MERCY CORPS
Humanitarian Access Team

MEASURING AGRICULTURAL PRODUCTION

Drought and the 2018 to 2022 growing seasons in northeast Syria

Quantitative report

July 2022

Key takeaways

- The extent of agricultural production has decreased during the 2022 growing season in areas under the control of the Autonomous Administration in northeast Syria:
    - ◊ Compared to previous **non-drought** seasons, agricultural production decreased significantly: by 82% compared to the 2020 growing season and 84% compared to the 2019 growing season.
    - ◊ Compared to previous **drought** seasons production has also decreased by 27% compared to the 2021 growing season and 29% compared to the 2018 growing season.
- There was less rain and groundwater-fed agricultural land in the 2022 winter growing season than in the previous four winter seasons, but the vitality of the cultivated land decreased at a slower rate, indicating that resilient farmland has become more intensively cultivated.
- Cultivation has expanded in some areas relative to non-drought seasons, most notably along the Euphrates in southern Deir-ez-Zor.
- Drought coping mechanisms include delays in sowing seeds to preserve seed moisture, selling or renting farmland, and drilling deeper or new surface wells and boreholes. Drilling is prohibitively expensive for most farmers, both for the machinery needed, and the cost of imported parts and fuel needed for maintenance and pumping.
- Relative to the 2018 and 2021 drought seasons, cultivation has expanded around Rweished (west of Al-Suwar) and in the northern portions of Qamishli, Ras al Ain and Ain al Arab districts.
- Agricultural production diminished the most during the past two drought seasons in arid climates with soils that have limited moisture retention capacities.
- Food, water and livelihood priority needs increased at a lower rate in communities where agriculture was generally more resilient to drought, and increased more in communities with lower or lost agricultural production.
- Humanitarian actors working in food security should consider the following:
    - ◊ Optimizing viable arable land by targeting areas where agricultural production has remained resilient or expanded despite drought conditions.
    - ◊ Continuing to provide more efficient irrigation technologies (eg, drip irrigation).
    - ◊ Piloting alternative agricultural solutions in areas where cultivation has drastically decreased due to the drought, such as drought-resilient plant varieties for grazing.
    - ◊ Advocating for groundwater conservation policies to the Autonomous Administration to slow down groundwater abstraction, which increases when rainfall levels are low.

Contents

Water in northeast Syria is an increasingly scarce commodity: severe drought in 2018 and 2021 has meant ground and river water levels are low, while disruptions in water flow from Turkey into Syria have further reduced levels in the Euphrates. Agricultural production in the the northeast, once the breadbasket of Syria, has declined, however with considerate agricultural policy, it can be restored.

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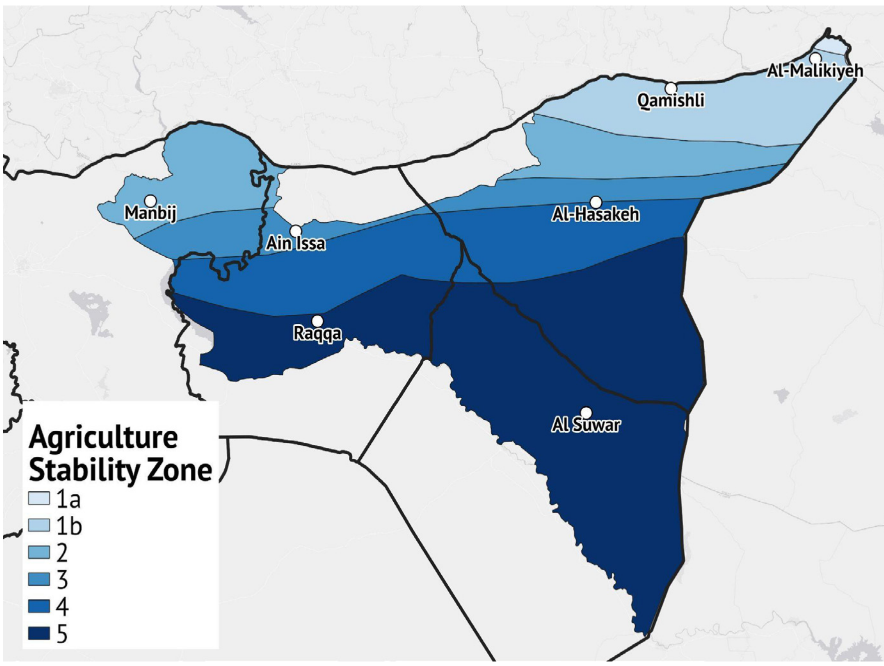

In order to measure agricultural production, the HAT aggregated northeast Syria using three different methods, one of them based on agricultural stability zones throughout the region, shown right.

Introduction

In 2021, northeast Syria experienced significantly below-average rainfall, causing the worst drought in approximately 70 years.[1,2] Water levels of the Euphrates flowing through northeast Syria have been significantly reduced, as the Turkish government has been accused of hydro-politics; that is, increasingly diverting water through infrastructure projects within Turkey that disrupt water flows into Syria, specifically to the Tishreen and Taqba dams, and, on a smaller scale, blocking water pumping from the Alouk water station near Menbij into Al-Hasakeh. Turkish water management – as well as additional factors related to the Syrian conflict such as scarcity in commodities and inputs – has lowered the quantity and quality of drinking water and hydroelectric power generated from dams operated along the river within Syria.[3,4] As a result of these changes, agricultural crop production has significantly declined, while at the same time, access to safe drinking and agricultural water has become a critical issue across northeast Syria.[5,6,7]

The region has also been particularly susceptible to drought – groundwater over-extraction has been a problem since 1985, when the Syrian government began a policy of subsidizing agricultural inputs and providing low-interest loans and facilitating the acquisition of permits to drill groundwater wells to farmers that agreed to sell specified quantities of their harvests to the government.[8] This further propelled the northeast into a center of agricultural production, increased the number of groundwater wells by 134% (53,000 to 124,000) and expanded the amount of irrigated land by 127% between 1988 and 1994.[9] The number of wells continued to increase, leading to groundwater-based agriculture comprising about half of the total irrigated land in 2010; but the amount of irrigated land had plateaued in 2005, signaling a lower groundwater well productivity and a drop in the groundwater supply, which then required farmers to deepen wells.[10] Since taking control of the region, the Autonomous Administration has continued the policy of agricultural input subsidies, however, their application has been inconsistent and unreliable.[11]

Irrigated farming is particularly vulnerable to drought and insufficient provision of subsided inputs. Groundwater levels drop faster during droughts due to reduced recharge rates and the increased amount of abstraction needed to compensate for the lower rainfall levels, which eventually deplete wells or necessitate the deepening of wells. Insufficient quantities of subsidized diesel increases the cost of irrigation, particularly during droughts, because water pumps must be operated longer and more intensively to pump water from the lower depth of deepened wells. Additionally, the depreciation of the Syrian pound over the past two years has increased the price of agricultural inputs; for example, fertilizer and mechan-

1 IRC, [via Reliefweb], 'Syria 11 years on: Hunger, drought and a collapsing economy threatens even more misery for millions, the IRC warns,' March 2022
2 Recent drought seasons include the 2008 to 2010 and 2018 winter growing seasons.
3 WASH Working Group, North East Syria, '2021 Euphrates Crisis Dashboard,' June–October 2021.
4 Atlantic Council. 'Syria has a water crisis. And it's not going away,' February 2022.
5 Assessment and analysis with regards to quality of water resources (potable and agricultural water) is outside the scope of this report.
6 Mercy Corps HAT, 'Drought, pollution, and the Euphrates,' August 2021
7 July 2021, ' Syria: Alouk Water Station Flash Update: Disruption to Alouk Water Station.' July 2021
8 Aw-Hassan, A., et al., 'The impact of food and agricultural policies on groundwater use in Syria,' Journal of Hydrology, 2014: 513(26), 204–215.
9 ibid.
10 ibid.
11 KII, humanitarian FSL staff

ical parts are increasingly unaffordable while higher fuel prices and seed availability issues have reduced the ability of farmers to plant, grow, and harvest their crops. These factors combined to reduce overall agricultural production, evident in the drought-stricken 2021 growing season, with an approximately 75% reduction in rainfed crop yield in Al-Hasakeh governorate, and a 25% reduction in irrigated yields across the whole of the northeast.[12]

Purpose of the study

The central analysis of this research measures the level of agricultural production in northeast Syria in the 2022 winter growing season and the previous four seasons. Agricultural production was measured using remote sensing vegetation indices calculated from Sentinel-2 multispectral satellite images.[13,14] Images captured near the end of the growing season (within two weeks of 15 April) were obtained from 2018 to 2022. The entirety of land controlled by the Autonomous Administration was divided into grid areas that were classified according to several aggregations:

1. Agricultural water source; including farmland near rivers or canals, and 'land'; that is, farms located far from the water sources and reliant on rainfall or irrigation from groundwater.
2. Combinations of Köppen climate zone (hot, arid or Mediterranean) and soil type (eg, complex, nutrient-rich, shallow).
3. Agricultural stability zones, mainly based on average annual rainfall levels.

Each of these aggregations offer insight into where and why agricultural production has declined more or less relative to past seasons due to the ongoing drought. This was achieved by identifying areas of agricultural production using satellite imagery from the 2018 to 2022 growing seasons and explaining the spatial dynamics of changes in production.

Potential areas of intervention for development and humanitarian programming, and for policy were identified from the results of the analysis; specifically, areas where agricultural activity has expanded, but is relatively less irrigated.

This paper concludes that groundwater abstraction is generally the solution, and has been the main coping mechanism, to drought or low-rainfall seasons; farmers in northeast Syria should therefore adopt more efficient irrigation techniques to ensure sustainability. Programming should also focus on cash and in-kind assistance to farmers to compensate for the Autonomous Administration's insufficient distribution of subsidized seeds, fertilizer, and diesel, which are needed to maintain profitability.[15] These interventions, in combination with the gradual implementation of policies focused on sustainability utilizing groundwater resources, offer northeast Syria a conceivable path to agricultural resilience in Syria despite past, present, and inevitably future drought conditions.[16]

12 iMMAP, 'Northeast Syria Crop Monitoring and Food Security Situation Update.' May 2022.
13 Multi-spectral satellite images taken from Earth Explorer
14 Atmospherically-corrected using the sen2cor package in R.
15 Aw-Hassan, A., et al., 'The impact of food and agricultural policies on groundwater use in Syria,' Journal of Hydrology, 2014: 513(26), 204–215.
16 Kelley, C.P., et al., 'Climate change in the Fertile Crescent and implications of the recent Syrian drought,' Proceedings of the National Academy of Sciences, 2015: 112(11), 3241–3246.

Drought in northeast Syria

Drought is defined as "a prolonged period of abnormally low rainfall, leading to a shortage of water." In order to identify drought seasons in northeast Syria, the Humanitarian Access Team (HAT) measured the average temperature and rainfall levels in the region to compare the rainfall levels of the 2022 growing season to past growing seasons.[17] As shown in Figure 1, rainfall in northeast Syria during the 2022 winter growing season (October 2021 to May 2022) is markedly lower than in the 2021 winter growing season. In fact, rainfall is 47% lower in Al-Hasakeh governorate, 74% and 83% lower in Autonomous Administration-controlled Ar-Raqqa and Deir-ez-Zor governorates. Al-Malikiyah was the only location in Administration-controlled areas where rainfall increased from the 2021 growing season, with 68mm (28%) more rainfall; however, this is still about 54% lower than the same period in the 2020 growing season and 74% lower than in 2019. Conversely, Abu Kamal in Deir-ez-Zor experienced the sharpest decline in rainfall, with 64mm (88%) less rainfall in the 2022 growing season than in the 2021 growing season.

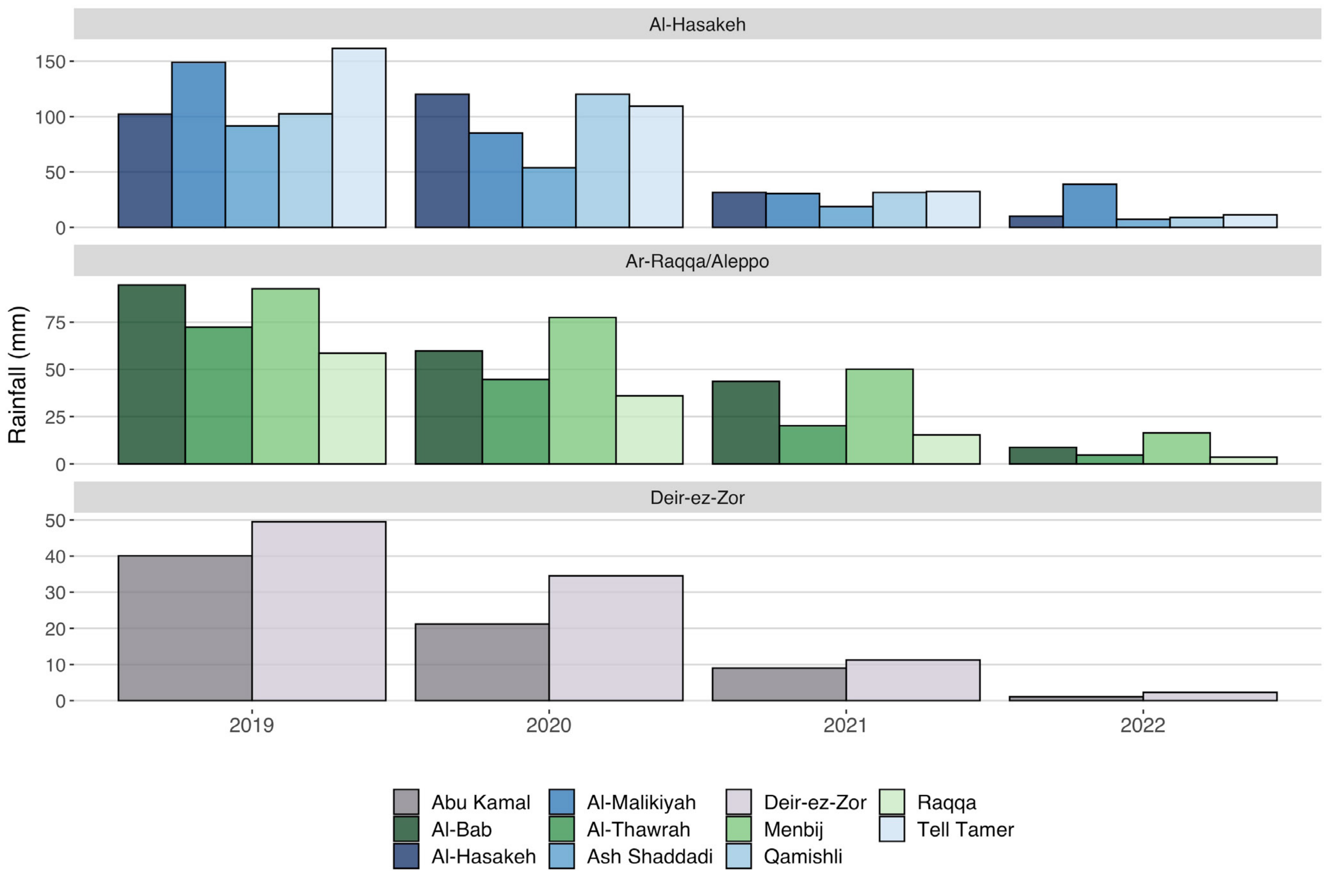

Figure 1. *Total rainfall (mm) during the wheat growing season (October to April).*

17 Temperature and rainfall data gathered from the historical monthly data freely available at [World Weather Online.](#)

Figure 2 shows the total difference in monthly rainfall from 14-year monthly averages (2009 to 2022) for the 2019 to 2022 winter growing seasons. Within Administration-controlled areas, the total rainfall in the 2022 growing season was farthest from the 14-year average in Deir-ez-Zor governorate (92% below average), followed by Ar-Raqqa and Eastern Aleppo governorates at 85% below average, and Al-Hasakeh governorate at 75% below average rainfall levels.

The 2019 and 2020 growing seasons experienced above-average rainfall levels, which provided additional water to aquifers; however, due to a lack of data on private wells, it is unknown whether these gains were lost to the additional groundwater abstraction needed for irrigation to stabilize yields in the 2021 and 2022 seasons. However, a member of the local council in Quamishli subdistrict interviewed by the HAT stated that the groundwater wells replenished by the 2020 rains were able to cover the need for additional irrigation the following season, but the lack of rain in 2021 and continual groundwater abstraction has substantially lowered the level of groundwater wells.

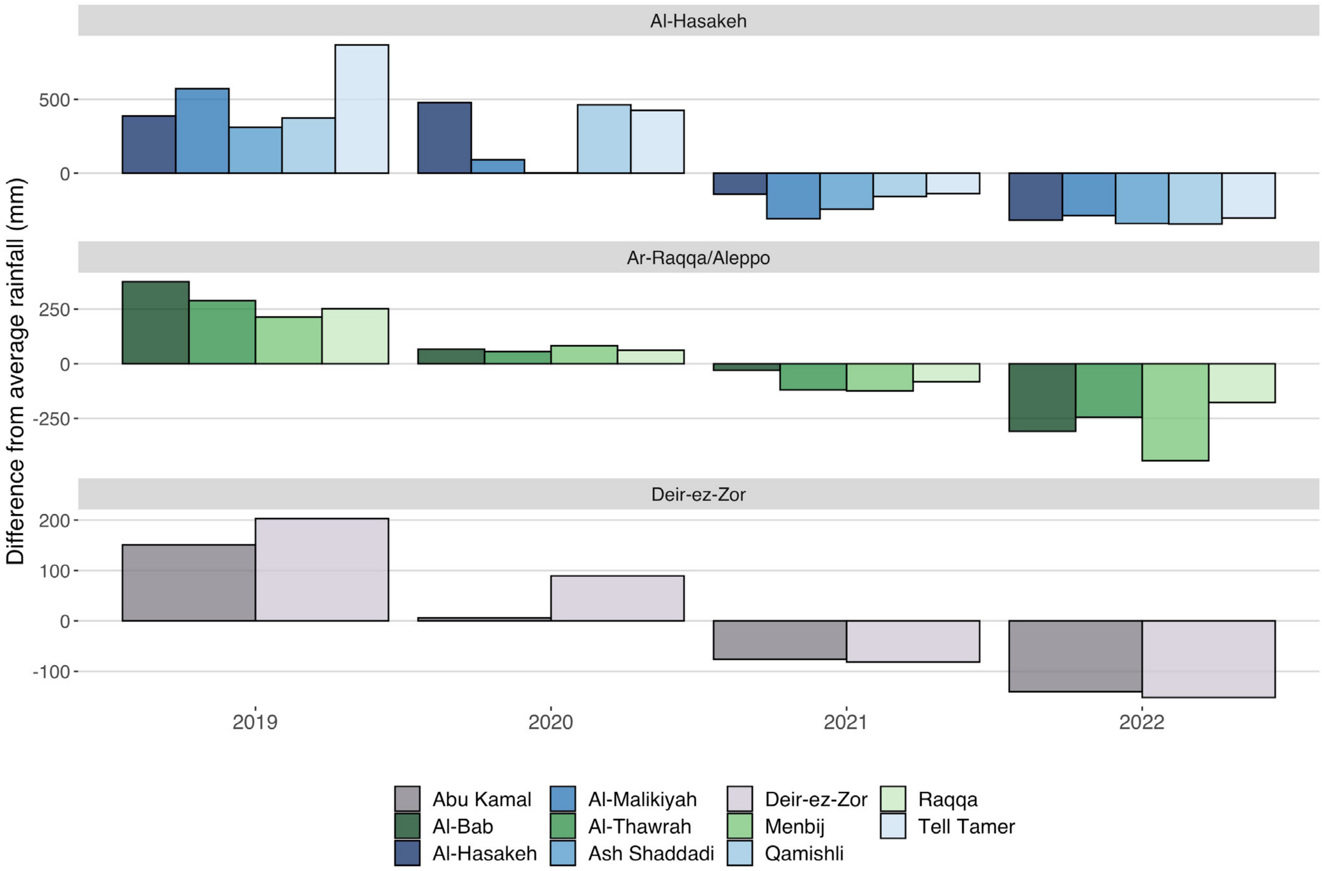

***Figure 2.** Difference from the average monthly rainfall during the partial wheat growing season (October to April).*

The lack of rainfall and consistent temperatures have increased the aridity of northeast Syria, which perpetuates the ongoing desertification of the area. The De Martonne aridity index is a measure of climate dryness calculated using temperature and precipitation data; scores lower than 20 indicate semi-arid conditions and scores lower than 10 indicate arid conditions.[18] The index was calculated for the 2019

18 Croitoru, A-E., et al., 'Spatiotemporal distribution of aridity indices based on temperature and precipitation in the extra-Carpathian regions of Romania,' Theoretical and Applied Climatology, 2013: 112, 597–607.

to 2022 winter growing season and results are shown in Figure 2. Ten of the eleven recorded locations have become, by definition, arid in 2022, with the aridity index approaching zero in Abu Kamal (0.52). This is in contrast to only three locations producing an aridity index below ten during the 2021 growing season. Al-Malikiyah was the only location to remain above the arid classification with an index of 20.6, which classifies the location as semi-arid; however, the location's 2022 aridity index is still 55% lower than the 14-year average. Additionally, a more arid climate raises the risk of crop fires (naturally occurring and conflict-related), which have already burned thousands of acres of farmland across the Administration-controlled northeast.[19]

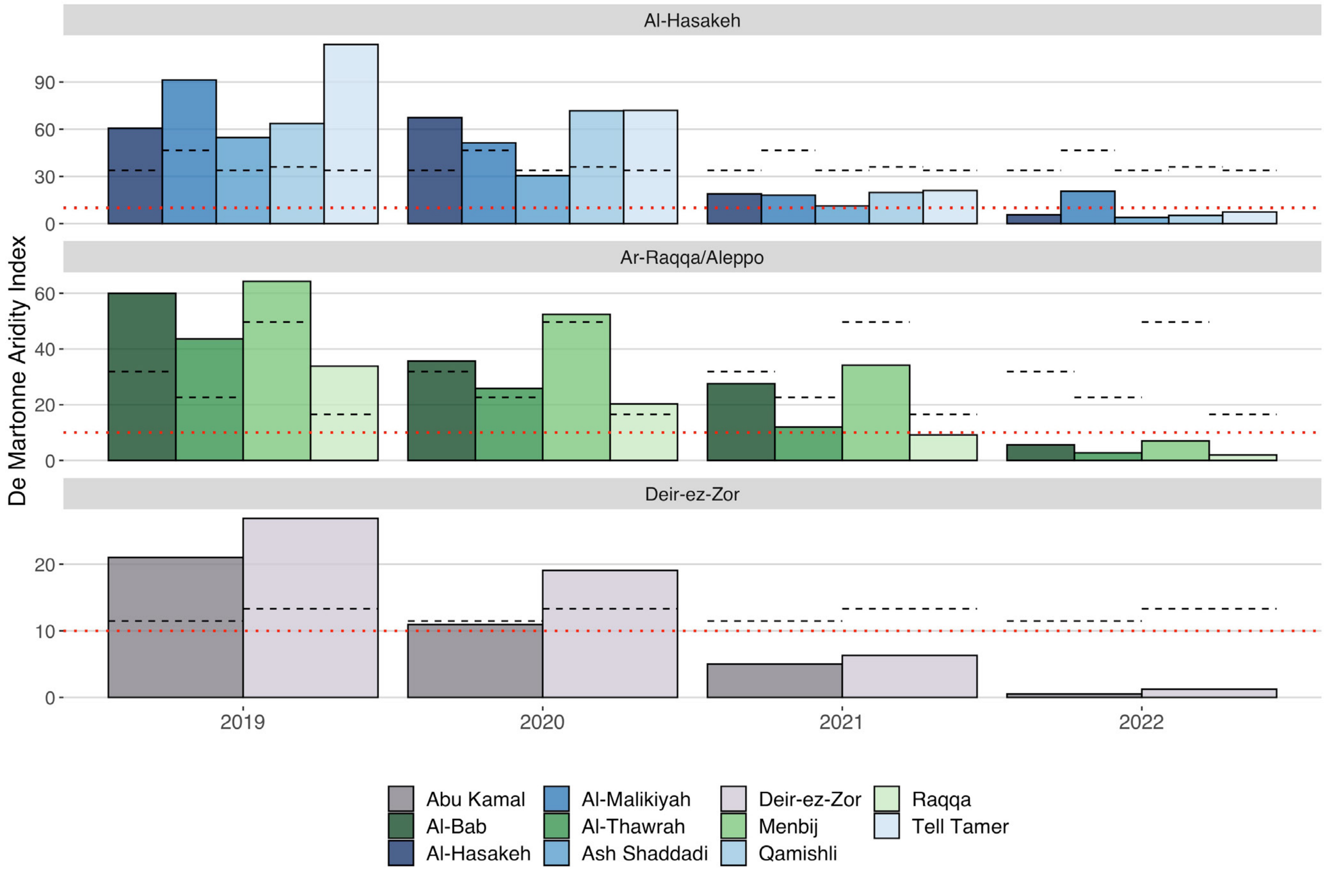

Figure 3. De Martonne aridity index during the wheat growing season (October to April). The black dotted lines indicate the average aridity index for each location, and the red dotted line indicates arid conditions (Aridity Index <10).

19 The New Humanitarian, 'Conflict and climate change collide: Why northeast Syria is running dry.' December 2021

Measuring agricultural production

Critically lower-than-average rainfall levels render rainfed farming unfeasible and do not replenish groundwater wells, as a result, farmers attempt to extract more groundwater from existing wells to compensate for the lack of rain. However, water pumping requires diesel, which is expensive (and subsidized diesel is in short supply), while deepening or drilling a new groundwater well is beyond the financial capacity of most farmers. Farmers must then choose to increase their irrigation (which has a lower profit margin), lower the size of cultivated areas, or opt not to grow for the season. The last two options are the most likely for farmers in northeast Syria, meaning agricultural production decreases in drought seasons.

HAT measured the level of agriculture production in the 2022 winter growing season and the past four winter growing seasons. Agricultural production was measured using remote sensing vegetation indices calculated from Sentinel-2 multispectral satellite images.[20,21] The Sentinel 2 satellite collects light reflectance in several bands of visible and infrared light, which have a wide range of analytical applications to agriculture.[22] Images taken near the end of the growing season (within two weeks of 15 April) were obtained from 2018 to 2022.

Box 1: NDMI and NDVI vegetation indices

Vegetation indices use the wavelengths absorbed and reflected by green plants, which are collected by satellite sensors, to measure the vitality and density of vegetation. This report uses two vegetation indices: the normalized difference vegetation index (**NDVI**) to identify agriculture activity and the normalized difference moisture index (**NDMI**) to measure the water stress of the crop. **NDVI** values above 0.3 were considered very likely to represent agricultural activity,[1] and the **NDMI** of these areas were used to measure the vitality of the crop.

1 As determined by the average NDVI values for crops in Lebanon, as measured by the following article: Nasrallah, A., et. al., 'A novel approach for mapping wheat areas using high resolution Sentinel-2 images,' *Sensors, MDPI*, 2018: 18(7), 1-23.

Two vegetation indices were used in the analysis: the normalized difference vegetation index (NDVI) and the normalized difference moisture index (NDMI). The NDVI measures the presence of chlorophyll and green biomass, which is useful to identify the presence of vegetation. The NDMI indicates the relative abundance of dry plant structure that determines the development of a plant, and is calculated by the ratio of the difference between dry and moisture-related internal plant structure. Both the NDVI and NDMI have proven to be useful as measures of vegetation identification and drought in past research.[23 24]

20 Multi-spectral satellite images taken from Earth Explorer.
21 Atmospherically-corrected using the *sen2cor* package in R.
22 Yang, C. et al., 'Using High-Resolution Airborne and Satellite Imagery to Assess Crop Growth and Yield Variability for Precision Agriculture,' Proceedings of the IEEE, 2012: 101(3), 582-592.
23 Gu, Y., et al., 'A five-year analysis of MODIS NDVI and NDWI for grassland drought assessment over the central Great Plains of the United States,' Geophysical Research Letters, 2007: 34(6).
24 El-Hendawy, S.A., et al., 'Spectral assessment of drought tolerance indices and grain yield in advanced spring wheat lines grown under full and limited water irrigation Author links open overlay panel,' Agricultural Water Management, 2017: 182(1): 1-12.

The entirety of land controlled by the Autonomous Administration was divided into grid areas that were classified according to the presumed water source for agricultural activity; particularly, water supplied by wells or rainfall (hereby known as 'land'), river irrigation, and canal irrigation.[25] Grid areas were also stratified by agriculture stability zone[26], soil type and climate zone.[27,28] Crop extent (number of NDVI pixels >0.3) and intensity (sum of the NDMI measured in pixels identified as agriculture) were analyzed over time and space to explore the dynamics of agricultural productivity across the northeast.[29,]

Box 2. Aggregating changes in agricultural production

Changes in agricultural production were calculated according to several aggregations, including:

1. Zones by agricultural water source; there are three sources of water used in agricultural production throughout northeast Syria – canals, rivers and land (rainwater).
2. Zones of climate and soil type; the different climates were identified based on Koppen's climate categorization:
    - Group B (dry climates); BSk (cold, semi-arid climate), BWh (hot desert climate), BSh (hot, semi-arid climate);
    - Group C (temperate climates); Csa (hot summer Mediterranean climate).

    Soil types were classified using USDA soil taxonomy which organizes soil into different soil properties and levels; the six classifications identified were:

    - Alfisols-Xeralfs – Alfisols form in semi-arid to humid areas. They have a clay-enriched subsoil and relatively high native fertility. Alfisols represent one of the more important soil orders for food and fiber production. The suborder Xeralfs are located in hot summer Mediterranean climates.
    - Aridisols-Gypsids – Water deficiency is a major defining characteristic of aridisols. Because of the dry climate in which they are found, they are not used for agricultural production unless irrigation water is available. The suborder Gypsisols are located in the most arid parts of the world.

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25 Land within 1km of rivers were considered river-fed areas; Land within 500m of canals were considered canal-fed; the remaining area was considered rainfed or groundwater-fed.
26 Agro-ecological zones typically used to classify farming regions in the northeast.
27 Soil type data obtained from the USDA.
28 Climate zone data was obtained from Kottek, M., J. Grieser, C. Beck, B. Rudolf, and F. Rubel, 'World Map of the Köppen-Geiger climate classification updated,' [Meteorol. Z., 15, 259-263. DOI: 10.1127/0941-2948/2006/0130], 2006.
29 Areas with no agricultural land use were removed; however, some of those areas with significant agricultural activity in the rain-rich 2020 growing season were retained, as agricultural production has expanded since the land use definitions of the reference file were established in 1965.

Box 2. ***cont.***

- Entisols-Fluvents – Entisols are soils of recent origin (their categorization is based on a lack of ability to categorize distinguishing features), and are normally sandy mineral soils low in organic matter, natural fertility, and water-holding capacity. The suborder Fluvents are found in areas of repeated flooding (ie, river deltas), where soil development is prevented.
- Entisols-Orthents – Entisols are soils of recent origin (their categorization is based on a lack of ability to categorize distinguishing features), and are normally sandy mineral soils low in organic matter, natural fertility, or water-holding capacity. The suborder Orthents are found mainly on steep slopes and weatherable surfaces.
- Mollisols-Xerols – Mollisols are soils of grassland ecosystems, with deep, high organic matter, and nutrient-enriched surface soil. The suborder Xerols are found in Mediterranean climates.
- Vertisols-Xererts – Vertisols are clay-rich soils, which expand and shrink according to their moisture levels. The suborder Xererts are mostly found in Mediterranean climates.

3. Zones of agricultural stability; In northeast Syria, there are six categorizations of this, based on yearly rainfall averages – from Zone 1a (>600mm) to Zone 5 (>200mm, desert/steppe).

Changes in agricultural production by water source

The 2022 growing season produced the lowest level of agricultural production compared to the previous four growing seasons in farms dependent on all types of water sources in northeast Syria. Figure 4 shows the change in the extent and intensity of agricultural production according to the land's agricultural water source, relative to the 2022 growing season. Agricultural production is lower in 2022 than in the previous four growing seasons, particularly the relatively rainfall-rich 2019 and 2020 seasons. Compared to the previous drought season in 2021, agricultural production in the 2022 season decreased by 12% along canals, 23% along rivers, and 28% in rainfed or groundwater-fed areas. This decline in production follows very significant losses in the output of all crop types in the previous 2021 growing season.

The ratio between the extent and intensity of agriculture provides an insight into the relative change in irrigation per plant; that is, crops are likely generally better irrigated if the total water stress decreases at a lower rate than the rate of decline in the total level of agricultural production. The ratio of change in the extent and intensity of agriculture from the 2019 and 2020 seasons is essentially 1 to 1; however, agricultural intensity decreased at a higher rate along canals in the 2018 and 2021 drought seasons. This suggests that agricultural production has remained relatively resilient along canals, but the crops grown in these areas are substantially more water-stressed – and thus underdeveloped – compared to the previous drought seasons, perhaps due to diminished water flow or reduced canal functionality.

The ratio along rivers in the 2018 season favored agricultural intensity, suggesting that farms able to continue despite lower river water levels were able to optimize their irrigation schemes and more thoroughly irrigate their plants, compared to the 2018 drought season. This was especially true for rainfed and groundwater-fed areas in the 2018 and 2021 drought seasons, and also implies that farms that survived the drought seasons have managed to extract enough additional groundwater to compensate for the lack of rainfall, whether from sufficiently abundant groundwater wells, or by deepening existing wells, or drilling new wells.

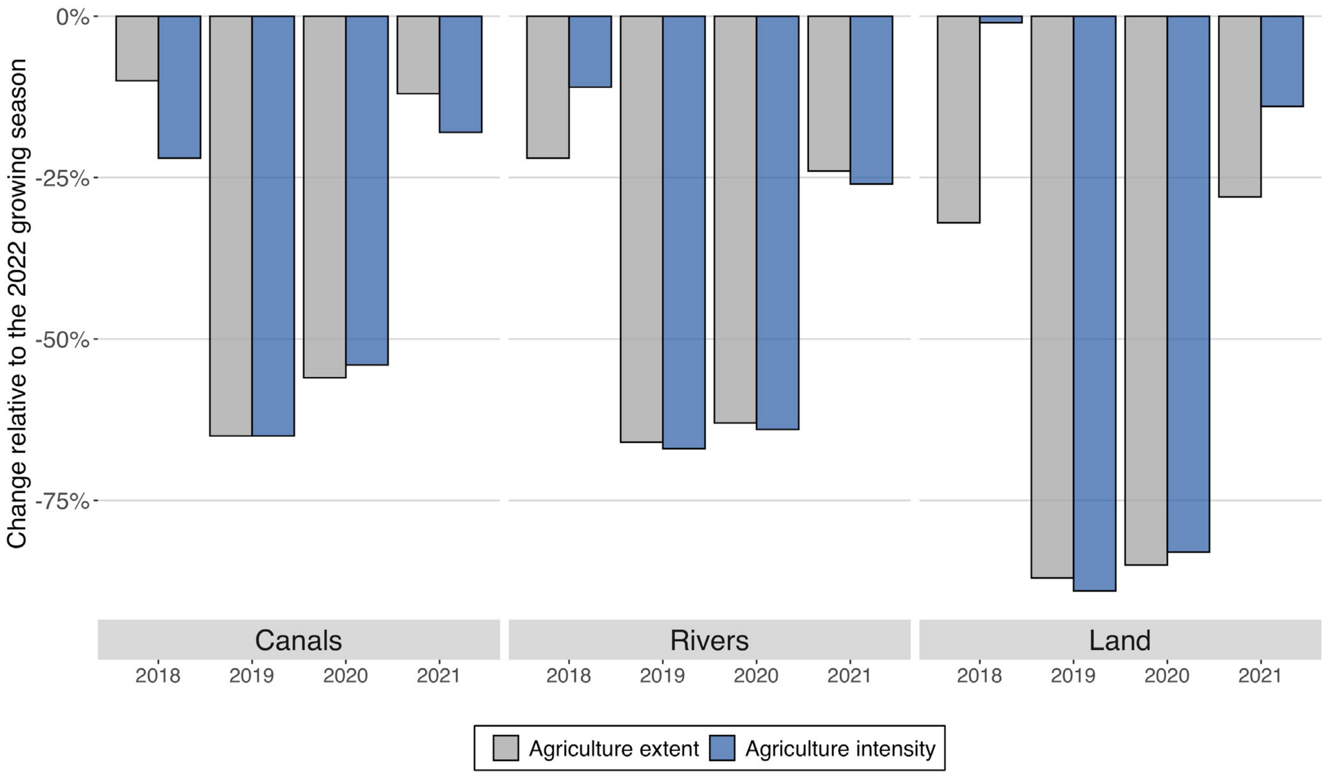

Figure 4*. The change in the extent and intensity of agriculture among different farming typologies. Years represent growing seasons, and measurements are relative to the 2022 growing season.*

Changes in agricultural production by climate zone and soil type

The change in agricultural production was measured against the Köppen climate zone categorization and the US Department of Agriculture's soil type classifications. Figure 5 shows that the extent of agricultural production was generally lower among all climate zone and soil type combinations; however, Entisol-Orthent and Mollisols-Xeroll soil types experienced the greatest decline. Entisols-Orthents are a shallow and rocky soil usable for low-intensity agricultural activity that have moisture limitations and generally require irrigation;[30] therefore, they are considered highly prone to desertification and unsurprisingly most negatively affected by drought conditions.[31] Mollisols-Xeroll soils typically occur in grasslands and are

30 Özsoy, G. and Aksoy, E., 'Genesis and classification of Entisols in Mediterranean climate in Northwest of Turkey,' Journal of Food Agriculture and Environment, 2011: 9(3 and 4), 998-1004.
31 UNDP & Syrian Arab Republic Land Directorate, 'National Action Plan to Combat Desertification in the Arab Republic.' 2002.

often used for growing wheat and as rangeland for livestock grazing but tend to have moisture retention issues in drier climates without sufficient compensatory irrigation.[32]

Not all farmers can afford, or extract, enough water for compensatory irrigation, which has caused the especially sharp decline of agricultural productivity in this soil type. Only the Vertisol-Xerert soil in hot semi-arid (BSh) climates featured an increase in agricultural production from the 2021 to 2022 growing season, probably because farmers cultivating this soil provided sufficient irrigated water and tillage, benefitting the soil which contains high levels of plant nutrients, and is especially productive when well-managed.[33]

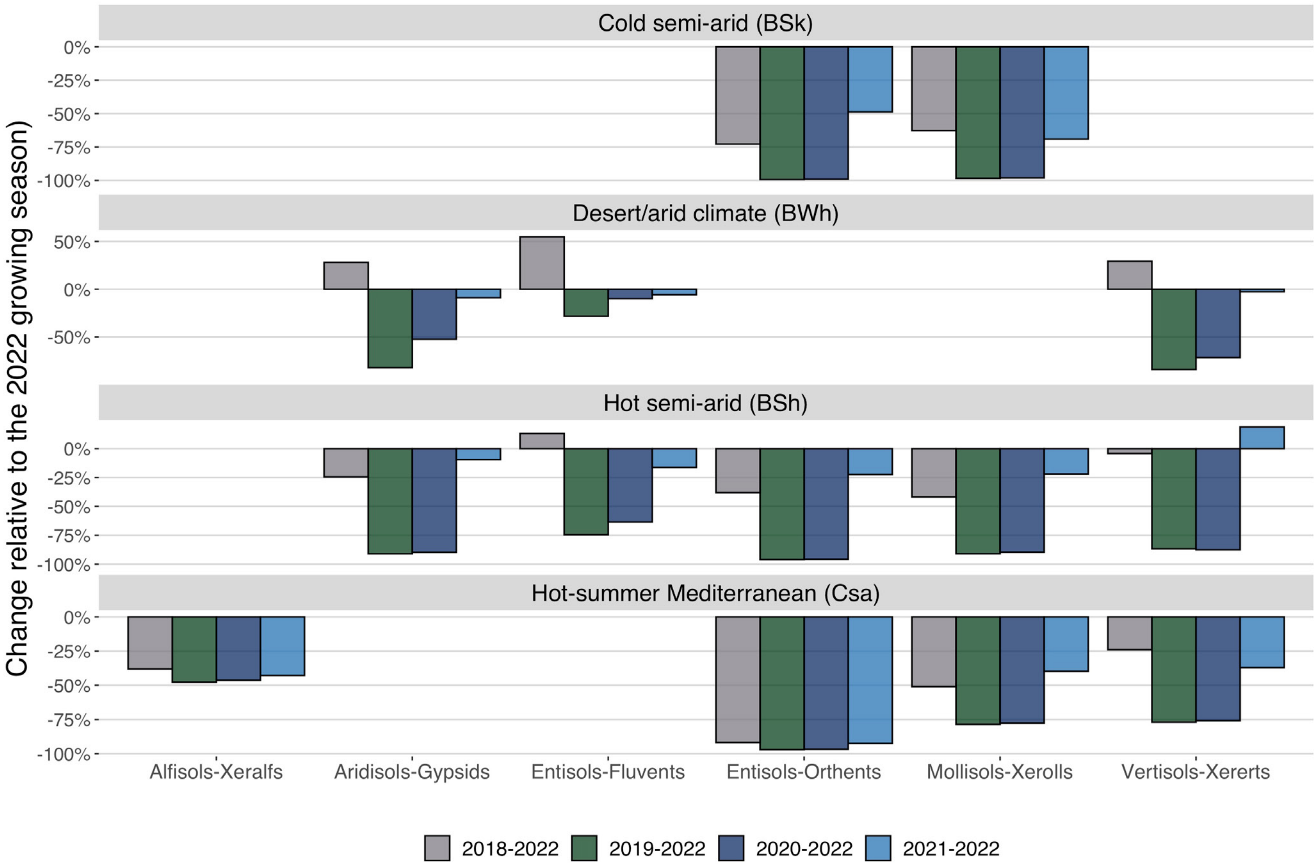

Figure 5*. The change in the extent and intensity of agriculture in rainfed or groundwater-fed farmland among different Koppen climate zones and soil types. Years represent growing seasons and measurements are relative to the 2022 growing season.*

32 Özsoy, G. and Aksoy, E. 'Genesis and Classification of some Mollisols Developed under Forest Vegetation in Bursa, Turkey,' International Journal of Agriculture and Biology, 2012: 14(1), 75-80.

33 Özsoy, G. and Aksoy, E. 'Characterization, classification and agricultural usage of vertisols developed on neogen aged calcareous marl parent materials,' Journal of Biological and Environmental Sciences, 2007: 1(1), 5-10.

Changes in agricultural production by agricultural stability zone

The greatest decline in agricultural production by stability zone came in more arid (but not desert/steppe) areas. The extent of agricultural production was measured in the six agricultural stability zones across the Administration-controlled northeast and is shown in Figure 6.[34] Agricultural production in 2022 decreased the least in the driest stability zones (3, 4 and 5), compared to the 2021 drought season. This indicates that the 2021 drought season inflicted near-maximum damage on drier areas, and additional cultivation losses from the 2022 drought season have generally occurred in traditionally more viable agricultural stability zones. In short, the additional (2022) drought season has spread losses in agricultural production geographically into different agricultural zones. Surprisingly, agricultural production has expanded in the driest stability zones (4 and 5) compared to the 2018 season: this is probably the result of deepening existing, or drilling additional, wells to preserve arable land and maximize the remaining groundwater in response to the 2018 drought season.

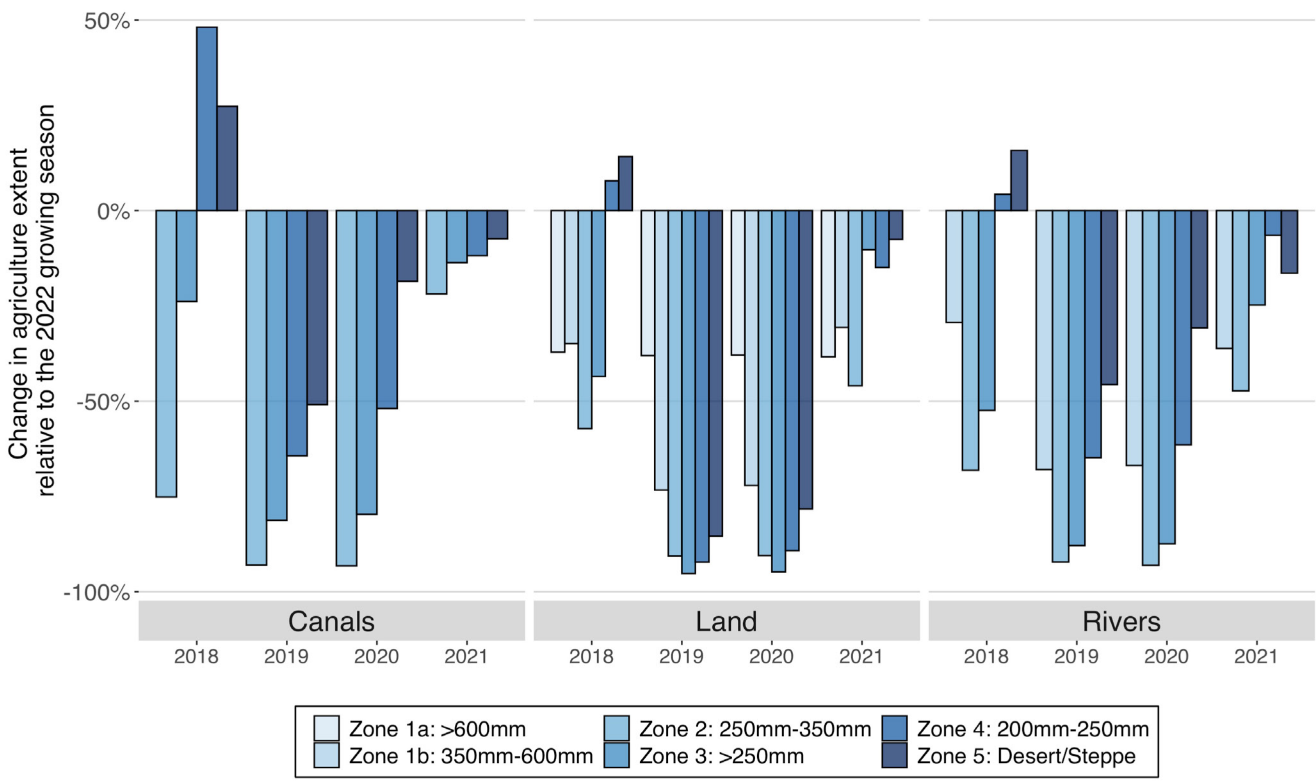

***Figure 6.** The change in agricultural production by agricultural stability zone. Agricultural stability zones are in ascending order according to the annual average rainfall levels and the soil suitability for rainfed crop production. Years represent winter growing seasons, and measurements are relative to the 2022 growing season.*

34 Agricultural stability zones in ascending order according to the annual average rainfall levels and the soil suitability for rainfed crop production: Shideed, K., Ahmed, et al., '3.3. Returns to Policy-oriented Agricultural Research: The Case of Barley Fertilization in Syria.' In E. Gotor, E. and F. Caracciolo (Eds.), Impact Assessment of Policy-Oriented Research in the CGIAR: Evidence and Insights from Case Studies (pp. 36-45). CGIAR Science Council Secretariat, 2008.

Declines in the 2022 level of agricultural production compared to the 2019 and 2020 growing seasons can be attributed to harm caused by the two recent drought seasons. Agricultural production contracted more in stability zones 2, 3, and 4 than in drier (5) and wetter (1a and 1b) stability zones. This is because stability zones 2, 3, and 4 feature most rainfed agriculture in the region and are on the frontlines of desertification.[35] That is, they are more quickly becoming arid than stability zones 1a and 1b while more arid areas (5) have already experienced a sharp decline in agricultural production in the past and farmers in this stability zone are apparently salvaging arable land by abstracting more groundwater.

Compared to the rainfall-rich 2019 and 2020 seasons, 2022 agricultural production in rainfed and groundwater-fed areas decreased at noticeably lower rates in stability zones 1a and (to a lesser extent) 1b relative to the other stability zones, probably due to the existence of significant groundwater wells that have allowed farmers to compensate for rainfall shortages.

Watering system in Al-Hasakeh: Farmers are having to dig deeper and invest in greater infrastructure to water their crops. For those without the means to do so, renting or selling their land are often the only coping mechanisms available.

Crop failure in northeast Syria: Drought and poor agricultural management dating back to the 1970s have meant land is left uncultivated, causing a decline in agricultural production.

35 According to the author's calculation of the total area classified as "Dry farming" according to the Land use Dataset for the Jazira Region of Syria in each agriculture stability zone.

Spatial dynamics of agricultural production in northeast Syria

Cultivated land identified using satellite imagery analysis was measured in northeast Syria for the 2018 to 2022 growing seasons. These areas were categorized according to the most probable water source for agriculture: rainfed or groundwater-fed, river water-irrigated, and canal-irrigated cultivated land. Changes relative to the 2022 growing season were measured and mapped to highlight improvements and deteriorations relative to other drought-hit growing seasons (2018 and 2021) and rainfall-rich growing seasons (2019 and 2020).

Spatial dynamics of rainfed and groundwater-fed agricultural production

There have been clusters of increased rainfed and groundwater-fed agricultural production in 2022 relative to the previous two drought seasons (2018 and 2021), but very few areas of expansion compared to the rainfall-rich 2019 and 2020 seasons. Figure 7 maps changes in agricultural production in rainfed or groundwater-fed farming areas; that is all areas with significant agricultural activity further than 1km from rivers and 500m from canals. The level of agricultural production in 2022 is much lower compared to the 2019 and 2020 growing seasons. Most of the areas colored in red, relative to the 2022 season, have been sold for fodder because their crops did not develop. Unfortunately, in these cases, the fodder revenue does not recover the cost of planting.[36]

Compared to the 2018 and 2021 drought seasons, resilient agriculture can be identified in Quamishli subdistrict, and in eastern Menbij, western Ar-Raqqa subdistrict, and Rweished, west of Suwar in Al-Hasakeh governorate. The expansion around Rweished in the 2022 season is attributed to its abundant groundwater and the fact that many landowners have recently returned to farms there.[37] The patches of additional agricultural production in northern Menbij are likely the result of groundwater abstraction, and the large increase in western Ar-Raqqa compared to the 2018 season is likely due to the refurbishment of canals since then, as the same area had an increase in production from the analysis of canal-based water sources. Similarly, there was a noticeable expansion of production along the Euphrates in southern Deir-ez-Zor, probably also owed to improvements to the canal system. The increase in Quamishli subdistrict relative to the 2018 and 2021 drought seasons is likely due to additional groundwater drilling, particularly the deepening of sea wells,[38] which are predominantly located in the area on the border strip from Dirbasiyah to Malikiyya – however, only a small proportion of farmers could afford such improvements.

The response to the drought depends on the resources of the farmer. Though most farmers cannot afford to develop a contingency plan, planting later to avoid seeds drying in the soil was a common cost-saving solution, as was renting land to those that could afford to farm. The sale of farmland has also been observed

36 KII, humanitarian FSL staff
37 KII, humanitarian FSL staff
38 Sea wells range from 180 to 300 meters deep.

in the 2022 season, traditionally to the neighboring landowners, relatives, or family.[39] Drilling deeper or new surface wells, which range from 25 to 35m deep, is necessary due to lower groundwater levels, but the cost is prohibitive. It costs about 30,000 SYP per meter to deepen a well, not including additional fixed costs such as a longer submersible power cable or a stronger water pump. Deepening surface wells are still much cheaper than drilling a new borehole, which costs around $3,000 including the costs associated with drilling (including labor), water pumps, and hoses.[40] However, the cost of operating the water pump may be the most significant obstacle for farmers with an adequate supply of groundwater – farmers need fuel to operate the pumps, and imported parts to repair and maintain the pumps, both of which have become increasingly unaffordable as a result of supply issues and the depreciation of the Syrian pound.[41]

Despite the focus on groundwater abstraction to salvage farmland located away from rivers and canals, more sustainable efficiency gains have been observed and considered during the 2022 season. There is a shortage of subsidized diesel throughout the northeast, and market prices are increasing; therefore, more farmers are using solar-powered pumps compared to last year. Additionally, reportedly more households purchased water collection containers in 2022 in response to last year's drought; however, the lack of rainfall meant they were of limited use.

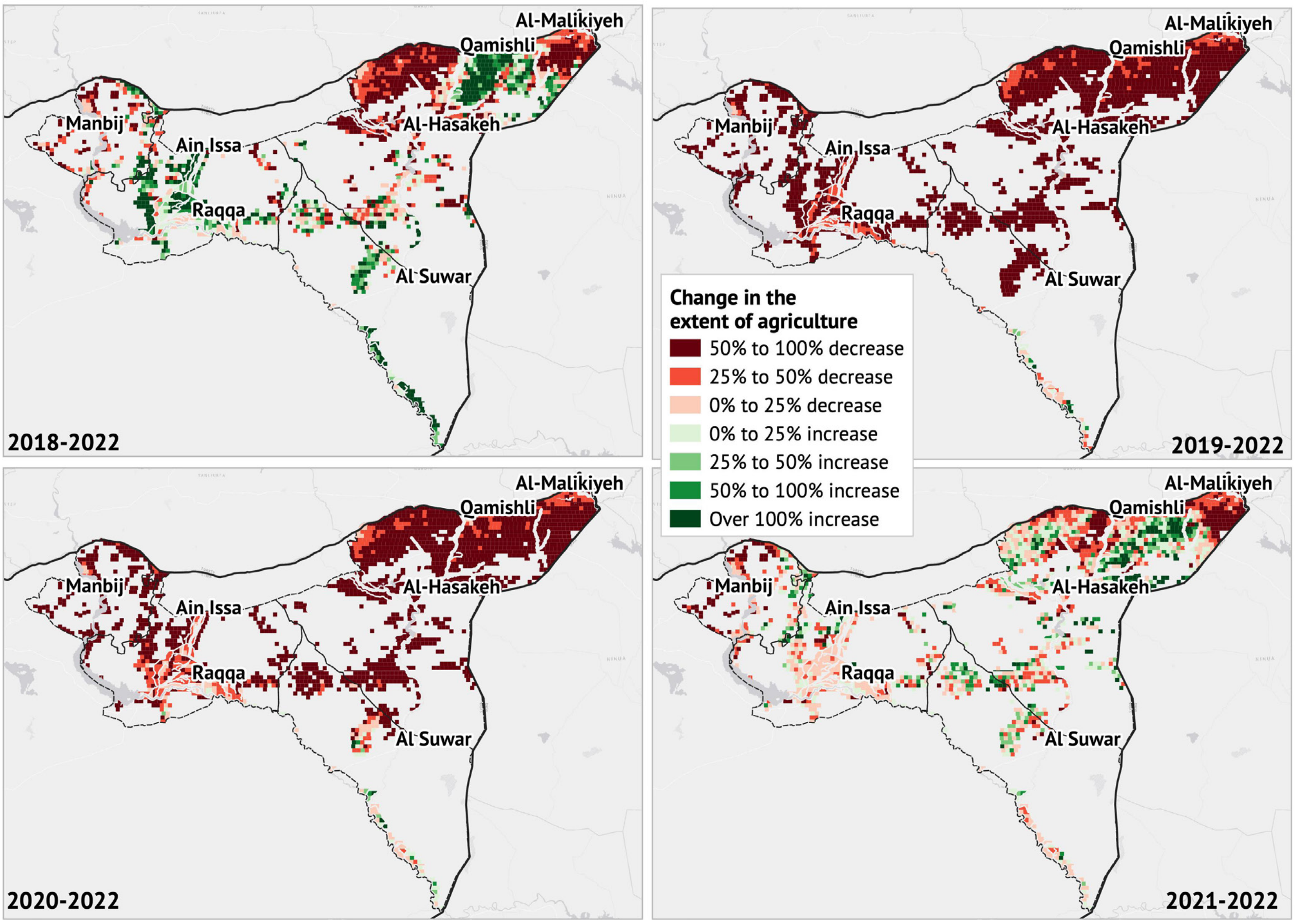

Figure 7. The change in the extent of agriculture among rainfed or groundwater-fed agricultural areas. Years represent growing seasons, and measurements are relative to the 2022 growing season.

39 KII, member of a local commune in Al-Hasakeh subdistrict in April 2022.
40 KII, humanitarian FSL staff
41 KII, member of a local commune in Quamishli subdistrict in April 2022.

Spatial dynamics of agricultural production along rivers

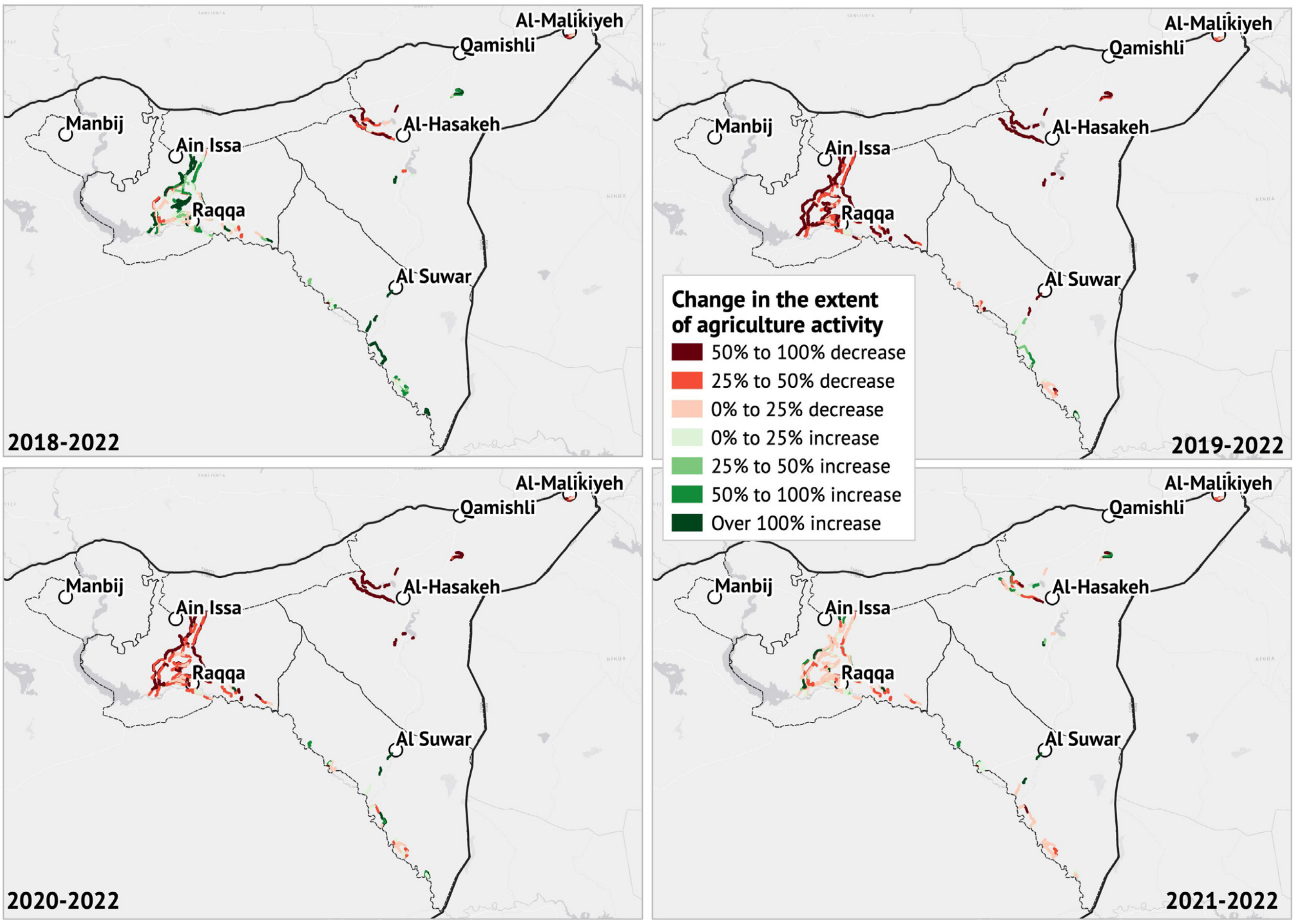

Figure 8. *The change in the extent of agriculture in northeast Syria among agriculture areas along rivers. Years represent growing seasons, and measurements are relative to the 2022 growing season.*

Figure 8 maps the change in agricultural production within 1km of rivers in the northeast. The Euphrates is the predominant river in the region; therefore, the disruption of water flow from Turkey has reduced the quantity and quality of the river water. Nevertheless, there have been clusters of increased agricultural production along rivers in the 2022 season relative to the 2018 and 2021 drought seasons. Firstly, farmland near rivers is attractive because it is cheaper to irrigate; utilizing smaller water pumps and shorter hoses is possible, and boreholes can be shallower than inland wells (20–30m deep).[42] As a result, land along rivers has been more intensely cultivated by land owners in the past two growing seasons.[43] The increase in agricultural production south of Al-Hasakah city along the Khabour river, relative to the 2021 season, is likely the result of the Autonomous Administration flooding the reservoir at the Al-Hasakeh south dam near Al-Arishah several times over the 2022 season.[44] Planned flooding of this reservoir is what sustains farming along the Khabour; however, the river is dry in most areas beyond the reach of this floodwater.

42 KII, humanitarian FSL staff
43 KII, humanitarian FSL staff
44 KII, humanitarian FSL staff

Spatial dynamics of agricultural production along canals

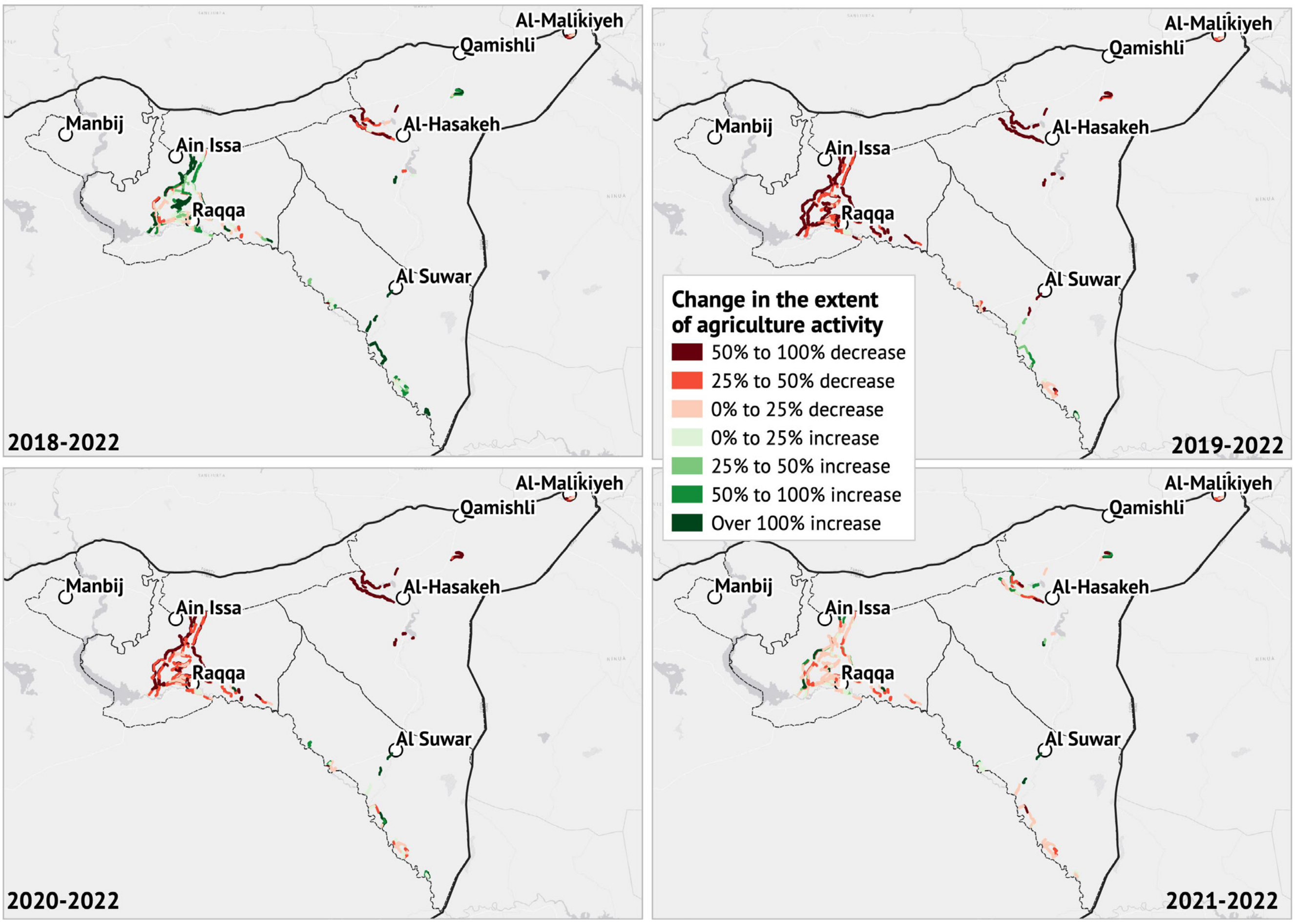

Figure 9. *The change in the extent of agriculture in northeast Syria among agricultural areas along canals. Years represent growing seasons, and measurements are relative to the 2022 growing season.*

Figure 9 maps the change in agricultural production within 500m of a canal. The expansion of agricultural production in Deir-ez-Zor, compared to the 2018 season, is likely the result of canal improvements in the area.[45] Lower agricultural production, compared to the 2019 and 2020 seasons, reflects the dramatic drop in river water level and rainfall. The increase in production around canals in Ar-Raqqa relative to the 2018 season is perhaps indicative of canal improvements,[46] though the lack of rainfall and the persistent low water level of the Euphrates have apparently diminished their utility compared to last year. Canals in Al-Hasakeh are generally unfit to support agriculture,[47] and completely dependent on rainfall to replenish the extremely low water level of the Khabour river.

45 Syria Recovery Trust Fund [via Reliefweb], 'The SRTF Successfully Completes the Rehabilitation Activities for Two Water Pumping Stations in Deir Ez-Zor.' June 2022.

46 North Press Agency, ' Delayed Rehabilitation Of Irrigation Channel In Raqqa Threatens To Damage The Agricultural Crops,' March 2020.

47 KII, humanitarian FSL staff

Potential areas of intervention for more efficient irrigation systems

Farms in specific areas would likely benefit most from more efficient irrigation techniques, such as drip irrigation systems. Drip irrigation provision is a common intervention provided by humanitarian actors across the Administration-held northeast, and Figure 10 is intended to assist in targeting future programming.

Figure 10 shows areas of northeast Syria where agricultural production has expanded at a faster rate than the total water content of the crops relative to the 2021 drought season; that is, areas where water resources exist, even in the face of drought conditions, but are being utilized inefficiently.

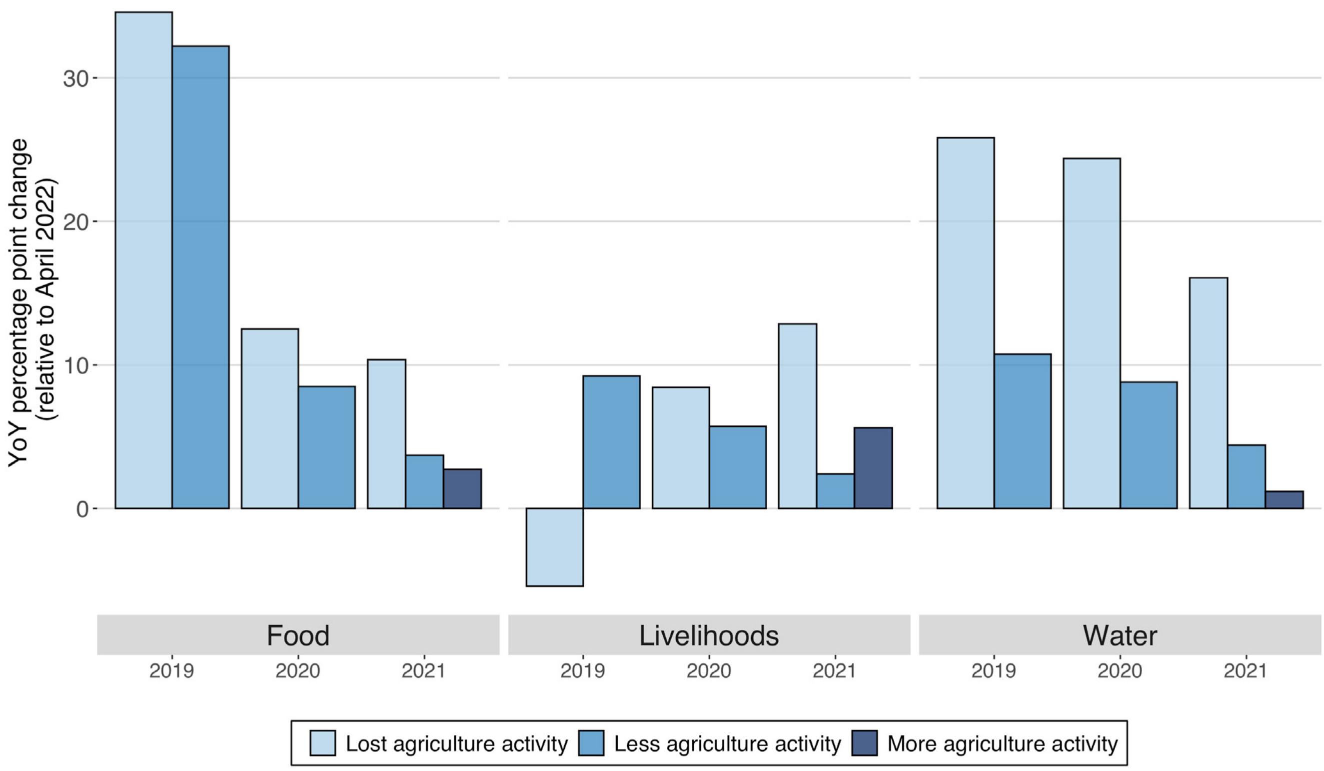

Figure 10. *Areas where agriculture expanded, but at a higher rate than the water content of the plants, relative to the 2021 drought season. All water source areas are included.*

Agricultural production dynamics and priority humanitarian needs

The level of agricultural production within 2km of agrarian communities in the northeast was also measured to assess how the level of the proportion of residents that reported food, water, or livelihoods as a priority need differ among communities that experienced more or less agricultural production relative to past seasons.[48,49,50] The results of the analysis are shown in Figure 11. The level of food and water priority needs appear to grow more in communities that completely or partially lost agricultural activity, and decreased the least in communities that expanded agriculture production. Unsurprisingly, the change in food needs grew the most relative to the abundant 2019 season; further, the smaller increase in food need relative to the rainfall-rich 2020 growing season suggests that the rapid depreciation of the Syrian pound since 2020 has negatively affected food consumption despite the productive growing season. Water needs also increased in communities that experienced lower levels of agricultural production, which supports the expected link between household and agricultural water needs in agrarian communities.

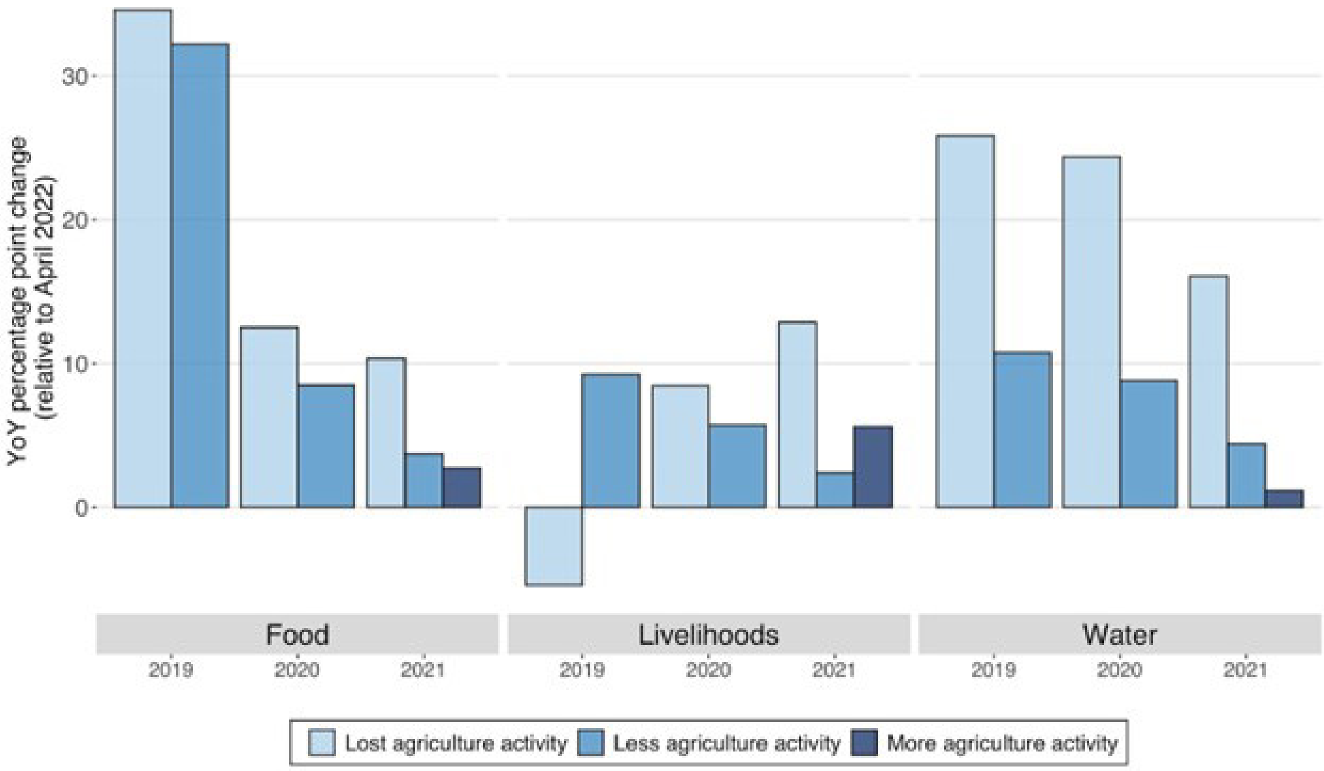

Figure 11. *Year-on-year (YoY) changes in priority need in agrarian communities at the end of the growing season (April) from 2019 to 2021, compared to April 2022 priority needs levels.*

Changes in livelihood need among communities that lost or produced less agriculture relative to the 2020 and 2021 seasons experienced the same proportional increases as food and water need; however, livelihood need surprisingly increased in communities that expanded agricultural production compared to the 2021 growing season, and decreased in communities that lost agricultural production. The latter case is counterintuitive, and so the HAT investigated the population figures of these communities but found no abnormal population changes.[51] Therefore, the change in need cannot be explained by out-migration,

48 Communities were identified as agrarian if they featured a certain density of agricultural land within a 2km radius during at least one winter growing season between 2018 and 2022. The density threshold was empirically determined by the HAT after measuring the density of farmland in several communities surrounded by many farms outside the center.

49 Priority needs data obtained from HNAP's Monthly Mobility and Needs Monitoring datasets; priority needs calculated for the resident population.

50 The 2018 season was not included due to a lack of priority needs data.

51 These communities were very small, about half the size on average than the average agrarian community (86 resi-

and may be due to livelihood adaptation, such as changing to livestock herding. Conversely, communities that managed to increase production in 2022 after the 2021 drought season are likely endowed with attractive natural resources (eg, groundwater) and farmers capable of adequately investing in their farm (eg, having sufficient resources to deepen a groundwater well). These farms incentivize residents, especially less-fortunate locals that had to halt farming due to the drought conditions, to stay and work as agricultural laborers.[52] However, this trend would also increase livelihood needs because working as an unskilled laborer is less lucrative than farming.

A historic canal irrigation system in Deir-ez-Zor. Agricultural production along canals has expanded, likely due to improvements and repairs of canals in the region.

dents), and are located in northern Al-Hasakeh governorate. Population data obtained from HNAP's Monthly Mobility and Needs Monitoring datasets.

52 An interview with a member of a local commune in Al-Hasakeh subdistrict reported that farmers who are no longer able to sustain themselves with rainfed cropping often migrate to irrigated agricultural areas to find work as laborers. The HAT suspects this process occurs within communities among farmers unable to continue farming towards those that managed to continue farming.

Conclusions

Northeast Syria became Syria's breadbasket because of its arable land, and expanded largely as a result of the government's pre-conflict agricultural subsidies and low-interest loans that facilitated the rapid expansion of groundwater well drilling.[53]

The results of this report suggest that additional groundwater abstraction has been the primary solution to sustain agricultural yields during drought seasons; however, the Autonomous Administration is struggling to provide enough subsidized inputs, particularly diesel, to facilitate farmers to continue to operate according to non-drought conditions. The lack of subsidized inputs is exacerbated by lower levels of affordability via currency depreciation and higher prices for imported goods, causing aggregate agricultural production to substantially decrease.

To support the northeast to remain a major agricultural region in Syria, it is important to accelerate the provision of more efficient irrigation technologies and production inputs.

Considerations

Humanitarian organizations

- Continue and expand programming that optimizes crop irrigation, particularly the provision and implementation of drip irrigation systems, as well as other in-kind fixed-cost items; for example, hoses or hose patch kits, solar-powered water pumps, and rainwater containers.
- Continue and expand cash or in-kind assistance for seeds, fertilizer, and diesel.
- Evaluate programming related to groundwater abstraction to include the rate of groundwater abstraction before and after the implementation of irrigation interventions to assess efficiency gains.
- Promote alternative crop rotations that preserve groundwater and increase farm incomes; for example, planting forage and grain legumes in the summer growing seasons following the winter wheat crop has been observed to be more profitable than consecutive wheat crops or fallow fields following the winter wheat season.[54]
- Consider catastrophe bonds to finance humanitarian interventions in response to future drought seasons.[55]

Research

- Measure and monitor groundwater well depths and rates of abstraction across northeast Syria.
- Continue to expand existing body of knowledge and understanding of the 'human' element on agriculture and water in northeast Syria, including policy, the decade-long conflict and its impact, and resource management.

53 Aw-Hassan, A., et al., 'The impact of food and agricultural policies on groundwater use in Syria,' Journal of Hydrology, 2014: 513(26), 204–215.
54 Christiansen, et al., 'Potential legume alternatives to fallow and wheat monoculture for Mediterranean environments,' Crop and Pasture Science, 2015: 66(2), 113-121.
55 Federal Reserve Bank of Chicago. 2018. Catastrophe Bonds: A Primer and Retrospective.

Policy and Advocacy

- Develop regulations with the Autonomous Administration centered on controlling the drilling of new groundwater wells and incentivizing the acquisition and utilization of more efficient irrigation techniques.
- Raise awareness of the need for the Autonomous Administration to provide more oversight on the usage of lower-quality groundwater for agriculture.

Future considerations

Though outside the scope of this report, it is worth noting that water quality is a major issue in the north-east,[56] and lower river, canal, and groundwater levels will continue to necessitate the use of lower quality water sources:

- A key informant in Quamishli reported that the water is salty in some villages in the subdistrict but adequate for agriculture; however, irrigating with water relatively high in saline content accelerates the process of soil salinization because salt is left behind when the water evaporates.[57]
- A key informant in Al-Hasakeh subdistrict reported that land used to grow vegetables on the bank of Kahbour River in Al-Hasakah city is irrigated with the remnants of the river that is polluted by sewage from its appearance and smell. Though this has been reported to the Administration in the hopes they would forcibly shut down the farm, the Administration has not moved to resolve the issue and the vegetables grown there are currently being sold in the local market.

56 PAX. June 2020. A River of Death.
57 FAO. Chapter 7: Salty soils.

CONTACT

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The Humanitarian Access Team (HAT) was established in Beirut in March 2015 in response to the collective challenges facing the remote humanitarian response in Syria. HAT's most important function is to collect and analyze disparate data and information. Since 2015, HAT analysis has provided a forward-looking template for international interventions in Syria, and facilitated an increasingly adaptive, integrated, and ultimately impactful international response to the conflict.

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