The influence of Climate Change on Wheat Production

A review study on Northeast Syria.

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North East Syria (NES)
FOOD SECURITY & LIVELIHOODS
Agriculture Working Group

iMMAP

Executive Summary

Climate change is widely recognized as a global threat to humans and the environment. As part of the monitoring and evaluation activity on wheat production in Northeast Syria (NES), the NES FSL Cluster assigned iMMAP to do a review study on the impact of climate change on wheat production in NES. The study exclusively adopted the qualitative secondary data collection and analysis techniques that included a systematic desk review of all key documents generated by authoritative sources including but not limited to UN agencies and Humanitarian partners operating in NES. Study findings highlighted that the average temperature has been rising in NES, and the region is now approximately 0.8°C hotter today than it was 100 years ago[1] with a decreased mean rainfall of about 18 mm per month per century[2]. Despite the agricultural input support to farmers, poor rainfall and the climate-induced aridity conditions had severe negative impacts on wheat grain harvests, causing cycles of wheat crop failures across NES. Climate change exacerbates the challenge of crop pests and diseases causing a reduction in wheat crop yields and loss of wheat crop produce. Focus group discussions led by REACH with key informants knowledgeable about wheat production, said that farmers predict devastating wheat yield losses due to climatic factors that include drought-like conditions and rising temperatures that also increase the likelihood of pre-harvest wheat crop fires. Most secondary sources reported that farmers in NES demonstrated limited understanding of and access to many other climate change adaptation options like access to accurate weather and climate forecasting information, limited knowledge of soil and water conservation techniques like zero tillage, and lack of knowledge of the importance of timeliness of operations on varying planting dates given the changing climate.

Summary results from the household survey in NES by the FAO Crop and Food Security Assessment Mission to the Syrian Arab Republic in 2021, recorded that about 16 percent of the interviewed farmers could not access any source of irrigation water, therefore, adopting rainfed agriculture only in the 2020/21 season[3]. However, more than half of the farmers who were able to secure water to irrigate their crops agreed that the availability of irrigation water from all sources decreased compared to the previous seasons. Decreased availability of irrigation water was partially attributed to the lack of rain and decreasing water table, but also due to the scarcity and unaffordable prices of fuel needed to operate water pumps. Climate-induced aridity that causes diminishing surface water levels in rivers, streams, and dams compounded by other factors like pest and diseases, high cost of production inputs, prohibitive high fuel price, dilapidated public irrigation infrastructure, led to diminishing returns in wheat production in NES. For instance, taking wheat production records for the past five years with the changing climate; compared to the best winter cropping season of 2019/2020 production figures, the 2020/2021 wheat production in Al-Hassakeh governorate was only 26 percent of the 804, 700 tons of wheat grain produced in the 2019/2020 season in the same governorate [4].

1 World Bank Group. Turn down the heat: Confronting the new climate normal. Washington, DC: World Bank Group, 2014. https://openknowledge.worldbank.org/handle/10986/2059

2 United States Agency for International Development (USAID). Climate change risk profile: Syria – Country overview,2017.https://www.climatelinks.org/sites/default/files/asset/document/2017_USAID_GEMS_Climate%20Change%20Risk%20

3 FAO Crop and Food Security Assessment Mission to the Syrian Arab Republic of 2021. https://reliefweb.int/report/syrian-arab-republic/special-report-2021-fao-crop-and-food-supply-assessment-mission-syrian

4 FAO/WFP Crop and Food Security Assessment Mission to the Syrian Arab Republic of 2018 & 2019, and the FAO Crop and Food Security Assessment Mission to the Syrian Arab Republic of 2021

Whereas, for Ar-Raqqa governorate, wheat grain produced in 2020/2021 season was only 35% of the wheat production levels of the 2019/2020 winter season. Furthermore, compared to the 2019/2020 production figures, the 2020/2021 wheat production in Deir-ez-Zor governorate was only 21 percent of the 221,900 tons of wheat grain produced in the same governorate. Despite all the challenges generated by the protracted crisis, coupled with the impact of years of climate-induced aridity, wheat production continues to play an essential role in NES, where it is a productive pillar of the economy, a key source of livelihood, and a critical economic safety net for poor households. There is still some hope. A diverse group of international organizations, local academics, community representatives, and civil society groups met at the first International Water Forum in Al-Hassakeh in September 2021 to discuss causes of and solutions to water insecurity, declining agriculture, and water pollution. Several communities across the NES have launched or expanded successful tree planting projects, and there is growing interest from local activists in environmental research and climate change. These initiatives and interested parties could provide useful entry points to deeper and more meaningful environmental protection, food and water security action if effectively supported to ensure the adoption of climate change adaptation and mitigation measures to promote food security and livelihood restorations.

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List of Acronyms

AWG	Agriculture Working Group
FAO	Food and Agriculture Organization
FSL	Food Security and Livelihood
GDO	Global Drought Observatory
ND-GAIN	Notre Dame Global Adaptation Initiative
NDVI	Normalized Difference Vegetation Index
NES	Northeast Syria
PQRS	Preview, Question, Read and Summarize
UN	United Nations
WFP	World Food Program

DISCLAIMER

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Cover Photo: Daniela Sala/DW

Introduction

Climate change is widely recognized as a global threat to humans and the environment. Even before the current crisis in the Syrian Arab Republic, the government was concerned about the impact of climate change – extreme weather events of rising temperatures and reduced and/or more erratic rainfall affecting water resources, wheat production and rural livelihoods[5]. Eleven years of the crisis have seen the damage to irrigation infrastructure, overgrazing, wildfires, vegetation damage and soil erosion, all confounded with induced climate aridity to negatively affect wheat production in northeast Syria (NES). Despite all the challenges generated by the protracted crisis, coupled with the impact of years of drought-like conditions from 2006 to 2009, 2014, 2017/2018 and in 2020/2021 agricultural seasons[6] and the increasing pressure on scarce natural resources, the agriculture sector and wheat production continue to play an essential role in NES, where it contributes as a productive pillar of the economy, a key source of livelihoods and a critical economic safety net for poor households[7]. The wheat production system, though severely weakened, is still in operation and it provides a platform on which to build recovery and resilience, and to mitigate some drivers of distress migration[8].

Climatic shocks and vulnerabilities may still be manageable, but improvements in readiness are urgently needed to face a climate-resilient and low-carbon future. At the same time, there is still a high level of ambition in NES to scale up climate change adaptation measures to improve wheat production. A review of wheat grain yield and availability is critical to inform program design or redesigns, implementation strategies on wheat farmers support in NES to sustain food security and livelihood restoration interventions. As part of the monitoring and evaluation activity by the NES FSL Agriculture Working Group, with the end of the 2020/2021 harvesting season, it was imperative that iMMAP was assigned to do a preliminary assessment review of the changing climate and its influence on wheat production in NES.

Study objectives

The overall aim of the study was to review and assess the influence of climate shocks on wheat crop production and yield productivity in NES. Specific study objectives were:

- To document an overview of the climate change experienced in the wheat farming environment of NES
- To review and document the impact of climate change on selected wheat farming practices in NES.
- To review the influence of climate shocks on wheat production and wheat grain yield in NES
- To recommend context-specific opportunities for relevant stakeholders and local farmers' adoption of climate change adaptation measures to improve wheat farming productivity.

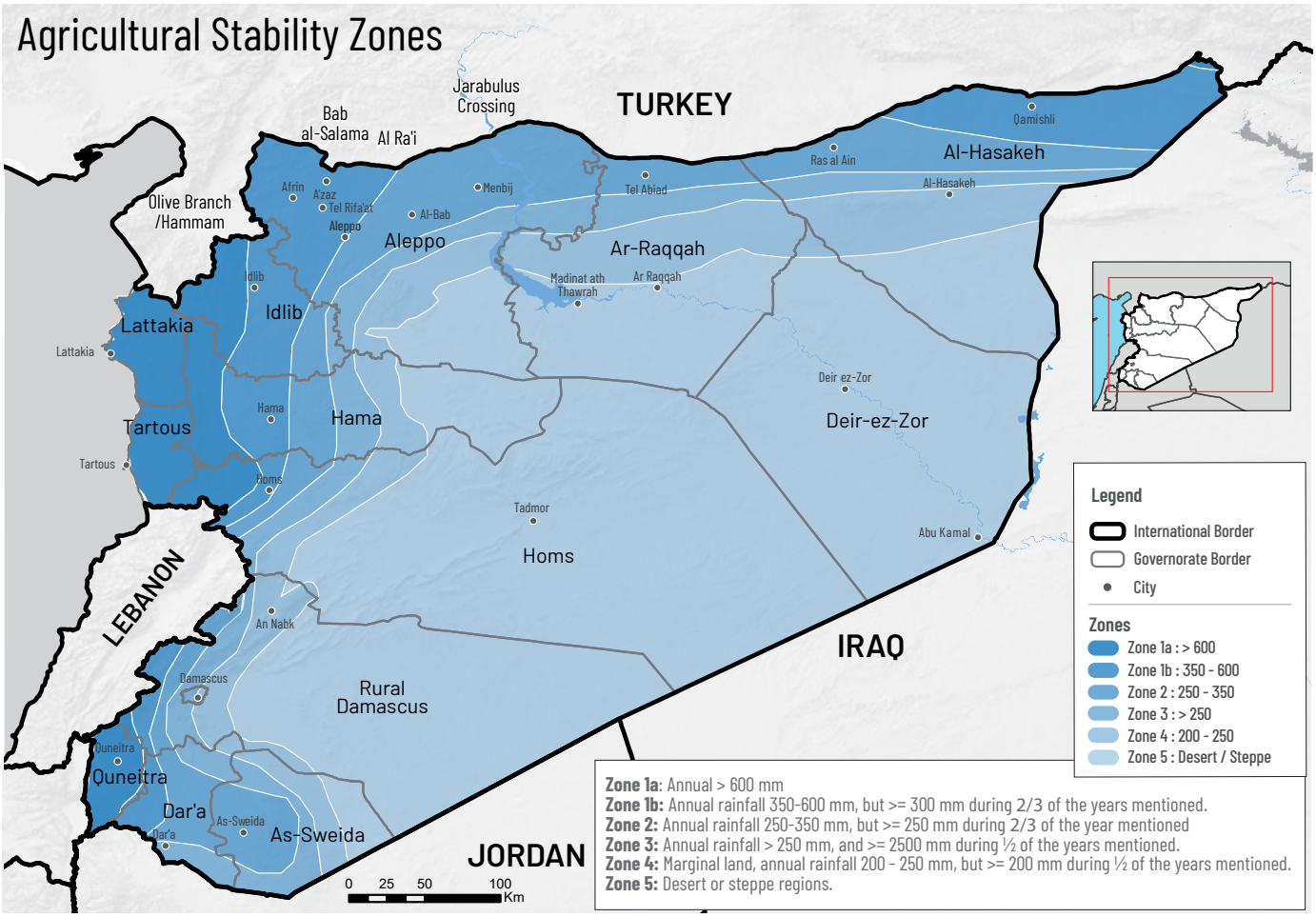
5 https://www.fao.org/emergencies/fao-in-action/stories/stories-detail/en/c/1202263/

6 https://www.preventionweb.net/publication/gdo-analytical-report-drought-syria-and-iraq-april-2021

7 Francesca de Châtel, 2014. The Role of Drought and Climate Change in the Syrian Uprising: Untangling the Triggers of the Revolution, Middle Eastern Studies, DOI: 10.1080/00263206.2013.850076

8 FAO Syria, GIEWS Country Brief, The Syrian Arab Republic, May 2021

Figure 1: *Agroclimatic-Ecological Zones map of Syria showing the study location of NES made up of the governorates of Al-Hassakeh, Ar-Raqqa and Deir-ez-Zor*[9]



Methodology

The study review exclusively adopted the qualitative secondary data collection and analysis techniques that included a systematic desk review of all key documents generated by authoritative sources including but not limited to UN agencies (WFP, FAO, UNHCR, UNDP); NES Food Security and Livelihood (FSL) Cluster, NES Agricultural Working Group (AWG), REACH Syria, ACTED Syria, iMMAP and other humanitarian partners in NES. This review study was approached from a historical perspective to allow for the tracking and evaluation of the wheat production in NES for the past five years including the 2020/2021 winter cropping season. This review study focused on reports of original research articles and reports gathered from humanitarian partners in Syria [see footnote reference list]. To ensure relevance of gathered information, each article, especially the abstract/executive summary, was examined using the preview, question, read and summarize (PQRS) system outputs for review analysis[10]. At the preview stage of PQRS, articles whose abstracts/executive summary were considered relevant to the study objectives were selected for literature review.

9 Northeast Syria Crop Monitoring and Food Security Situation Update: Impact of low rainfall and other crop stressors on winter crops - iMMAP Data Cube; Food Security and Livelihoods (FSL) Sector- Northeast Syria and iMMAP Food Security Analysis and Geoinformatics Units May 26, 2021

10 Cohen G (1990) Memory. In: Roth I, ed. The Open University's Introduction to Psychology. Volume 2. Milton Keynes, Lawrence Eribaum: pp. 570–620

Data analysis

After the preview stage of PQRS, a meta-synthesis technique was used to evaluate, analyze and interpret the study findings from the literature review. According to Polit and Beck (2006), meta-synthesis involves analyzing and synthesizing key elements in each study and transforming the findings into new conceptualizations and interpretations[11]. Using this analysis, findings were presented based on the afore stated study objectives.

Study findings

Overview of climate change in NES

Syria ranks 146 out of 181 countries in the Notre Dame Global Adaptation Initiative (ND-GAIN) index. The ND-GAIN index summarizes a country's vulnerability to climate change and other global challenges in combination with its readiness to improve resilience. This ranking indicates that Syria and with no exception of NES has high vulnerability levels and low levels of readiness to adapt to climate change[12]. Furthermore, an extrapolation of the climatic data and indicators suggest that in the long term there is a likelihood that the NES will experience drought once every three years[13]. Table 1 presents that climate forecasting suggests that rains will become less frequent, and groundwater will become more limited and contaminated. With a reduction in rainfall and decreased mountain runoff, rivers will flow at lower levels, leaving even less water available for wheat production[14].

Table 1: *Climate change in Northeast Syria*[15]

Historical climate	Projected climate
Temperature	
Average temperatures have been rising in NES, and the region is now approximately 0.8°C hotter today than it was 100 years ago[16].	Temperatures will continue to rise in NES and are expected to be at least 2°C higher by 2050[17]. This will be associated with a decrease in the number of frost days and an increase in heat extremes.
NES has experienced heatwaves in the recent past, with temperatures 8–10°C higher than usual[18].	Models predict that extreme temperatures will increase, and the hottest day of the year could be 4-10°C hotter by the end of this century, depending on the magnitude of global climate change[19].

11 Polit, D.F., Beck, C. T and Hunger, B. P. 2006. Essentials of nursing research methods, appraisal and utilization (6th e.d)Philadelphia: Lippinott Williams and Wilkins.

12 https://gain.nd.edu/our-work/country-index/

13 World Bank Group. 2016. "Syria." Climate Change Knowledge Portal. http://sdwebx.worldbank.org/climateportal/countryprofile/home.cfm?page=country_profile&CCode=SYR&ThisTab=ClimateFuture

14 Syrian Centre for Policy Research. 2016. Syria: Confronting Fragmentation! http://www.sy.undp.org/content/syria/en/home/library/poverty/confronting-fragmentation.html

15 https://www.climatecentre.org/wp-content/uploads/RCCC-ICRC-Country-profiles-Syria.pdf

16 World Bank Group. Turn down the heat: Confronting the new climate normal. Washington, DC: World Bank Group, 2014. https://openknowledge.worldbank.org/handle/10986/2059

17 World Bank Group. Turn down the heat: Confronting the new climate normal. Washington, DC: World Bank Group, 2014. https://openknowledge.worldbank.org/handle/10986/2059

18 United States Agency for International Development (USAID). Climate change risk profile: Syria – Country overview,2017.https://www.climatelinks.org/sites/default/files/asset/document/2017_USAID_GEMS_Climate%20Change%20Risk%20

19 World Bank Group. Turn down the heat: Confronting the new climate normal. Washington, DC: World Bank Group, 2014. https://openknowledge.worldbank.org/handle/10986/2059

Historical climate	Projected climate
Rainfall and water	
There has been a trend towards warmer and drier conditions in the Eastern Mediterranean, and this is seen as the main reason behind the intensity and high frequency of droughts in NES[20]. Decreased mean rainfall of 18.23 mm per month per century[21].	Several studies on NES suggest that both the frequency and intensity of droughts will increase as global temperatures rise. Increase in the number of consecutive dry days by 5 and decrease in annual frost days by 13. "With much of the infrastructure dilapidated and minimal maintenance because of the conflict, NES is more vulnerable than ever to future climate-influenced shocks"[22].
While there have been more frequent droughts in the recent past, some seasons have also recorded extra rainfall or flooding[23].	While a few climate models show a possibility of increased rainfall, most of them show an overall decrease, especially in the winter. In NES, precipitation has been projected to decrease by 11 per cent over the next three decades, especially in the winter, spring and fall[24]. Decrease in runoff by 25-27 percent. Precipitation decrease most pronounced from September to November and from March to May.
Dust storms are a regular phenomenon in NES, with a particularly large storm causing destruction in 2015 that was likely caused by a period of extremely hot and dry weather[25]. These storms can originate from deserts across the region and have different microbes and characteristics[26].	Since dust storms happen during times of extreme heat and dryness, it is likely that climate change exacerbates the conditions that allow large dust storms to form[27].

According to the University of East Anglia Climatic Research Unit (UEA, CRU) and the Global Historical Climatology Network data from the stations which were in Deir ez-Zor on the Euphrates River and Kamishli near the Turkish border - the century-long observed trends in rainfall/precipitation, temperature, and sea-level pressure, supported by climate model results, strongly suggest that the climate is changing towards an increasingly drier and hotter climate for Syria, and NES is no exception . Erratic rainfall pattern and warmer winter temperatures are detrimental to winter wheat crop productivity. Winter crop physiology thrive well under cold temperatures which favors wheat tillering and its reproductive phase of crop development.

20 Kelley, Colin P. 'Climate change in the fertile crescent and implications of the recent Syrian drought' in Proceedings of the National Academy of Sciences of the United States of America (PNAS), 2015. http://www.pnas.org/ content/112/11/3241.full.pdf?with-ds=yes

21 United States Agency for International Development (USAID). Climate change risk profile: Syria – Country overview,2017.https://www.climatelinks.org/sites/default/files/asset/document/2017_USAID_GEMS_Climate%20Change%20Risk%20

22 United States Agency for International Development (USAID). Climate change risk profile: Syria – Country overview,2017.https://www.climatelinks.org/sites/default/files/asset/document/2017_USAID_GEMS_Climate%20Change%20Risk%20

23 Selby, J., Dahi, O., and Hulme, M. 'Climate Change and the Syrian civil war revisited', in Political Geography, Vol. 60, pp. 232-244, 2017. https://www.sciencedirect.com/science/article/pii/S0962629816301822

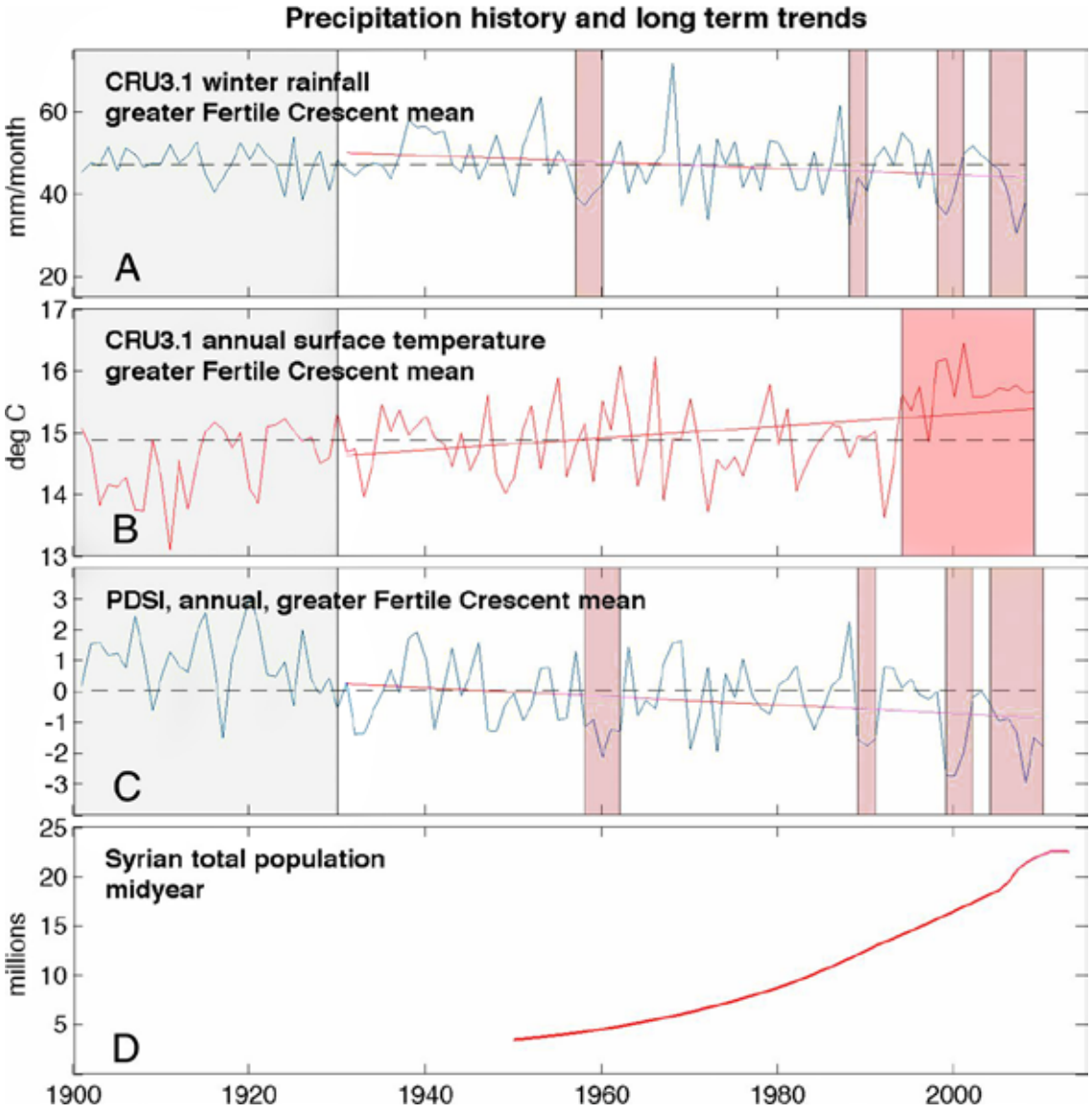
24 United States Agency for International Development (USAID). Climate change risk profile: Syria – Country overview,2017.https://www.climatelinks.org/sites/default/files/asset/document/2017_USAID_GEMS_Climate%20Change%20Risk%20

25 Parolari, A.J., Li, D., Bou-Zeid, E., Katul, G.G. and Assouline, S. 'Climate, not conflict, explains extreme Middle East dust storm' in Environmental Research Letters, Vol. 11(11), 2016. https://doi.org/10.1088/1748-9326/11/11/114013

26 Gat, D., Mazar, Y., Cytryn, E. and Rudich, Y. 'Origin-dependent variations in the atmospheric microbiome community in eastern Mediterranean dust storms' in Environmental Science and Technology, Vol. 51(12), pp. 6709–6718, 2017. https://doi.org/10.1021/acs.est.7b00362

27 Parolari, A.J., Li, D., Bou-Zeid, E., Katul, G.G. and Assouline, S. 'Climate, not conflict, explains extreme Middle East dust storm' in Environmental Research Letters, Vol. 11(11), 2016. https://doi.org/10.1088/1748-9326/11/11/114013

Figure 2: *(A) Six-month winter (November–April mean) Syria area mean precipitation, using Climate Research Unit 3.1 gridded data. (B) Climate Research Unit annual near-surface temperature (red shading indicates persistence above the long-term normal). (C) Annual self-calibrating Palmer Drought Severity Index. (D) Syrian total midyear population. Based on the area mean of the Fertile Crescent as defined by the domain 30.5°N–41.5°N, 32.5°E–50.5°E.*

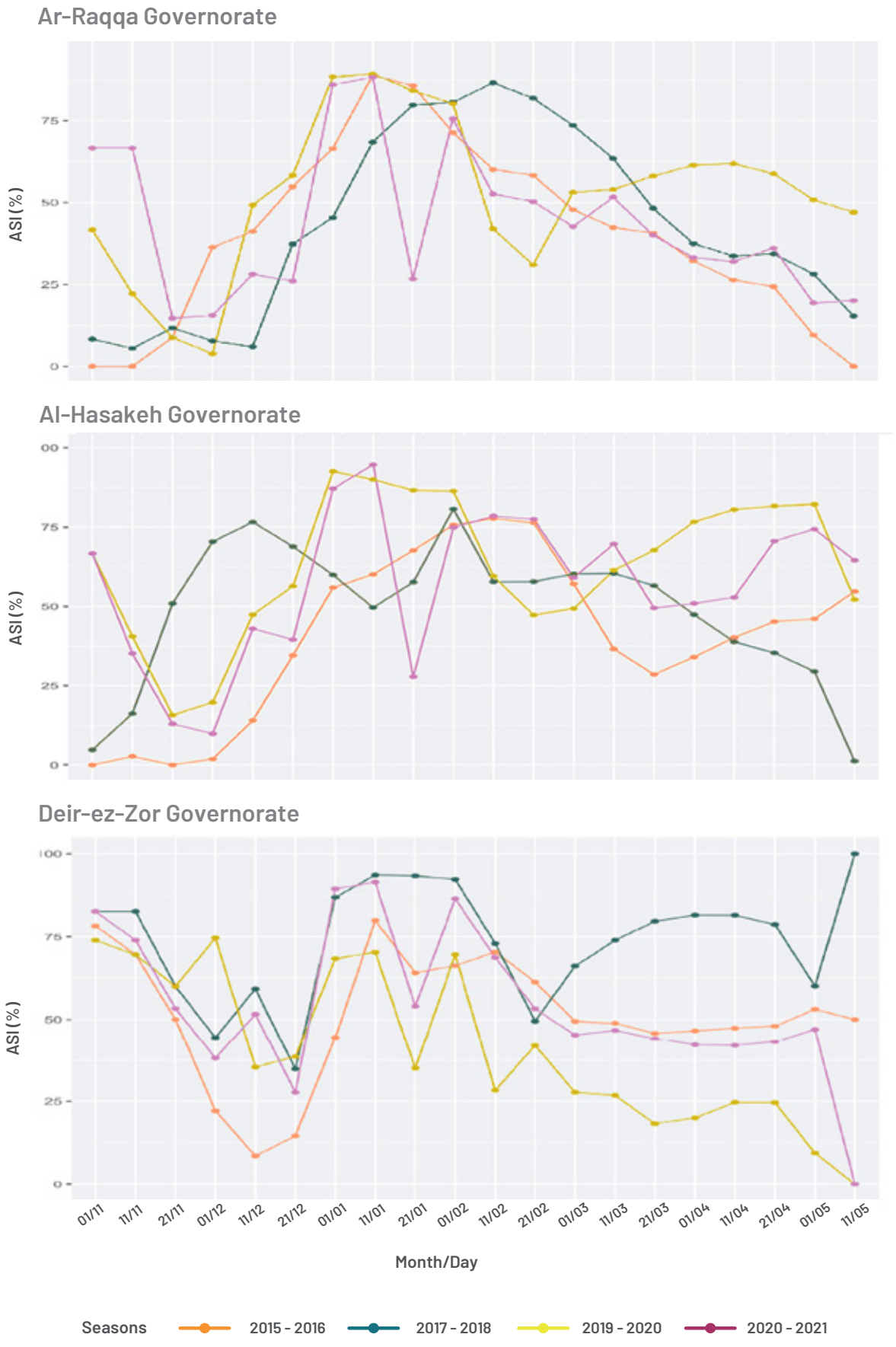


Agricultural Stress Index in Northeast Syria

FAO's Agricultural Stress Index System (ASIS) monitors climate induced aridity conditions by looking at the Vegetation Health Index based on photosynthetically active radiation. A higher percentage coverage of NES region represents a more severe climate induced aridity resulting in anomalous vegetation growth (Figure 3)[28]. The graphs on figure 3 show the comparison of the ASIS between November and May for the 2020-2021 winter cropping season with the three most similar seasons for Al-Hassakeh, Ar-Raqqa, and Deir-ez-Zor governorates. The ASIS was extremely higher between mid-February and mid-March in Al-Hassakeh and Ar-Raqqa governorates in 2020-2021 compared to 2017-2018. As of mid-April, above-average temperatures exacerbated the impact of the moisture deficit on winter wheat crop that would be at crucial reproductive stages. This climate induced aridity usually coincides with the wheat flowering and grain-filling phases which are particularly sensitive to water scarcity, preventing wheat crop from reaching both physiological and harvestable maturity. In other words, the changing climate resembling high frequencies of drought like conditions in NES is always detrimental and reduces wheat yield across NES.

28 REACH Briefing Note: Humanitarian Situation Overview in Northeast Syria, June 2021.

Figure 3: *Climate induced aridity and Agricultural Stress Index for Al-Hassakeh, Ar-Raqqa and Deir-ez-Zor governorates in Northeast Syria.*



Impact of climate change on selected wheat farming practices in Northeast Syria.

Access to irrigation

Summary results from the household survey in NES by the FAO Crop and Food Security Assessment Mission to the Syrian Arab Republic in 2021, recorded that about 16 percent of the interviewed farmers could not access any source of irrigation water, therefore, adopting rainfed agriculture only in the 2020/21 season[29]. However, more than half of the farmers who were able to secure water to irrigate their crops agreed that the availability of irrigation water from all sources decreased compared to the previous seasons. Decreased availability of irrigation water was partially attributed to the lack of rain and decreasing water table, but also due to the scarcity and unaffordable prices of fuel needed to operate water pumps. Climate induced aridity that causes diminishing surface water levels in rivers, streams and dams compounded by dilapidated public irrigation infrastructure, led to increased dependence on private groundwater wells on which 40 percent of the farmers in NES rely for irrigation (Table 2). However, fuel shortages were singled out as the main obstacle of extracting groundwater.

Table 2: Access to irrigation water supply in Northeast Syria by 2021[30]

Water Source	Farmers using each source		Water was reported to be extremely less available in 2021	
	% of farmers	Most common in the governorate of;	% of Users who reported that	Mostly in the governorate of;
Public Wells	40	Al-Hassakeh	54	Al-Hassakeh
Public Grid	27	Ar-Raqqa	46	Deir-ez-Zor
Rivers and Springs	15	Deir-ez-Zor	46	Ar-Raqqa

Farmers in the areas with difficult access to irrigation water relied on purchasing water in tanks which have become less available and more expensive. A further complication is represented by the international water agreements. Turkey and Syria have a long-standing dispute over the management of the Euphrates River. Those tensions have worsened over the past several decades as average annual flows in the Euphrates at the Turkish–Syrian border have declined substantially since 1990, coinciding with both the completion of the Ataturk Dam and an apparent decrease in precipitation in NES. In NES, the heavy dependence of livelihoods on wheat production means that efforts to improve the productivity of water use to produce higher yields and income with less water will help cut pressure on the shared waters among communities that are experiencing climate change induced aridity.

29 FAO Crop and Food Security Assessment Mission to the Syrian Arab Republic of 2021. https://reliefweb.int/report/syrian-arab-republic/special-report-2021-fao-crop-and-food-supply-assessment-mission-syrian

30 FAO Crop and Food Security Assessment Mission to the Syrian Arab Republic of 2021. https://reliefweb.int/report/syrian-arab-republic/special-report-2021-fao-crop-and-food-supply-assessment-mission-syrian

Pest and disease management

Climate change exacerbates the challenge of crop pests and diseases causing reduction in wheat crop yields and loss of wheat crop produce. In fact, there are many possible pathways through which climate change may affect crop and grain pests, including ecology, spatial distribution, and food chains. Climate change may induce higher metabolic, developmental, survival, and reproductive rates in crop pests. For example, the main effect of temperature in NES may be seen in winter survival. Non-diapausing, frost-sensitive species and those that can overwinter in their active stages, such as the aphid *Myzus persicae*, show increased winter survival in warm winters under wheat production[31]. Host wheat crop tolerance or resistance to pests and diseases may decrease because of climate change. It has been projected that global yield losses of major staple crops such as wheat, rice, and maize due to insects and diseases will increase by 10 to 25 percent for each degree of global mean surface warming[32]. Warm conditions throughout the 2020/21 winter season increased prevalence of pests, diseases and weeds for wheat production, while expensive herbicides and high wage rates of skilled labor applying chemicals constrained farmers' ability to control weeds and favored widespread occurrence of broad-leaved weeds[33]. For the first time in NES, desert locust outbreaks were reported in April 2021. A few small groups of mature adult desert locusts moved northwest along the Euphrates Valley from Al Bukamal to Deir-ez-Zor governorate. The arrival of Desert Locusts was recorded as a single unusual event caused by several days of climate change related strong southerly winds that brought adult groups and swarmlets from infested areas several hundred kilometers to the south in northern Saudi Arabia near Tabuk and Al Jawf[34].

With the changing climate, for the past five years or so in NES, unusual high pest and diseases outbreaks were reported by the FAO/WFP Crop and Food Security Assessment Mission to the Syrian Arab Republic. For instance, despite dry weather conditions, presence of yellow rust (Puccinia striiformis) and wheat burn (Tilletia tritici) was reported on wheat crops in NES's limited areas of Deir-ez-Zor governorate. During the 2018/19 winter season, the unusual humid conditions towards the end of the season favored the spread of yellow rust (Puccinia striiformis) on wheat in NES. In most instances, the infection was below the economic threshold, but the Agricultural Directorate in Hassakeh governorate estimated that yield reduction in the more affected stands of wheat was between 10 and 25 percent. In Hassakeh governorate, the American thistle worm spread up with a record to an estimated 11 percent of the wheat fields in some areas in 2021. Across the NES region, field rodents (meadow voles and field mice) were becoming present in much higher numbers than in the past. It is probable that the weeds, pests and disease incidents will further increase with the changing climate. Wild eggplant (Solanum sp) is becoming a more troublesome weed. Farmers complained that it is difficult to eliminate using the herbicides that are available in the country. Elsewhere in Syria, the spread of voles in Homs was attributed to climate change and the absence of snow or heavy rain, which would contribute to reducing their population, uncontrolled hunting of natural enemies and resulting long-term imbalance in the ecological system. Flocks of storks, migrating from northern Europe to sub-Saharan Africa, used to pass through Homs and feed on the field mice, but in 2020/21 storks appeared in unusually small numbers, presumably due to changes in migration patterns and routes due to climate change[35].

31 Davis J A, Radcliffe E B. Reproduction and feeding behavior of Myzus persicae on four cereals. J. Econ Entomol. 2008 Feb;101(1):9-16. doi: 10.1603/0022-0493(2008)101[9:rafbom]2.0.co;2. PMID: 18330110.

32 https://www.science.org/doi/10.1126/science.aat3466

33 FAO Crop and Food Security Assessment Mission to the Syrian Arab Republic of 2021. https://reliefweb.int/report/syrian-arab-republic/special-report-2021-fao-crop-and-food-supply-assessment-mission-syrian

34 FAO Crop and Food Security Assessment Mission to the Syrian Arab Republic of 2021. https://reliefweb.int/report/syrian-arab-republic/special-report-2021-fao-crop-and-food-supply-assessment-mission-syrian

35 FAO Crop and Food Security Assessment Mission to the Syrian Arab Republic of 2021. https://reliefweb.int/report/syrian-arab-republic/special-report-2021-fao-crop-and-food-supply-assessment-mission-syrian

Climate change has given rise to difficulties in pest and disease monitoring and prediction, due to its alteration of pest and disease behavior and dynamics. Predicting the direct effects of climate change on pests and disease incidences has been further complicated by the interacting influences of the changing climatic regimes and altered frequency and intensity of extreme weather events. Projections have also been challenged by the fact that climate change can exert its effects on pests indirectly. For example, the differing responses of host crops and pest natural enemies, as well as changes in the efficacy of pest control strategies (biological control, synthetic pesticides, etc.), also affect pest responses. The effectiveness of traditional pest and disease control techniques is also challenged by the changing climate. There could be a decrease in host plant resistance, an increase in the pesticide resistance of pests, and a lack of synchronization in the prey-predation system[36]. All the above-mentioned climate induced challenges on pest and disease management in wheat are being exacerbated by the cessation of the government subsidies support on the agriculture transport airport in Abu Haj with the start of the conflict in 2011 and the subsequent stoppage of the aerial chemical sprays for wheat production.

Use of drought tolerant seed varieties of wheat crop

Reduced plant productivity due to climate induced aridity is a major concern for wheat grown in arid and semi-arid areas of NES. Wheat crop growth and photosynthesis are two of the most important processes abolished partially or completely by water stress and both are major causes of decreased wheat crop yield. The best option for crop production, yield improvement, and yield stability under soil moisture deficient conditions is to develop drought tolerant crop varieties. In NES, eight drought tolerant and susceptible durum wheat varieties viz., Cham 1, Cham 3, Cham 5, Cham 6, Hourani and Doma1 (drought tolerant), while ACSAD 65, Bohouth 7 and Bohouth 11 (moderately susceptible to drought) are common wheat cultivars grown in the region[37].

A seed assessment study described the diversity of wheat varieties and landraces available in farmer's fields in NES using different indicators[38]. Analysis of spatial and temporal diversity and coefficient of parentage along with measurements of agronomic and morphological traits were used to explain the diversity of wheat varieties or landraces grown by farmers in NES. Farm-level surveys showed low spatial diversity of wheat seed varieties where only a few dominant varieties occupied a substantial proportion of wheat cropping coverage in NES. The five top wheat varieties (ACSAD 65, Cham 1, Cham 3, Lahan and Cham 6) recorded 81% of the wheat cropping coverage in NES and were reportedly grown by 78% of the sample farmers[39]. An agronomic concern of deviating from the good general agricultural practice in use of open pollinated seed was highlighted by a record of the weighted average age of wheat varieties with an average of 10.8 years showing low temporal diversity by farmers. This was against the rule of thumb that calls for the non-use of open of open pollinated varieties beyond the age of 4 years, in this case the use of OPV (open pollinated varieties) seed not beyond four winter cropping seasons.

36 https://foodtank.com/news/2019/03/climate-change-exacerbates-the-challenge-of-plant-pests/

37 https://www.ccsenet.org/journal/index.php/jas/article/view/12054

38 Zewdie Bishaw, Paul C. Struik, A. J. G. van Gastel. 2015. Wheat and barley seed system in Syria: How diverse are wheat and barley varieties and landraces from farmer's fields. International Journal of Plant Production, 9 (1), pp. 171-150. https://www.icarda.org/publications/2128/wheat-and-barley-seed-system-syria-how-diverse-are-wheat-and-barley-varieties-and

39 Zewdie Bishaw, Paul C. Struik, A. J. G. van Gastel. 2015. Wheat and barley seed system in Syria: How diverse are wheat and barley varieties and landraces from farmer's fields. International Journal of Plant Production, 9 (1), pp. 171-150. https://www.icarda.org/publications/2128/wheat-and-barley-seed-system-syria-how-diverse-are-wheat-and-barley-varieties-and

In NES, bread wheat showed lower average diversity and weighted diversity than durum wheat. The principal component analysis from the referred study explained the variations that existed among modern varieties and landraces[40]. The variation that existed among the landraces showed broad opportunities for use in plant breeding programs to develop varieties suitable for different agro-ecological zones as affected by climate-induced aridity. To date, large areas previously grown to traditional varieties and landraces are now increasingly replaced by contiguous expanse of land planted to uniform modern bread and durum wheat varieties and are grown by considerable number of farmers despite the changing climate that is threatening seed viability on some of the less drought-tolerant varieties. The study by ACTED found that 55% of farmers interviewed reported that they accessed seeds through retaining from granary, while 31% reported that they accessed certified open-pollinated variety seeds. Using retained seeds for several years beyond four years reduces seed viability and can lead to a decrease in agricultural productivity[41]. All farmers reported that the seeds they access are from unreliable sources, with low quality holding a high percentage of foreign materials, impurities, and exotic seeds.

Access to weather and climate information

Most secondary sources reported that farmers in NES proven limited understanding and access of many other climate change adaptation options like access to accurate weather and climate forecasting information, limited knowledge on soil and water conservation techniques like zero tillage, lack of knowledge on the importance of timeliness of operations on varying planting date given the changing climate. During the field work for the FAO 2021 Crop and Food Security Assessment Mission for Syria, farmers in NES mentioned they had been experiencing shifts in the rainy season: the rain now starts after mid-November (used to be in October) and stops in mid-March (used to be until the end of April). They also reported experiencing increased heatwaves and decreased frost frequency. This shift in weather patterns might be worth exploring in a detailed study to fully understand the current situation and allow the implementation of proper climate change adaptation measures to ensure improved wheat production.

For instance, the 2020/2021 winter cropping season recorded a generally late start to the rains in NES, which delayed planting for as much as two months. When the rains eventually arrived, they initially looked promising, but a prolonged dry spell then set in which desiccated much of the rainfed wheat crop at the critical time of heading and flowering[42]. Furthermore, the unseasonably heavy rainfall followed in late April 2021, and this was accompanied by unusually hot temperatures and localized hailstorms, all of which tended to damage the wheat crop stand through lodging, infection by mould, and poor wheat grain development due to compromised cereal grain formation and filling, contributing to quantitative and qualitative reduction of yields. This main climate change related shock observed during the Mission was the crop failure caused by a combination of a dry spell during the core growing season (February to April) followed by heavy rain combined with elevated temperatures and in some parts hailstorms during the pre-harvest period (May to June) causing wheat crop failure mainly in Al-Hassakeh and Ar-Raqqa governorates. Yield losses caused by hot temperatures during the wheat grain filling stage are estimated at up to 30 percent in the 2020/2021 winter cropping season.

40 Zewdie Bishaw, Paul C. Struik, A. J. G. van Gastel. 2015. Wheat and barley seed system in Syria: How diverse are wheat and barley varieties and landraces from farmer's fields. International Journal of Plant Production, 9 (1), pp. 171-150. https://www.icarda.org/publications/2128/wheat-and-barley-seed-system-syria-how-diverse-are-wheat-and-barley-varieties-and

41 ACTED. 2021. Impact Assessment Post-Harvest Survey on Wheat and Barley in northeast Syria: Com paring 2020 and 2021

42 FAO Crop and Food Security Assessment Mission to the Syrian Arab Republic of 2021. https://reliefweb.int/report/syrian-arab-republic/special-report-2021-fao-crop-and-food-supply-assessment-mission-syrian

Land and Soil fertility management

Major soil degradation processes in NES are salinization in irrigated areas, water erosion in mountain regions and wind erosion in the steppe area. The Euphrates valley (lower terrace): The fertile alluvial soils (Fluvents) are the prevailing soils in the valley. The Euphrates valley is the largest irrigated area in NES. Misuse of irrigation water accompanied with the less presence of good drainage systems and improper management led to the excessive draw-down of the ground water level and consequently salt accumulation within the root layers by evapo-transpiration. The Euphrates valley (higher terraces): Ar -Raqqa about 10,000 ha mainly located within the second Euphrates terrace experience severe salinization with more than 16 dS/m of the soil paste extract took place in about 24% of the area because of insufficient and improper drainage system[43].

About 50% of the soils in NES are Aridisols[44]. These soils are characterized by an aridic soil moisture regime. Without irrigation, Aridisols are not suitable to grow small grain crops (e.g., wheat) in most years. Under the prevailing climatic conditions in NES, Aridisols occur when the annual average of the rainfall drops below 250 mm. In Deir-ez-Zor governorate, located within the steppe, the annual average of the rainfall is about 160 mm. The climate data for 20 consecutive years show that in 2/3 of the years the actual annual rainfall was below the average, and in some years, it was even below 1/3 of the average. As a result of the expansion of the rainfed agriculture in the steppe and climate induced aridity, severe environmental consequences of soil erosion causing poor soil fertility on wheat production lands have been seen mainly in Deir-ez-Zor and Ar-Raqqa governorates. These consequences are mainly related to the nature of the soil. Many lands in NES are known to show salt efflorescence in patches. The origin of the salts was also studied. They proved to be largely magnesium sulphates and were linked to the vicinity of terminal Pleistocene River channels, which crossed the swamps during a period of pronounced droughts, when the valleys dried up and the deposits mineralized[45].

Preliminary field indicators show an increase in the groundwater consumption in NES due to climate induced aridity causing low water availability on surface water resources. The increased use of groundwater wells, in addition to lowering the water table, results in prohibitive cost of water extraction and increased salinity of the water, so causing poor soil fertility lowering wheat yields. Increased salinity has been reported in Deir-ez-Zor and Hassakeh governorates. Water pumps working on solar power, both self-financed and donated via projects, although popular with farmers and perceived as a win-win solution, are also blamed for increased extraction and resulting in declining water table.

43 https://om.ciheam.org/om/pdf/b34/01002096.pdf

44 https://om.ciheam.org/om/pdf/b34/01002096.pdf

45 https://om.ciheam.org/om/pdf/b34/01002096.pdf

Pre-harvest fire management

In June 2021, focus group discussions led by REACH with KIs knowledgeable about wheat production, indicated that farmers predict devastating wheat yield losses due to climatic factors that include drought-like conditions and rising temperatures that also increase the likelihood of pre-harvest wheat crop fires[46]. Pre-harvest fires in wheat crop stands are not uncommon in NES and most are accidental. In 2019, climatic factors of hot temperatures and intense winds in May and early June made fires much more frequent and extensive, the FAO/WFP Crop and Food Security situation monitoring Mission in Syria in 2019 estimated that about 85 000 hectares of crops were burnt, mostly wheat and barley. Hassakeh governorate reported the production loss to fire of 11 000 hectares of wheat, while Ar-Raqqa lost 2 000 hectares of wheat. In the 2020/21 crop season, with weather conditions less prone to fires compared to 2019, field fires were less frequent. About 16 500 hectares of wheat were burnt in Al-Hassakeh, Ar-Raqqa, Aleppo, Hama and Dara'a governorates combined.

Climate change and its impact on wheat production in Northeast Syria

In the winter cropping season of 2021 report, FAO Syria declared drought for portions of Syria, principally including NES, which has historically been the breadbasket of the country.[47] This drought declaration report concurred with the reports from the Global Drought Observatory on drought in eastern Syria and northern Iraq, and subsequent briefing papers in June 2021 from OCHA, REACH, and the NES Forum.[48] On 30 May 2021 iMMAP's mid-season Crop Monitoring and Food Security Situation Update, using iMMAP Data Cube remote sensing, demonstrated how the changing climate and erratic rainfall was driving a massive decrease in vegetative cover in NES[49]. The "triple water crisis" in NES has been detailed in a series of reports, including iMMAP's July 2021 report on water dynamics and NES Forum's June 2021 briefing paper[50]. Poor rainfall and the drought like conditions had severe impacts on wheat production, grain harvests, causing crop failures across NES. In NES, which cumulatively provide about 80 percent of the annual wheat grain produce in Syria, the changing climate has been causing erratic and low annual rainfall that is irregular (Figure 3), thus negatively affecting wheat production and reduce wheat grain yield [51].

46 REACH Briefing Note: Humanitarian Situation Overview in Northeast Syria, June 2021

47 FAO (May 2021). GIEWS Country Brief: The Syrian Arab Republic.

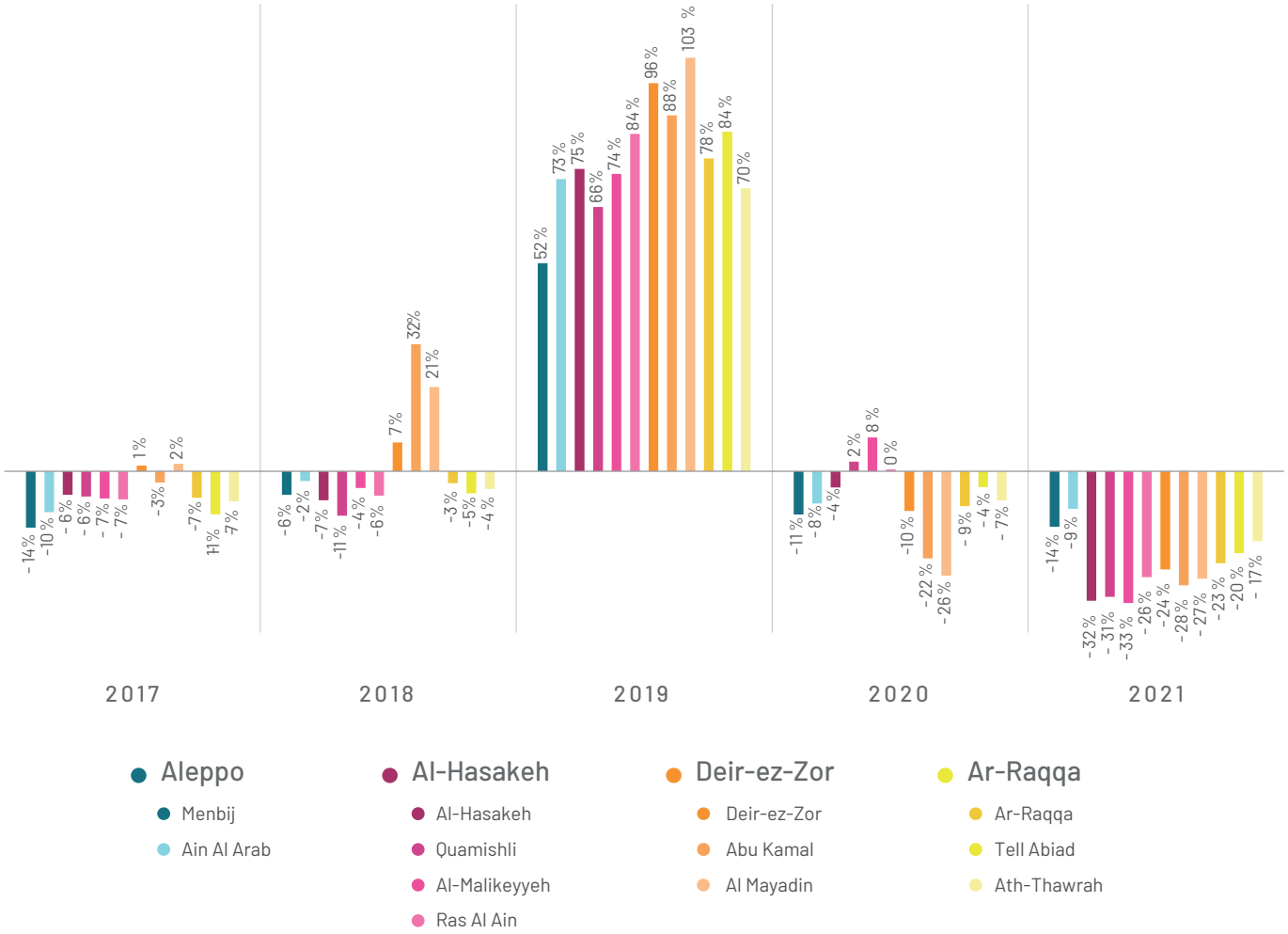
48 Global Drought Observatory (April 2021). Drought in Syria and Iraq – April 2021. edo.jrc.ec.europa.eu. REACH (June 2021). Briefing Note: Humanitarian Situation Overview in Northeast Syria, June 2021.

49 iMMAP and NES AWG (May 2021). Crop Monitoring and Food Security Situation Update: Impact of low rainfall and other water stressors on winter crops – iMMAP Data Cube.

50 OCHA Syria. Euphrates Water Crisis & Drought Outlook, OCHA: June, 2021

51 FAO Syria, GIEWS Country Brief, The Syrian Arab Republic, May 2021

Figure 4: *Percent Change in Winter Growing Season (September-April) Rainfall Totals in Northeast Syria by District, 2017-2021*[52]



** District Rainfall Totals and Long Term Averages from WFP VAM Seasonal Observer Database*
*** Rainfall Totals calculated as total rainfall over growing season: September April*

Quantity of wheat grain produced annually over the past five years in NES, disaggregated by Governorates.

The 210 000 tons of wheat grain produced in Al-Hassakeh governorate, 46 200 tons of wheat grain produced in Deir-ez-Zor governorate and the 220 500 tons of wheat grain produced in Ar-Raqqa governorate for the winter cropping season of 2020/2021 were the lowest since 2017, with the 2019/2020 winter cropping season recording the highest wheat grain produce (Table 3)[53]. Compared to the best winter cropping season of 2019/2020 production figures, the 2020/2021 wheat production in Al-Hassakeh governorate was only 26 percent of the 804 700 tons of wheat produced in the 2019/2020 season in the same governorate (Table 3). For Ar-Raqqa governorate, wheat grain produced in 2020/2021 season was only 35% of the wheat production levels of the 2019/2020 winter season. Furthermore, compared with the best winter cropping season of 2019/2020 production figures, the 2020/2021 wheat production in Deir-ez-Zor governorate was only 21 percent of the 221 900 tons of wheat produced in the in the same governorate (Table 3).

52 iMMAP Crop Monitoring and Food Security Situation Update – northeast Syria, October 2021.

53 FAO/WFP Crop and Food Security Assessment Mission to the Syrian Arab Republic of 2018 & 2019, and the NES Agricultural Working Group of 2021 of NES FSL Cluster

The main contributors to the low wheat production levels were the climate induced aridity that includes the long dry period experienced by most parts of NES during the winter cropping seasons, which desiccate much of the developing wheat crop. The effects of low rainfall were of course, exacerbated by the subsequent ongoing water crises and challenges—namely reduced water flow reaching the Syrian portion of the Euphrates River basin and historically low rainfall levels—have had significant impacts on access to irrigated and rain-fed crops, and electrical energy for irrigation agriculture in NES. Though long-standing agreements require Turkey to provide Syria with 500 cubic meters of water per second, inputs have fluctuated between 188 and 230 cubic meters of water during peak winter cropping seasons over the years as the changing climate dwindles annual rainfall and political decisions in Turkey rationing downstream water supply into NES, significantly lowering water levels at Tishrin reservoir and Lake Assad[54]. Beyond reducing supplies for drinking water and irrigation, low water levels critically undermined electricity production at the Tishrin and Tabqa dams, which is critical and much needed power to pump water for irrigated wheat production in NES. Due to the changing climate and its climate induced aridity, rainfed wheat production is no longer ideal in Deir-ez-Zor governorate where for the past five years there was no record of wheat production under rainfed agriculture (Table 3).

Table 3: *Wheat grain harvested by governorate in Northeast Syria, 2017 to 2021('000 tons)*[55]

Governorate	Irrigated				Rainfed				Total				2021 Deficit/ Gap based on the best harvest for the past five seasons
	2017/ 2018	2018/ 2019	2019/ 2020	2020/ 2021	2017/ 2018	2018/ 2019	2019/ 2020	2020/ 2021	2017/ 2018	2018/ 2019	2019/ 2020	2020/ 2021	
Al-Hassakeh	276	176	354.2	210	10	472	450.5	-	286	648	804.7	210	-594.7
Deir-ez-Zor	50	97	221.9	46.2	-	-	-	-	50	97	221.9	46.2	-175.7
Ar-Raqqa	224	336	508	220.5	0	70	125.5	-	224	406	630.5	220.5	-410
TOTAL	550	609	1084.1	476.7	10	542	576	-	560	1151	1657.1	476.7	-1180.4

Source: FAO/WFP Crop and Food Security Assessment Mission to the Syrian Arab Republic of 2018 & 2019, and the FAO Crop and Food Security Assessment Mission to the Syrian Arab Republic of 2021.Note: Totals computed from unrounded data.

Estimation of the wheat grain deficit for 2020/21 in Northeast Syria

The FAO Crop and Food Security Assessment Mission to the Syrian Arab Republic of 2021 reported that NES recorded 476 700 tons of wheat grain for the 2020/2021 winter cropping season, however, this quantity is far short by about 21% to meet the bread needs of NES. This quantity is far short of the estimated 600,000 tons of wheat grain needed for domestic staple bread production in NES as confirmed by the Agriculture and Economic Affairs office of NES. This implies that if no more wheat grain is brought to the Self Administration of NES's silos and mills, there remains to be a deficit of about -123 300 tons of wheat grain until the harvest of 2021/2022 in NES. This will negatively affect the wheat-flour to bread value chain across NES.

54 OCHA Syria. Euphrates Water Crisis & Drought Outlook, OCHA: June, 2021

55 FAO/WFP Crop and Food Security Assessment Mission to the Syrian Arab Republic of 2018 & 2019, and the NES Agricultural Working Group of 2021 of NES FSL Cluster

Annual yield of wheat cropping across the governorates of Northeast Syria.

Harvest and Wheat Crop Yield

Yields are calculated based on harvested area rather than planted area. Yields of wheat were particularly low for the 2018/2019 and 2020/2021 winter cropping seasons as influenced by the drought-like conditions experienced in NES. Crop water requirements, if not met, then soil moisture becomes one of the most limiting factors of wheat production that negatively affects wheat yield. As per ACTED post-harvest crop survey of NES, in 2020, 87.5% of interviewed farmers who planted rainfed crops – mainly in Al-Hasakeh governorate – were able to harvest their crops, however, in 2021 no rainfed crops were harvested as normal. It was reported that 37% of the wheat crop stand coverage was harvested early and 63% not harvested at all in Al-Hassakeh governorate. Again, in 2020, 97% of farmers were able to harvest irrigated wheat crop, while in 2021, 10 % of the farmers practiced early harvesting to save the irrigated wheat crop and 3% of the farmers did not harvest at all in Al-Hassakeh governorate. Deir-ez-Zor governorate by virtue of its location within the semi-arid climate region of NES, this governorate practices less rainfed wheat crop production, thus, it relies mainly on irrigation agriculture. The decreases in irrigated wheat crop yield highlighted the fact that while irrigated wheat crop in Deir-ez-Zor and Al-Hassakeh governorates could still be harvested, the impact of climate induced aridity and the related water scarcity on the 2018/2019 and 2020/2021 winter cropping/harvest seasons had a significant negative impact on wheat crop productivity in NES.

Table 4: *Wheat crop yield by governorate in northeast Syria, 2017 to 2021 (tones per hectare)*[56]

Governorate	Irrigated				Rainfed			
	2017/ 2018	2018/ 2019	2019/ 2020	2020/ 2021	2017/ 2018	2018/ 2019	2019/ 2020	2020/ 2021
Al – Hassakeh	3.0	1.4	2.9	1.7	0.5	1.5	1.3	-
Deir-ez-Zor	2	2.2	3.2	1.6	-	-	-	-
Ar-Raqqa	2.8	2.4	3.2	1.4	-	1.3	1.6	-

Source: FAO/WFP Crop and Food Security Assessment Mission to the Syrian Arab Republic of 2018 & 2019, and the FAO Crop and Food Security Assessment Mission to the Syrian Arab Republic of 2021.Note: Totals computed from unrounded data.

56 FAO/WFP Crop and Food Security Assessment Mission to the Syrian Arab Republic of 2018 & 2019, and the NES Agricultural Working Group of 2021 of NES FSL Cluster

Conclusion

In recent years, NES has experienced a steady reduction in its water resources, with diminishing rainfall, depleted aquifers, and reduced surface water flow, which is detrimental to wheat production. Last summer, the flow of the Euphrates, the largest of the area's rivers, fell to around 40 percent of its January volume, while many of its tributaries run completely dry due to drought-like conditions and expansive Turkish dam construction[57]. Upstream Turkey has an enormous agricultural sector of its own and is itself suffering from climate induced aridity. The impact of these water shortages has been magnified by oil pollution, solid-waste dumps, and inadequate agricultural and industrial wastewater disposal, which have sullied much of the water that is still available. In the longer run, farmers will need considerably deeper help in re-working a crumbling agricultural supply chain and natural landscape both being hit by climate induced aridity. Though long-range rainfall projections are deeply uncertain, most forecasts anticipate even less precipitation throughout the NES region in the years to come. At the same time, climate change and its drought like conditions appears to be fueling more 'water nationalism,' with comparatively water-rich upstream states, such as Turkey, holding back more river flow. For downstream NES, with its heavy agricultural dependence, limited prospects of diversifying its economy, and inability to address internal threats to its withering water supply, such as solid-waste and oil pollution, all this spells even deeper future trouble[58]. However, there is still some hope. A diverse group of international organizations, local academics, community representatives, and civil society groups met at the first International Water Forum in Al-Hassakeh in September 2021 to discuss causes of and solutions to water insecurity, declining agriculture, and water pollution. Most communities across the NES have launched or expanded successful tree planting projects, and there is growing interest from local activists in environmental research and climate change. These initiatives and interested parties could provide useful entry points to deeper and more meaningful environmental protection, food and water security actions if effectively supported to ensure the adoption of climate change adaptation and mitigation measures to promote food security and livelihood restorations in NES.

Recommendations

Finally, this report concludes with a series of recommendations to respond to the ongoing crises of climate change and to improve in the long term. To respond to short- and mid-term crises, this report makes the following recommendations for the international community, donors, humanitarian partners, local authorities and farmers:

To the local authorities, humanitarian partners and farmers

- Engage with the local authorities, humanitarian partners to stress the importance of, and support farmers' awareness campaigns on the adoption of Climate Smart Agriculture practices, soil and water conservation techniques, particularly for rainfed wheat production.
- Promote relatively drought tolerant wheat seeds in the local farming systems, including access to drought tolerant wheat seeds, is of paramount importance, since these can withstand reduced water availability caused by the changing climate in NES. Syria is the center of origin and domestication for tetraploid wheat where a considerable wealth of genetic variability and diversity still exists on the farms. It is important to design an innovative and integrated wheat seed genetic resources conservation, maintenance, enhancement and utilization strategies and approaches that could meet the aspiration and food security of most farmers that depend for their livelihood on wheat production with the changing climate towards the semi-arid climate.

57 IFRC (2021) Emergency Plan of Action Syria: Droughts. International Federation of Red Cross and Red Crescent Societies. Accessed at https://reliefweb.int/sites/reliefweb.int/files/resources/MDRSY006do.pdf

58 IFRC (2021) Emergency Plan of Action Syria: Droughts. International Federation of Red Cross and Red Crescent Societies. Accessed at https://reliefweb.int/sites/reliefweb.int/files/resources/MDRSY006do.pdf

- Scale-up support towards the light rehabilitation of irrigation systems, linking this with efficient systems for water delivery to wheat production, as well as the use of non-conventional water (i.e., treated water) for irrigation. The nexus between water, food and nutritional security is intrinsic. Irrigation systems can be rehabilitated through conditional cash programming, where appropriate.
- Rehabilitate the fertilizer production sector, while considering other sources of nutrients available domestically, such as compost production, animal manure, and food waste management.
- Promote agricultural diversification with context-specific climate smart agriculture, including with a focus and increase of production of wheat and livestock feed formulations using wheat crop residue.
- Construct safe landfills and bioremediation ponds for wastewater from the NES's oil fields, rather than dumping it into waterways. Minimize the impact of flooding in oil-saturated river basins by constructing earth barriers along affected waterways. This could protect some of the most vulnerable agricultural land.
- Anticipate climate hazards before they turn into disasters.
    - Local authorities and humanitarian partners must support farmers and communities to develop early-warning systems to trigger humanitarian action before extreme weather events impact vulnerable families, capacitating them to adopt climate change adaptation measures for improved wheat production.
    - Local authorities and humanitarian partners must provide climate information to smallholder farmers, as well as providing analysis to vulnerable communities on the links between food security and climate risk.
- Restore degraded ecosystems as natural shields against climate hazards.
    - Nature itself is often the best way to protect both people and the environment. Rehabilitating ecosystems helps to reduce people's vulnerability to climate shocks and stresses while also protecting biodiversity and promoting social cohesion.
- Protect the most vulnerable with safety nets and insurance against climate extremes.
    - Humanitarian partners must support and enable communities to withstand shocks through climate risk insurance – which provides people with cash payouts following a climate-related disaster.
- Both humanitarian partners and local authorities should conduct systematic monitoring and assessment of surface and groundwater sources within NES – and integrate those results into their policymaking. Rapid identification and consistent monitoring of these water sources (through remote sensing and local citizen science tools) can help prevent aquifer depletion and address pollution and other water quality and quantity threats. In the long run, consider reworking agricultural systems to incentivize the cultivation of grains and other foods over non-edible and water-intensive crops, such as cotton, sugar beet and bananas.
- Push for afforestation and reforestation in suitable locations which is a mitigation to climate change
- Enhancing farmers' knowledge and skills to respond to climate change is key. Farmers must validate innovative technologies and approaches adapted to climate change, including digital-based technologies, and must integrate agro-ecological approaches. Farmer Field Schools (FFS) and other participatory approaches to improve integrated pest and disease management (IPDM) and sustainable wheat production systems. IPDM is responsive to changing conditions, including those caused by climate change, and remains the most appropriate way to manage pests and diseases.

To the international community:

- Building on Al-Hassakeh's International Water Forum in 2021, establish a regional diplomatic initiative to prevent and mitigate conflict over the use of transboundary water resources, including the Euphrates and other relevant rivers.
- Pressure Turkey to release more water to the Syrian-held portion of the Euphrates River to ensure equitable access to irrigation water and sufficient electricity production.
- Step-up international pressure to find a political solution for NES that accounts for regional security concerns. Such a solution could bolster stability, boost donor investment, and facilitate more rapid wartime reconstruction, particularly for the agricultural sector, and in the areas of environmental infrastructure and natural resource exploitation while addressing the negative impacts of climate change on livelihood and the natural resource base in NES.
- The UN Security Council (UNSC) should reauthorize cross-border humanitarian aid operations to NES through the Bab al-Hawa crossing, and re-open the closed Al-Yarubiyah crossing, ensuring that vital food and water assistance can get to those who most need it. This is particularly important in times of drought and/or when authorities are unable or unwilling to accommodate the needs of these communities.
- Systematize regular monitoring and reporting of the impacts of climate change on food and water insecurity in annual UN and other iNGO country assessments on NES, as well as within monthly briefings to the UNSC and OCHA situation reports.

Recommendation for further studies

Based on this review study findings and cognizant of the impacts of climate change on agriculture, humanitarian partners, donors and the local authorities must source funding for in-depth household surveys and key informants' interviews to assess local farmers' current responses to climate risk on agriculture (crops and livestock) in NES. The study may be designed to inform climate variability (water and temperature) response implementation strategies as stakeholders and partners support farmers and agricultural extension programs aimed at building climate resilience in agriculture-based livelihoods in NES. In addition, the recommended study will also highlight farmers' perceptions on the benefits of Climate Smart Agriculture (CSA) practices in terms of agriculture production, livelihoods diversification, overall resilience to climatic risks and household food security in NES. Recommended study objectives may include but are not limited to the following specific objectives;

- To determine the existing knowledge, attitude, and practice of CSA practices among small and medium scale farmers in NES.
- To record the local farmers' experience of climate change risks, their effects on farming and the use of agricultural inputs/materials, as well as the influence of climate shocks on the adoption of CSA practices among the small and medium scale farmers in NES.
- To understand how the climate shocks impact on household food security and livelihood restoration indicators in NES
- To recommend context-specific opportunities for local farmers' adoption of climate change adaptation measures to improve household agricultural productivity.