable climate data and past statistics at national and local levels undermines the ability of future predictions. Limited or no focus on climate change adaptation in Yemen has occurred (Price, 2022). This is the first study to focus on agriculture extension related to climate change in Yemen. This paper analyzes whether agricultural extension programs offer farmers adaptation tools to deal with extremes in climate such as flooding, drought, deforestation, soil erosion, soil degradation, and biodiversity losses, and how to resolve malnutrition.

2.0 Agriculture Extension Workers' Roles

Agricultural extension workers educate farmers to increase national agriculture production through innovation in food production processes (Oakley & Garforth, 1985; Khalid & Sherzad, 2019). Extension workers provide a bridge for farmers to transmit knowledge from researchers, policymakers, and NGOs (Van den Ban & Hawkins, 1996). Extension workers advocate technology transfer and raising awareness among farmers. Agricultural extension services include technical assistance, information on improved varieties, and agricultural technologies related to climate change adaptation. An understanding of land potential for climate change adaptation is necessary (Iwuchukwu & Onyeme, 2012). Agricultural extension workers have an important role in helping farmers make decisions about climate change's potential effects and offer adaptation strategies, but the literature does not consider their role in Yemen.

3.0 Method

The Khalil & Thompson (2024). surveyed extension workers regarding climate change. The survey was distributed directly to 40 agricultural extension workers who participated in an agricultural training workshop at the Ibb governorate's agriculture office. All 40 of those surveyed worked in agricultural extension at the governorate and district levels from Ibb, Al Hudaydah, and Dhamar governorates, respectively. Additionally, 12 extension workers were selected randomly from the Amran and Hadhramaut governorates. All 52 respondents responded, resulting in a return rate of 100%.

Data obtained from the respondents were coded, computed, and analyzed using the Statistical Package for Social Science SPSS (version 22). Sociodemographic characteristics included personal and professional profiles. The personal profile included gender and age. The professional profile included educational qualification, a field of study, total years of experience in an agriculture project/authority, number of in-service training attendance, agricultural region, and extension project where the respondents work. All sociodemographic variables were analyzed using descriptive statistics using SPSS 26. Descriptive statistics, including frequency and percentages, were used to describe the data and were compared with secondary data sources.

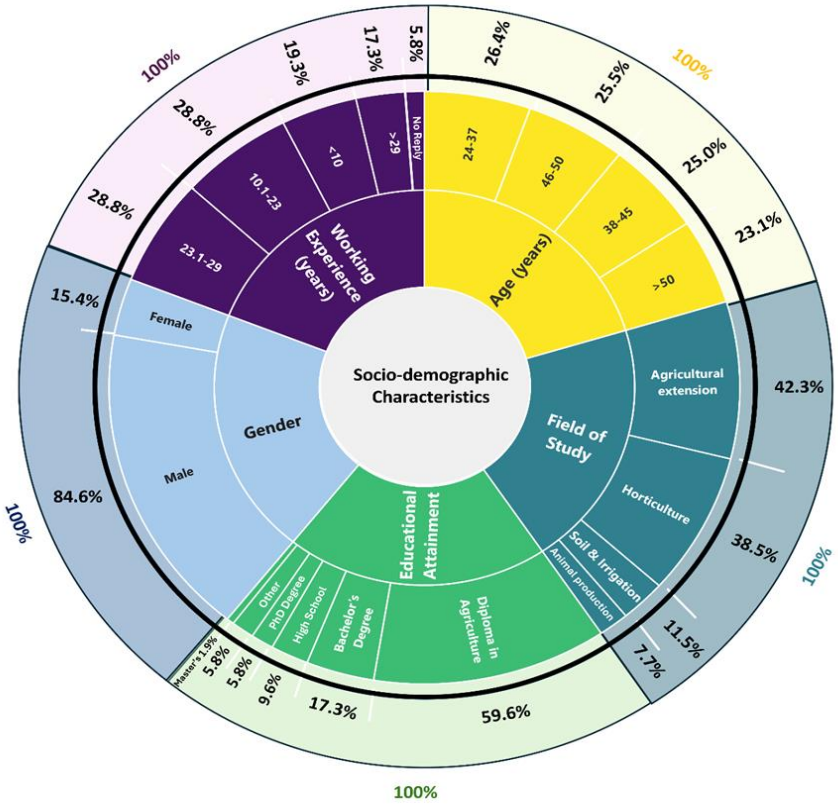
4.0 Results

4.1 Sociodemographic Characteristics of the Respondents

Most agricultural extension workers are middle-aged men with an agricultural technical diploma or bachelor's degree in agricultural science. The demographic profile of the respondents (see Figure 4) shows that the mean age of extension workers is 44 years, with the majority (75%) aged between 42 and 50 years. Most have several decades of work experience. The majority (85%) of the agriculture extension workers who responded were male, with only 15% female. Similarly, Ogunlade et al. (2014) found that men predominate in agricultural extension services. Yemen's patriarchy is unwelcoming to women working in rural and remote areas, which explains their lack of representation as adult extension workers. Most agricultural extension workers have a college or university education. Regarding the academic qualifications of extension workers, 60% had an agricultural technical diploma, 17% had a bachelor's degree in agriculture sciences, 8% had graduate degrees, including 6% with a doctorate and 2% with a master's degree, 6% had other qualifications, and 10% had only high school education.

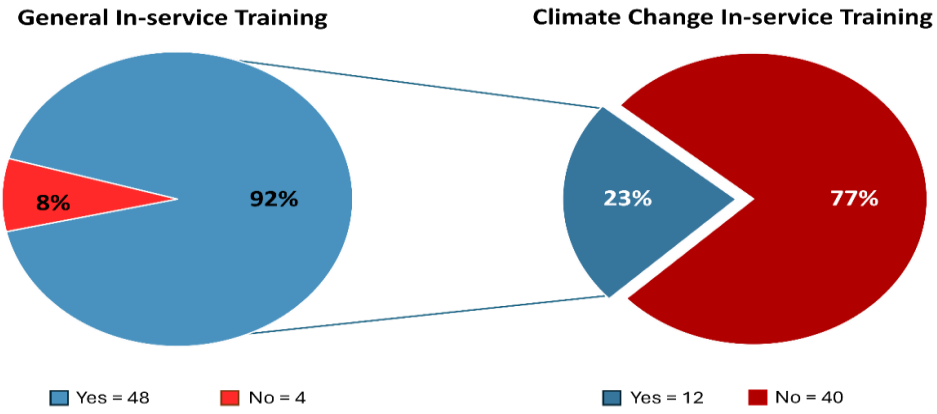
The majority (92%) of agricultural extension workers attended in-service training workshops during the last five years. However, 77% of these participants never received training on climate change issues. Figures 5 and 6 indicate that although in-service training occurs, climate change adaptation and mitigation are not covered. Similarly, in Missouri in the United States, Wilson & Mukembo (2023) found that most Missouri agricultural extension workers never received any formal training on climate change.

Figure 4: Sociodemographic characteristics of the 52 extension worker respondents.



Source: Authors.

Figures 5 and 6: In-service training involvement in general and climate change issues.



Source: Authors.

4.2 Level of Extension Workers' Perceptions Regarding Climate Change

Almost all (97%) extension workers surveyed had climate change awareness (see Table 2). Almost all respondents strongly agreed with scientific findings that the: high rate of human activities causes climate change; the temperature is increasing every year; rainfall level decreased compared with the previous 10 years; and climate change is a major threat to the agricultural sector in the

country. Hizam, an agricultural research expert at the Yemeni Ministry of Agriculture and Irrigation, blamed climate change for a general decline in agricultural productivity, due to the resulting droughts, floods, and heat-related stress to crops (Xinhua, 2023). Hizam stated: "Yemen's climate crisis is a stark reminder that the environment, too, bears the brunt of conflict, with far-reaching consequences for its people" (Xinhua, 2023, para. 11).

Table 2. *Extension Workers' Climate Change Knowledge (n=52)*

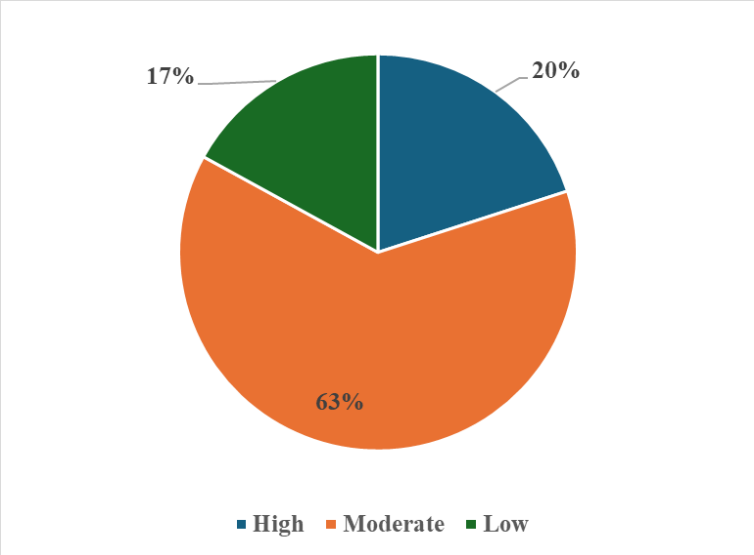
Knowledge of climate change agreement with scientific evidence	**M**	**Std.Dev.**	**Weighted percentage**	**Level of agreement**
Climate changed compared with the previous years	4.84	0.45	96.8	Strongly agree
Human activities lead to a high rate of CO_2, causing climate change	4.63	0.74	92.6	Strongly agree
Average temperature changed	4.57	0.72	91.4	Strongly agree
Rainfall pattern and timing changed.	4.15	1.22	83	Agree
Climate change threatens the agricultural sector.	4.07	1.11	81.4	Agree
Climate change has created new opportunities for the agriculture sector.	3.63	1.31	72.6	Agree
Knowledge overall	**25.9**	**3.27**	**86.3**	**Strongly agree**

The overall knowledge of climate change impacts was high (86%) among agricultural extension workers in Yemen. Their views align with the findings of the United States Agency for International Development (USAID) (2017) that climate change is leading to increasing temperatures, unpredictable rainfall patterns, and extended drought periods reducing crop production in Yemen. Similarly, Ghana's extension workers were found to have an excellent knowledge of climate change and its impact (Ogunlade et al., 2014).

4.3 Extension Workers' Roles Related to Climate Change

Figure 7 reveals that 63% of agricultural extension workers participated moderately in climate change adaptation activities as part of their extension work. Only 20% had high participation in climate change activities. However, 17% did not participate in any climate change adaptation activities.

Figure 7: Level of extension workers' participation (n=52) in climate change adaptation.



Source: Authors.

Table 3 details the extension roles in disseminating climate change knowledge and practices to the farmers. Sixty-three percent of the respondents sometimes held workshops for farmers and local rural leaders to implement drought-related interventions. These interventions included training on irrigation networks, drip irrigation techniques, and water harvesting for domestic and agricultural use.

In the agricultural sector, Yemen has historically depended on diesel-powered groundwater extraction and transport following the restructuring of its agricultural system in the 1970s with the assistance of international donors. Yemen's war destroyed the national grid and resulted in substantial price fluctuations and limited fuel access (Conflict and Environment Observatory [CEOBS], 2021). Yemen's farmers face significant challenges in accessing electricity. Although the rural population constitutes approximately 75% of the total population, only 23% have access to electricity, while 85% of the urban population has (Al-wesabi et al., 2022; Alkipsy et al., 2021). Yemen's electricity grid relies totally on fossil fuels, including diesel, heavy crude oil, and liquefied natural gas (Al-wesabi et al., 2022). To pump groundwater for their agricultural activities, local production of solar energy, has replaced the grid for many farmers (Aklan & Lackner, 2021) (see Figure 8).

Solar power use in irrigation is a reliable and popular energy source for both small-scale and large-scale farmers. Yemen's sunbelt areas have radiation levels ranging from 6.8 to 5.2 kWh/m^2 per day, with an annual average of daily sunshine lasting between 7.3 and 9.1 h per day. Even during winter, the average daily sunshine hours are estimated to exceed eight hours. In the central Sana'a governorate Basin, Yemen's agricultural heartland, more than 30% of farmers use solar pumps (Pearce, 2024). More than 70% of households in Yemen use solar as a primary energy source, and a 'complete shift' to solar energy is predicted by 2028 (Aklan & Lackner, 2021). However, an increasing body of evidence suggests that the solar power irrigation system (SPIS) is causing a decline in groundwater levels and deterioration in water quality due to its low operational cost and abundant energy supply (Shah & Kishore, 2012).

Figure 8: Solar power electricity for agricultural irrigation in Yemen.

Source: Adapted from IFC, 2021.

Agricultural extension workers should play a larger role in ensuring water resources are not overused, encouraging farmers to switch to less water-intensive crops, planting windbreaks to reduce the impact of wind, protect soils, and modify the cropping calendar to adjust to changing rainfall timings provide ways to reduce the need for irrigation of crops. For instance, the construction of spillways is a mitigation approach that was applied to regulate water flow and the impact of floods and eliminate the risk of erosion during the rainy season.

Salamah Youssef, a farmer and resident of Al-Sanif village, praised the climate change adaptation of spillways: "The construction of spillways has had a huge impact on farmers. They prevent soil erosion caused by torrential rains that were used to wash away both crops and soil" (UNDP Yemen, 2024, p. 1). Salamah lamented that land degradation and soil erosion had left her unable to grow anything at all until the spillways, explaining. "I had resorted to collecting firewood and selling it for a meager profit, barely enough to provide one meal a day for my children" (UNDP Yemen, 2024, p. 1).

Complementary irrigation and livestock rainwater harvesting reservoirs are another adaption. These rainwater harvesting reservoirs were established in the villages of Belila and Al-Misbar, Al-Sukhnah District, Al Hudaydah governorate. Yahya Qaid Othman, a farmer in Al-Sukhnah touted the benefits of the reservoir:

> These reservoirs will help ease our struggle with water scarcity and depletion and provide a source of water for irrigating crops and watering animals. It will allow farmers to benefit from rainwater stored in these reservoirs instead of going to waste (UNDP Yemen, 2023. p. 1).

Workshops on organic fertilizers from biological farms' waste provide a way to maintain soil fertility. However, extension work on climate change adaptation is often minimal. More (39%) extension workers reported sometimes providing rural leaders and farmers with technical knowledge about

climate change than extension workers reported often providing this knowledge (33%). However, 41% of the respondents reported teaching farmers to minimize climate change risk in agriculture very often, and 53% explored farmers' traditional practices to minimize climate change risk. Crop adaptations include adjustments to planting dates and the use of different crop varieties. Irrigation adaptation practices include drainage system minimization of tillage, the use of cover crops to protect soils from erosion, and organically building fertile soil to maintain yields (FAO et al., 2018).

The non-governmental organizations' (NGOs) involvement in extension programs is critical to the growth of climate change adaption capacity. However, NGOs rarely focus on climate change adaptation in Yemen. Occasionally, 50% of the agriculture extension workers encourage NGOs to participate in the planning and implementation of extension programs that focus on climate change adaptation practices. In Yemen, farmers receive little support from external agencies, including formal government agencies and non-governmental organizations (Ruijs et al., 2011). Agricultural extension workers help farmers identify problems related to climate change in the planning process of extension educational programs, rarely at 43%. This means that farmers are rarely involved in the extension program planning process. This lack of a participatory process affects the acceptance of program activities and their sustainability because the real needs of the majority of farmers are not reflected. In general, the weighted percentage of agricultural extension workers' roles in climate change adaptation and practices is 50%. These roles are rarely implemented and practiced by public extension services in Yemen because of several barriers.

Table 3. *Extension Workers Role in Climate Change Adaptation and Mitigation (n=52)*

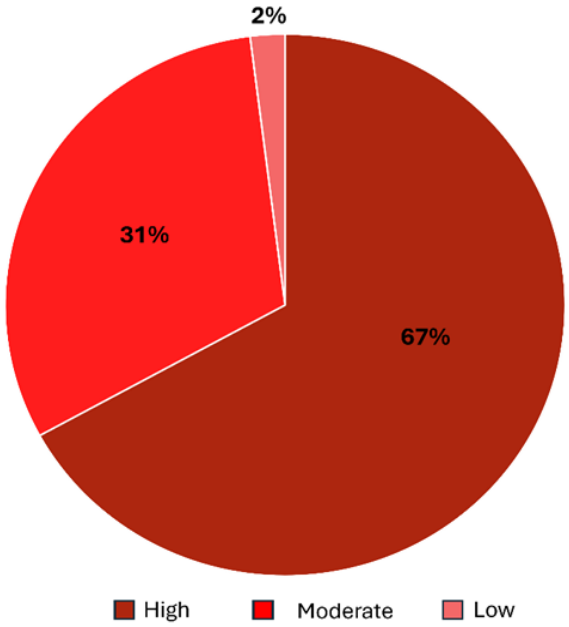
Extension agents' roles	**Mean**	**Std. dev.**	**Weighted %**
Participate in preparing training workshops for local rural leaders	3.13	0.97	62.6
Provide rural leaders and farmers with technical knowledge	2.94	0.95	58.8
Educate farmers about agricultural practices that minimize the risk of climate change	2.90	1.14	58
Interview farmers to explore their traditional practices to minimize the risk of climate change	2.65	0.94	53
Encourage NGOs to participate in extension program planning & implementation	2.50	0.80	50
Identify barriers preventing farmers from implementing agricultural practices and adapting to climate change	2.44	0.75	48.8
Participating in the development of farming solutions to climate change	2.42	0.84	48.4
Encourage farmers to identify problems related to climate change	2.17	0.61	43.4
Participate in the extension program evaluation	1.55	0.66	38.75
Overall variable	**24.9**	**4.93**	**49.96**

Although climate change science has been well articulated (Arbuckle et al., 2015), effective extension programming on climate change adaptation and mitigation for agricultural and natural resource audiences is in its early stages. More action is needed to ensure appropriate information is disseminated and applied. Therefore, extension educational programs on climate change adaptation for agricultural extension workers and the community level are highly needed.

4.4 Level of Barriers to the Implementation of Extension Programs

Many barriers limit agricultural extension workers working on climate change adaptation. Figure 9 reveals barriers to implementing climate change extension programs. Overall, two-thirds, 67% of the respondents experienced a high level of barriers, while 31 % indicated a moderate level. Only 2% of respondents had a low level of barriers to sharing climate change programming.

Figure 9: Level of barriers to implementing climate change extension programs.



Source: Khalil & Thompson (2024).

Table 4 reveals the key barriers that limit agricultural extension workers' teaching adaptation strategies. Barriers were experienced by almost all respondents, with almost all lacking supports: 98% without financial funds to plan and implement climate change adaptation extension programs, 95% indicated having no clear policy that deals with climate change issues, 95% with insufficient extension workers to serve farmers, and 88% lacked coordination between extension services and agricultural research centers. As well, most respondents lacked content on climate change: 95% were without training programs for extension workers concerning climate change matters, 90% lacked knowledge of climate change adaptation and practices, and 85% had low competence regarding climate change adaptation issues. These factors all had a negative impact on the performance of extension programs. However, agricultural extension services must regularly access new knowledge and disseminate it to farmers in a sufficient and timely manner (Maponya & Mpandeli, 2013) to adapt to climate change. Greater weather variability requires farmers to incorporate changes into their production systems (Haigh et al., 2015).

However, extension workers have not engaged in climate change leadership in Yemen despite the need to achieve synergies between climate change adaptation and mitigation (Christoplos, 2010; Abegunde et al., 2019). Farmers need to be continually updated about climate-smart agricultural practices, and strategies for adaptation and resilience (Abegunde et al., 2019).

Agriculture extension workers feel that their climate change adaptation is ineffective. Most (95%) respondents reported farmers' difficulties with technical practices. Further, 65% stated that the distrust between farmers and public extension services affects climate change extension program implementation.

These barriers to effective climate change strategies are further explained by Qamar (2012). Qamar (2012) reported that dozens of agricultural extension centers in Yemen are either nonfunctional or have been abandoned. Extension centers at the district and village levels were deserted because of lack of basic residential facilities and maintenance funding, which has worsened more recently with displacement due to disasters and war.

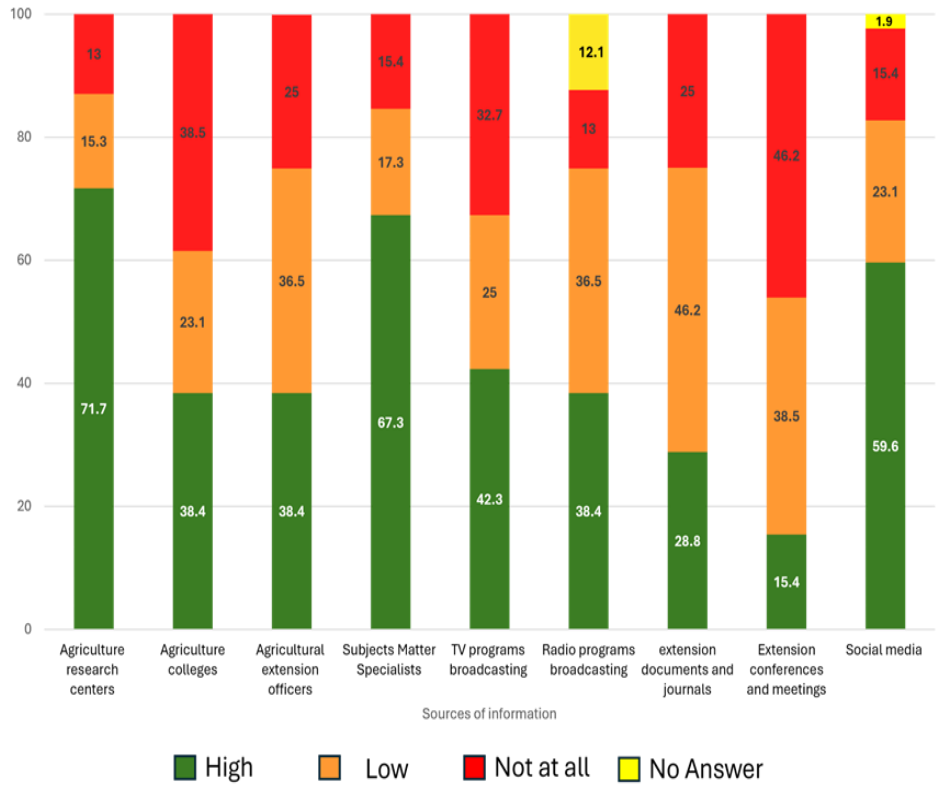
Table 4. *Barriers to Implementing Climate Change Extension Programs in Yemen (n=52)*

Barriers	**Mean**	**Std. Dev.**	**Weighted %**	**Barrier level**
Limited financial funds; plan and implement climate change extension programs.	3.9	0.23	97.5	High
No clear policy to deal with climate change issues.	3.8	0.36	95	High
Lack of climate adaptation training programs.	3.8	0.36	95	High
Insufficient extension workers to serve farmers.	3.8	0.39	95	High
Farmers face difficulties when applying technical practices.	3.8	0.39	95	High
Extension workers' have limited knowledge of climate change adaptation practices.	3.6	0.47	90	High
Lack of coordination between extension services and agricultural research centers.	3.5	0.64	87.5	High
Low competence of extension workers in climate change adaptation.	3.4	0.53	85	High
Lack of trust between farmers and public extension services.	2.6	0.97	65	Moderate
Barriers overall	**32.5**	**1.85**	**90.27**	**High**

4.5 Sources of Agricultural Extension Workers' Information on Climate Change

The findings in Figure 10 show the limited access to climate change information of extension agents. Their primary sources of information on climate change were agriculture research centers (72%), subject matter specialists (67%), and social media (60%). Other sources of information for extension workers were television programs (42%), radio programs (38%), agricultural extension officers (38%), agricultural colleges (38%), extension documents and journals (29%), and extension conferences and meetings (15%). This finding aligns with other findings of limited climate change media available to extension workers in Ghana, Anambra State and Nigeria (Ogunlade et al., 2014; Iwuchukwu & Onyeme, 2012).

Figure 10: Climate change information sources for agricultural extension workers (n=52).



Source: Khalil & Thompson (2024).

5.0 Conclusion

As climate change impacts agriculture, agricultural extension workers have an important role in helping farmers mitigate the effects of climate change to improve the nation's food security. This study shows that extension services need to be reformed to help farmers face the reality of new climate risks and opportunities and support long-term agricultural production. Overall, the study found that agricultural extension services are insufficient to the task and have relatively limited involvement in climate change adaptation and mitigation efforts. Many agricultural extension offices have been abandoned, and a new, more functional system needs to be put in place, preferably with NGO and community-led assistance. This programming should not only bring in science-

driven approaches but incorporate farmers' traditional ecological knowledge to develop and implement appropriate mitigation and adaptation strategies.

Small-scale farmers, already marginalized by war and environmental degradation face, the loss of their primary source of income and livelihood with climate change. The impact of climate change and war on agriculture in Yemen is catastrophic for both food security, farmer's livelihoods and food production. Conflict disrupts farming activities and worsens rural community vulnerabilities, while climate change creates extreme weather and amplifies the challenges faced by the agricultural sector. Addressing these intertwined crises requires coordinated efforts to promote peace, resilience, and sustainable development. Investments in conflict resolution, climate adaptation, and agricultural development are essential for building a more resilient and food-secure future for the people of Yemen. As food insecurity remains at a catastrophic level, particularly in rural areas, and disasters are ramping up with climate change, local food production needs to mitigate disasters and food insecurity.

Although agricultural extension workers are knowledgeable about climate change and its impact on agriculture, they require training on climate-smart agriculture to mitigate and adapt. This training is needed to increase resilience in a changing climate. The considerable capacity for solar energy in Yemen must be effectively regulated, considering the potential consequences on groundwater. Further, Yemen's forecasting and early warning systems require improved data collection and communication to enable agricultural extension workers to implement a range of resilience measures and agricultural practices.

References

Abah, R. C. (2014). Rural perception of the effects of climate change in Otukpo, Nigeria. *Journal of Agriculture and Environment for International Development (JAEID)*, *108*(2), 153–166. https://doi.org/10.12895/jaeid.20142.217

Ahmad, Q.-A., Moors, E., Biemans, H., Shaheen, N., Masih, I., & Ur Rahman Hashmi, M. Z. (2023). Climate-induced shifts in irrigation water demand and supply during sensitive crop growth phases in South Asia. *Climatic Change*, *176*(150), 1–22. https://doi.org/10.1007/s10584-023-03629-7

Abegunde, V. O., Sibanda, M., & Obi, A. (2019). Determinants of the adoption of climate-smart agricultural practices by small-scale farming households in King Cetshwayo district municipality, South Africa. *Sustainability*, *12*(1), 195. https://doi.org/10.3390/su12010195

Aklan, M. M., & Lackner, H. (2021, April 22). *Solar-powered irrigation in Yemen: Opportunities, challenges, and policies*. The Sana'a Center for Strategic Studies. https://devchampions.org/uploads/publications/files/Rethinking_Yemens_Economy-policy_brief_22-1.pdf

Alkipsy, E. I. H., Raju, V., & Kumar, H. (2020). A review of the challenges of the energy sector and prospects of renewable energy utilization in Yemen. *Global Journal of Management and Business Research*, *20*(A8).

Al-wesabi, I., Zhijian, F., Bosah, C. P., & Dong, H. (2022). A review of Yemen's current energy situation, challenges, strategies, and prospects for using renewable energy systems. *Environmental science and pollution research international*, *29*, 53907–53933. https://doi.org/10.1007/s11356-022-21369-6

Antwi-Agyei, P., & Stringer, L. C. (2021). Improving the effectiveness of agricultural extension services in supporting farmers to adapt to climate change: Insights from northeastern Ghana. *Climate Risk Management, 32*. https://doi.org/10.1016/j.crm.2021.100304

Arbuckle, J. G., Morton, L. W. & Hobbs, J. (2015). Understanding farmer perspectives on climate change adaptation and mitigation: The roles of trust in sources of climate information, climate change beliefs, and perceived risk. *Environment and Behavior, 47*(2), *205–234*. https://doi.org/10.1177%2F0013916513503832

Azadi, H., Moghaddam S., Burkart, S., Mahmoudi, H., Passel, S., Kurban, A., & Lopez-Carrj, D. (2021). Rethinking resilient agriculture: From climate-smart agriculture to vulnerable-smart agriculture. *Journal of Cleaner Production, 319*, 1–10. https://doi.org/10.1016/j.jclepro.2021.128602

Baig, M. B., Qureshi, A. M., Straquadine, G. S., & Hajiyev, A. (2018). Realizing food security through sustainable agriculture in the Republic of Yemen: Implications for rural extension. In M. Behnassi, O. Pollmann, & H. Gupta (Eds.), *Climate change, food security and natural resource management* (pp. 19–60). Springer.

Breisinger, C., Raouf, M., & Wiebelt, M. (2020, January). *Prioritizing agricultural value chains for reviving the food system in Yemen input for an agricultural strategy update IFPRI*. MENA Policy Note 03. International Food Policy Research Institute. https://doi.org/10.2499/p15738coll2.133552

Burke, M., & Emerick, K. (2016). Adaptation to climate change: Evidence from US agriculture. *American Economic Journal: Economic Policy*, *8*(3), 106–140. http://dx.doi.org/10.1257/pol.20130025

Conflict and Environment Observatory (CEOBS). (2021, April). *Groundwater depletion clouds Yemen's solar energy revolution.* https://ceobs.org/groundwater-depletion-clouds-yemens-solar-energy-revolution/

Christoplos, I., (2010). *Mobilizing the potential of rural and agricultural extension.* Food and Agricultural Organization (FAO) of the United Nations and the Global Forum for Rural Advisory Services (GFRAS). http://www.fao.org/docrep/012/i1444e/i1444e00.pdf

Dagmawi, M., & Padraig, W. (2015). Extension workers' awareness of climate change in Ethiopia, *The Journal of Agricultural Education and Extension, 21*(5), 479–495. https://doi.org/10.1080/1389224X.2014.946936

Davies, M., Oswald, K., & Mitchell, T. (2009). *Climate change adaption, disaster risk reduction, and social protection.* Promoting Pro-Poor Growth: Social Protection (OECD Report). www.oecd.org/dac/povertyreduction/43280946.pdf

Debela, N., Mohammed, C., Bridle, K., & Corkrey, R., & McNeil, D. (2015). Perception of climate change and its impact by smallholders in pastoral/agropastoral systems of Borana, South Ethiopia. *Springer Plus, 4*(1), 236. https://doi.org/10.1186/s40064-015-1012-9

Deutsch, C. A., Tewksbury, J. J., Tigchelaar, M., Battisti, D. S., Merrill, S. C., Huey, R. B., & Naylor, R. L. (2018). Increase in crop losses to insect pests in a warming climate. *Science, 361*(6405), 916–919. https://doi.org/10.1126/science.aat3466

El-Mokhtar, M. A., Anli, M., Laouane, R. B., Boutasknit, A., Boutaj, H., Draoui, A., Zarik, L., & Fakhech, A. (2019). Food security and climate change. In K. Kahime, M. A. El Hidan, O. El Hiba, D. Sereno, & L. Bounoua (Eds.), *Handbook of research on global environmental changes and human health.* (pp. 53–73). IGI Global. doi:10.4018/978-1-5225-7775-1.ch004

FAO. (2024, April 25). Agrometeorological Early Warning Bulletin: Early warning: Risk of flash floods increasing due to enhanced rain. *reliefweb.* https://reliefweb.int/report/yemen/agrometeorological-early-warning-bulletin-early-warning-risk-flash-floods-increasing-due-enhanced-rain-21-30-april-2024-enar

FAO. (2021). The state of food and agriculture 2021: Making agrifood systems more resilient to shocks and stresses. *FAO*. https://doi.org/10.4060/cb4476en

FAO. (2020). The state of food security and nutrition in the world 2020. Transforming food systems for affordable healthy diets. *FAO*. http://www.fao.org/3/ca9692en/ca9692en.pdf

FAO, IFAD, UNICEF, WFP, & WHO. (2018). *Climate-smart agriculture training manual − A reference manual for agricultural extension workers.* FAO. http://www.fao.org/3/ca2189en/CA2189EN.pdf

FAOSTAT. (2021). FAO food and agriculture data. *FAO*. https://www.fao.org/faostat/en/#home

Fevari, E., Geiger, M. Krishnaswamy, S., & Tandon, S. (2021). *The 2020 food security crisis in Yemen.* World Bank. https://thedocs.worldbank.org/en/doc/70c4a9845ac4bc5f5a857cbb943054de-0280012022/original/Food-Security-Crisis.pdf

Giovetti, O. (2024, April 3). The crisis in Yemen, explained five things you need to know in 2024. https://concernusa.org/news/yemen-crisis-explained/

Habib-ur-Rahman, M., Ahmad, A., Raza, A., Hasnain, M. U., Alharby, H. F., Alzahrani, Y. M., Bamagoos, A. A., Hakeem, K. R., Ahmad, S., Nasim, W., Ali, S., Mansour, F. & EL Sabagh, A. (2022). Impact of climate change on agricultural production; Issues, challenges, and opportunities in Asia. *Frontiers in Plant Sci*ence, *13*, 1–12. https://doi.org/10.3389/fpls.2022.925548

Haigh, T., Morton, L., Lemos, M., Knutson, C., Prokopy, L., Lo, Y., & Angel, J. (2015). Agricultural advisors as climate information intermediaries: Exploring differences in capacity to communicate climate. *Journal of Weather, Climate, and Society*, *7(*1), 83–93. https://doi.org/10.1175/WCAS-D-14-00015.1

Homaid, M., (2023). Communities bring life back to lands destroyed by the impacts of climate change. *International Organization for Migration (IOM) Yemen.* Communities Bring Life Back to Lands Destroyed by the Impacts of | IOM Yemen

International Committee of the Red Cross (ICRC). (2023). Making adaptation work: Addressing the compounding impacts of climate change, environmental degradation, and conflict in the Near and Middle East. *International Committee of the Red Cross.* https://www.icrc.org/en/document/report-impact-climate-change-and-armed-conflict-near-and-middle-east

International Labour Organization (ILO). (2016). Yemen damage and needs assessment: Crisis impact on employment and labour market. *International Labour Organization*. https://www.ilo.org/publications/yemen-damage-and-needs-assessment-crisis-impact-employment-and-labour

Integrated Food Insecurity Phase Classification (IPC). (2024, February 2024). Yemen: Acute food insecurity projection update October 2023 - February 2024. *IPC*. Yemen: Acute Food Insecurity Projection Update October 2023 - February 2024 | IPC - Integrated Food Security Phase Classification (ipcinfo.org)

Integrated Food Insecurity Phase Classification (IPC). (2022, March). Yemen: Food security & nutrition snapshot. *IPC*. https://www.ipcinfo.org/fileadmin/user_upload/ipcinfo/docs/IPC_Yemen_Food_Security_Nutrition_2022March_Snapshot_English.pdf

Intergovernmental Panel on Climate Change (IPCC). (2022). *Climate change 2022: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press. https://doi.org/10.1017/9781009325844

International Finance Corporation (IFC). 2021, January 21. In Yemen, solar power has become a lifeline. *IFC*. https://www.ifc.org/en/stories/2021/202101-yemen-solar#:~:text=More%20than%2050%20percent%20of,to%20scale%20up%20its%20use.%22

Iwuchukwu, J. C., & Onyeme, F. N. (2012). Awareness and perceptions of climate change among extension workers of agricultural development programme (in Anambra State, Nigeria. *Journal of Agricultural Extension, 16*(2), 104–118. http://dx.doi.org/10.4314/jae.v16i2.9

Karimi, V., Karami, E., & Keshavarz, M. (2018). Climate change and agriculture: Impacts and adaptive responses in Iran. *Journal of Integrative Agriculture, 17*(1), 1–15. https://doi.org/10.1016/S2095-3119(17)61794-5

Khalid, S. M. N., & Sherzad, S. (Eds.). (2019). *Agricultural Extension Manual*. FAO.

Lipper, L., & Zilberman, D. (2018). A short history of the evolution of the climate smart agriculture approach and its links to climate change and sustainable agriculture debates. In L. Lipper, N. McCarthy, D. Zilberman, S. Asfaw, & G. Brance (Eds.), *Climate smart agriculture: Building resilience to climate change* (pp. 13–30). Springer. https://doi.org/10.1007/978-3-319-61194-5_2

McCarthy, N., Cavatassi, R., & Maggio, G. (2022). *The impact of climate change on livestock production in Mozambique*. IFAD Research Series 88. IFAD. https://www.ifad.org/en/web/knowledge/-/ifad-research-series-no.-88-the-impact-of-climate-change-on-livestock-production-in mozambique?p_l_back_url=%2Fen%2Fweb%2Fknowledge%2Fpublications%3Fmode%3Dsearch%26keywords%3Dvalue%2520chain

Metz, B., Davidson, O., Bosch, P., Dave, R., & Meyer, L. (Eds.). (2007). *Climate change 2007: Mitigation of climate change. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Intergovernmental Panel on Climate Change. Cambridge University Press. https://www.ipcc.ch/site/assets/uploads/2018/03/ar4_wg3_full_report-1.pdf

Mulhern, O. (2021). Mapping the shocking extent of desertification. *EARTH ORG.* https://earth.org/data_visualization/how-desertification-has-affected-these-9-countries-since-1984/

Mundy, M. (2018, October 9). Strategies of the coalition in the Yemen war: Aerial bombardment and food war. *reliefweb.* https://reliefweb.int/report/yemen/strategies-coalition-yemen-war-aerial-bombardment-and-food-war

Mundy, M. (2017, April). *The war on Yemen and its agricultural sector*. Paper #50. https://www.elikadura21.ehnebizkaia.eus/wp-content/uploads/2017/04/50-Mundy.pdf

MAI (2021). *Annual statistics book.* Ministry of Agriculture and Irrigation.

Makuvaro, V., Walker, S., Masere, T. P., & Dimes, J. (2018). Smallholder farmer perceived effects of climate change on agricultural productivity and adaptation strategies. *Journal of Arid Environments, 152*, 75–82. https://doi.org/10.1016/j.jaridenv.2018.01.016

Maponya, P., & Mpandeli, S. (2013). The role of extension services in climate change adaptation in Limpopo province, South Africa. *Journal of Agricultural Extension and Rural Development, 5*(7), 137–142. DOI: 10.5897/JAERD12.117

Oakley, P., & Garforth, C. (1985). *Guide to extension training*. Food and Agricultural Organization of the United Nations. https://www.fao.org/3/T0060E/T0060E00.htm

Abdulwahab, A., & Mensah, A. O. (2014). Knowledge levels of extension workers and their perceived impact of climate change on extension service provision in Ghana. Ethiopian *Journal of Environmental Studies & Management, 7(1),* 96–103. http://dx.doi.org/10.4314/ejesm.v7i1.12

Pearce, F. (2024, February 27). How a solar revolution in farming is depleting world's groundwater. *Yale Environment 360. https://e360.yale.edu/features/solar-water-pumps-groundwater-crops*

Philip, K. A. (2024). *The socioeconomic impact of climate change in developing countries in the next decades: A review*. CGD Working Paper 681. Center for Global Development. https://www.cgdev.org/publication/socioeconomic-impact-climate-change-developing-countries-next-decades

Price, R. A. (2022, May 27). *Climate change risks and opportunities in Yemen.* K4D Helpdesk Report 1168. Institute of Development Studies. doi: 10.19088/K4D.2022.096

Red Cross Red Crescent Climate Centre (RCRCCC). (2024). Climate fact sheet 2024 - Yemen. *Red Cross Red Crescent Climate Centre*. https://www.climatecentre.org/wp-content/uploads/RCCC-ICRC-Country-profiles-Yemen_2024_final.pdf

Rouabhi, A., Hafsi, M., & Monneveux, P. (2019). Climate change and farming systems in the region of Setif (Algeria). *Journal of Agriculture and Environment for International Development (JAEID), 113(1).* https://doi.org/10.12895/jaeid.20191.928

Ruijs, A., de Bel, M., Mekonen, A., Linderhof, V. & Polman, N. (2011). *Adapting to climate variability: learning from past experience and the role of institutions*. Social Development Working Paper, No. 124. World Bank. http://hdl.handle.net/10986/26896

Schulman, S. (2021). Yemenis' daily struggles between conflict and climate change. *The RUSI Journal, 166* (1), 82–92. https://doi.org/10.1080/03071847.2021.1922196

Shah, T., & Kishore, A. (2012). Solar-powered pump irrigation and India's groundwater economy: A preliminary discussion of opportunities and threats. *IWMI-TATA water policy research highlight.* https://www.iwmi.cgiar.org/iwmi-tata/PDFs/2012_Highlight-26.pdf

Tamdeen Youth Foundation, & Oxfam. (2022, December). *A research study on climate changes and local preparedness in the districts of Al-Ma'afer, Taiz Governorate, Yemen*. https://tamdeen-ye.org/upfiles/publications/TYF-2023-02-26-61877.pdf

Thiombiano, B. A., Ouédraogo, D., Bao Le, Q., & Nii Odai, S. (2018). Role of climate change awareness in sustainable soil nutrient management by smallholder farms in Burkina Faso. *African Journal of Agricultural Research*, *13*(6), 294–301. https://dx.doi.org/10.5897/AJAR2017.12939

Thomas, E. (2022, February). *Food security in Yemen: The role of the private sector in promoting domestic food production*. Working paper 2. ODI. http://www.odi.org/en/publications/food-security-in-yemen/

Turyasingura, B., Ayiga, N., Tumwesigye, W. & Philip, H. J. (2023). Climate smart agriculture (CSA) for sustainable agriculture nexus: a tool for transforming food systems. *Turkish Journal of Agriculture - Food Science and Technology*, *11*(6), 1195–1199. https://doi.org/10.24925/turjaf.v11i6.1195-1199.5591

United Nations Development Programme (UNDP). (2024, February 13). Building resilience: Supporting farmers to face the impact of climate change in Yemen: FSRRP interventions transform agricultural production in Yemen. https://www.undp.org/arab-states/stories/building-resilience-supporting-farmers-face-impact-climate-change-yemen

United Nations Development Programme (UNDP). (2023, November 29). The impact of climate change on human development in Yemen. *The United Nations Development Programme.* https://www.undp.org/arab-states/publications/impact-climate-change-human-development-yemen

United Nations (UN). (2022, July 5). *Country programme document for Yemen (2023–2024). DP/DCP/YEM/3*. Executive Board of the United Nations Development Programme, the United Nations Population Fund and the United Nations Office for Project Services. https://www.undp.org/sites/g/files/zskgke326/files/2022-09/yemen_cpd_2023-2024.pdf

United Nations (UN). (2019). Humanitarian crisis in Yemen remains the worst in the world, warns UN. *United Nations News.* https://news.un.org/en/story/2019/02/1032811

United Nations Development Programme (UNDP). (2023, November 29). The impact of climate change on human development in Yemen. *The United Nations Development Programme*. https://www.undp.org/yemen/publications/impact-climate-change-human-development-yemen

United Nations Development Programme (UNDP). (2024, February 13). Building resilience

United Nations Development Programme (UNDP). (2014, January). *Prospects of solar energy in Yemen*. UNDP-Yemen. https://www.undp.org/sites/g/files/zskgke326/files/migration/ye/UNDP-YEM-Prospects-of-Solar-Energy-in-Yemen--Policy-Note1.pdf

United Nations High Commissioner for Refugees (UNHCR). (2024, March 21). Yemen crisis explained. *UNHCR.* https://www.unrefugees.org/news/yemen-crisis-explained/

United Nations Population Fund (2023). World population dashboard - Yemen. *UNFPA.* https://www.unfpa.org/data/world-population/YE

United States Agency for International Development (USAID). (20). Climate change risk profile -Yemen. *USAID*. https://www.usaid.gov/yemen/our-work

Van Den Ban, A. W., & Hawkins, H. S. (1996) *Agricultural extension* (2nd ed.). Blackwell Science Ltd.

Walthall, C. L., Hatfield, J., Backlund, P., Lengnick, L., Marshall, E., Walsh, M., Adkins, S., Aillery, M., Ainsworth, E. A., Ammann, C., Anderson, C. J., Bartomeus, I., Baumgard, L. H., Booker, F., Bradley, B., Blumenthal, D. M., Bunce, J., Burkey, K., Dabney, S. M., … Ziska, L. H., (2012). *Climate change and agriculture in the United States: Effects and adaptation.* USDA Technical Bulletin 1935. https://www.usda.gov/sites/default/files/documents/CC%20and%20Agriculture%20Report%20(02-04-2013)b.pdf

Wheeler, T., & von Braun, J. (2013). Climate change impacts on global food security. *Science*, *341*(6145), 508–513. https://doi.org/10.1126/science.1239402

Wilson K. R., & Mukembo, S. C. (2023). I talk to producers like I'm a producer: Exploring extension professionals' perceptions and framing of climate change. *Advancements in Agricultural Development, 4*(4), 24–38. https://doi.org/10.37433/aad.v4i4.377

World Bank. (2023). *Climate risk country profile: Yemen* [Report]. World Bank Group. https://climateknowledgeportal.worldbank.org/sites/default/files/country-profiles/16696-WB_Yemen%20Country%20Profile-WEB.pdf

World Bank. (2010). *Yemen aassessing the impacts of climate change and variability on the water and agricultural sectors and the policy implications*. [Report No. 54196-YE]. World Bank. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/979121468153566240/yemen-assessing-the-impacts-of-climate-change-and-variability-on-the-water-and-agricultural-sectors-and-the-policy-implications

World Food Program (WFP). (2023, May 25). Yemen situation report #4, April 2023. *reliefweb.* https://reliefweb.int/report/yemen/wfp-yemen-situation-report-4-april-2023

World Food Program (WFP). (2023). Yemen emergency. *WFP*. https://www.wfp.org/emergencies/yemen-emergency

Xinhua. (2023, September 15). Farmers reel from drought as climate change takes toll in war-torn Yemen. https://www.bignewsnetwork.com/news/273967521/farmers-reel-from-drought-as-climate-change-takes-toll-in-war-torn-yemen

Yemen Family Care Association (YFCA). (2023, September 23). Climate change impacts on Yemen and adaptation strategies. *eliefweb*. https://reliefweb.int/report/yemen/climate-change-impacts-yemen-and-adaptation-strategies

Yuan, X., Li, S., Chen, J., Yu, H., Yang, T., Wang, C., Huang, S., Chen, H., & Ao, X. (2024). Impacts of global climate change on agricultural production: A comprehensive review. *Agronomy*, *14*(7), 1360. https://doi.org/10.3390/agronomy14071360