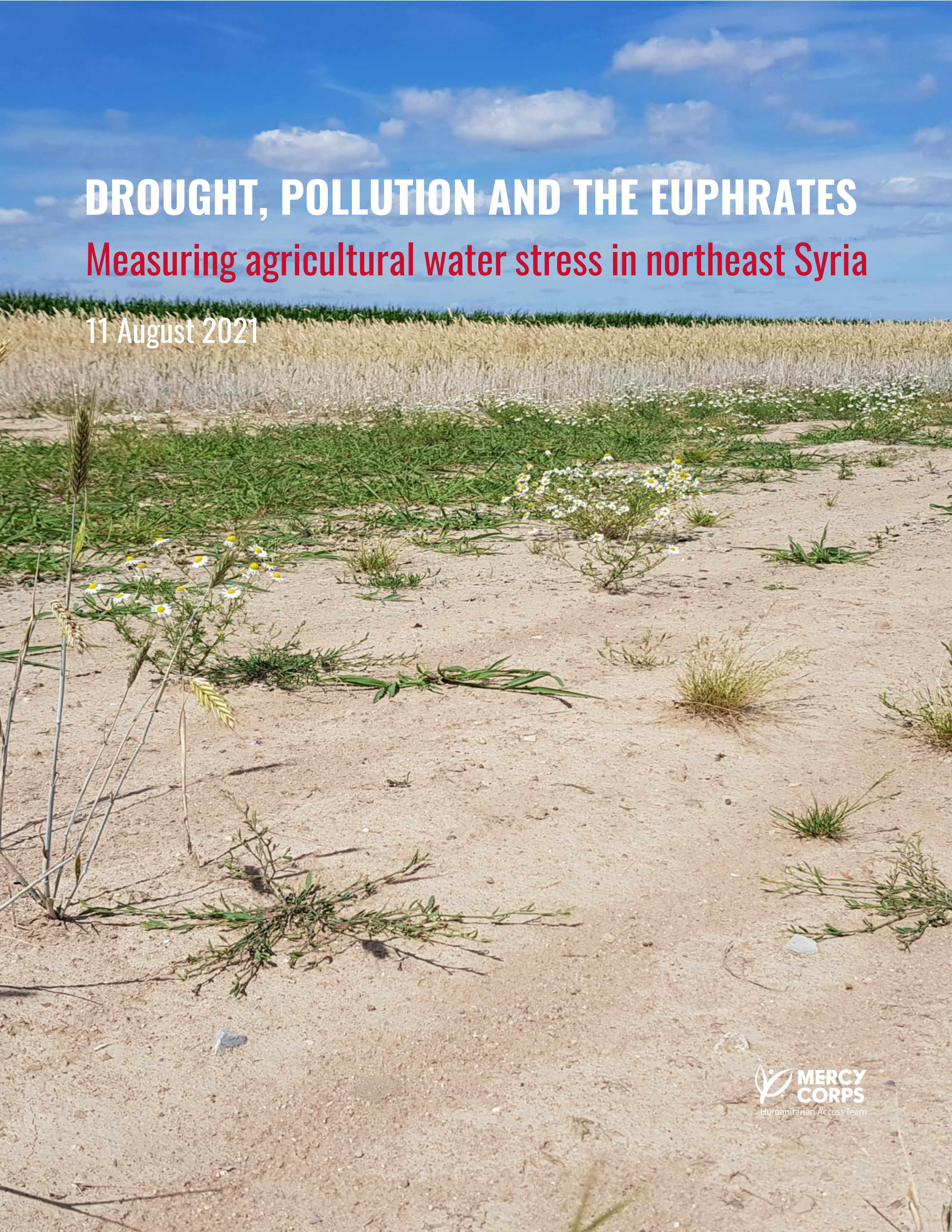
DROUGHT, POLLUTION AND THE EUPHRATES

Measuring agricultural water stress in northeast Syria

11 August 2021



MERCY CORPS
Humanitarian Access Team

EXECUTIVE SUMMARY

Syria's agricultural sector has been severely affected by regular periods of drought. These severe and sequential periods of low rainfall have caused low yields, crop failure and a reduction in national food security. Attempts to measure the impacts of these droughts on agricultural production have been limited, with the development quantitative methodology lacking. In this paper, the impact of drought in various agriculture producing areas of northeast Syria is estimated using changes in vegetation water content (May 2020 to May 2021), a proxy for the extent and vigor of agricultural production. Data from satellite imagery has been collected and aggregated according to several geographic boundaries; specifically, agricultural land use zones in the Jazira region, land surrounding canals in Raqqa governorate, northeast Syrian subdistricts and districts in south-eastern Turkey, and populated areas in northeast Syria.

Low levels of rainfall has also led to lower levels of water in the Euphrates river. Findings show that not only does this compromise agricultural production, the lower water level of the Euphrates has also lessened electricity generation: HAT has previously found that the nightlight reflectance (a proxy for economic activity) of the typical community under the control of the Autonomous Administration of northeast Syria decreased by an average of 23% from May 2020 to May 2021.

The largest decline in vegetation water content occurred in Al-Hasakeh governorate and areas of dry farming (cultivation of land without irrigation) throughout northeast Syria. Conversely, vegetation water content slightly increased in areas where irrigation farming is the primary type of agricultural land use; specifically, by 7% in Raqqa governorate and by 4% in Deir-ez-Zor governorate. These irrigation farming areas are located near the Euphrates; therefore, lower water levels in the Euphrates river did not significantly hinder many irrigation farmers from extracting the existing river or canal water for irrigation. The subdistrict-level analysis revealed large declines in vegetation water content in practically all bordering Turkish districts, particularly those just north of Qamishli district in Syria, highlighting the wide geographic area negatively affected by the drought.

Poor water quality is another factor affecting farming in the northeast. Spatial clusters of negative vegetation water content along downstream irrigation canals in central and northern Raqqa subdistrict suggests a greater concentration of saline agriculture drainage and polluted water from the Bailk river basin, as inflows from the Euphrates river decreased due to lower water levels. This trend was also observed among agrarian communities located in the Balikh basin, further indication that poor water quality has negatively impacted agricultural production in the region.

The analysis of WASH and livelihood indicators in agrarian communities showed that the decline of vegetation water content in agrarian communities that rely on a borehole as their main domestic water source 49 percentage points greater than in agrarian communities with another primary water source. Further, the decline of vegetation water content was 54 percentage points greater in agrarian communities that reported access to credit as a priority livelihood need than communities that did not report that livelihood need. The decline of vegetation water content was 53 percentage points greater in agrarian communities that reported purchasing water using credit, informal exchange, or using money typically used on other things than in agrarian communities that did not report purchasing water using those means.

The price of fodder increased due to fewer grazing areas and higher barley prices, which has had a negative impact on the livelihood of shepherds through the uneconomical sell-off of underweight livestock. Less agricultural production has lowered demand for agriculture labour, reducing the working hours and wages of agriculture workers in the region.

The already-tenuous profit margins of farms have been further tightened by higher diesel and fertilizer prices, according to KI interviews with farmers in the region. The farmers cited assistance buying diesel, borehole drilling, and canal repairs as the best ways to support the water security of their farms. Therefore, the humanitarian community can immediately support farmers through diesel delivery or subsidies, and should prioritize canal repair and the adoption of electric water pumping systems as medium-term solutions, and sustainable irrigation (for example, drip irrigation) methods as a long-term method to combat water insecurity in the region.

KEY POINTS

- Agricultural production in Syria has been significantly negatively impacted by severe and sequential droughts, which have caused lower yields and crop failure.
- In addition to lower climatic water availability, water levels in the Euphrates have been greatly reduced due to a lack of rainfall and upstream water constrictions, which has lessened inflows to irrigation canals.
- The lower water levels in the Euphrates have resulted in additional negative externalities, particularly reduced electricity generation (-23% on average) and the concentration of pollution in irrigation canals.
- Changes in the vegetation water content (May 2020 to May 2021) are measured using satellite imagery and aggregated according to several geographic boundaries.
- The largest decline in vegetation water content occurred in Hasakeh governorate.
- The vegetation water content of dry farming areas decreased by 50% compared to last year.
- Changes in the vegetation water content (May 2020 to May 2021) are measured using satellite imagery and aggregated according to several geographic boundaries.
- The largest decline in vegetation water content occurred in Al-Hasakeh governorate.
- The vegetation water content of dry farming areas decreased by at least 50% compared to last year.
- Vegetation water content slightly increased (≅6%) in irrigation farming areas, mainly located along the Euphrates and upstream irrigation canals in Raqqa and Deir-ez-Zor governorates due to additional water pumping and probably additional vegetable cultivation.
- The subdistrict-level analysis revealed large declines in vegetation water content occurred in practically all bordering Turkish districts (*ilçeler*), particularly those just north of Qamishli district in Syria, highlighting the wider geographic range of the drought.
- Clusters of negative change in vegetation water content among agrarian communities in the Balikh river basin suggests water pollution also contributed to lower levels of agricultural production in the area.

- The analysis of WASH indicators in agrarian communities showed that the decline of vegetation water content in communities where boreholes are the primary domestic water source was 49 percentage points greater than in communities with other primary domestic water sources.
- The analysis of livelihood indicators in agrarian communities showed that the decline in vegetation water content was 54 percentage point greater in agrarian communities that reported access to credit as a priority livelihood need, and 53 percentage points greater in agrarian communities that reported purchasing water using credit, informal exchange, or using money typically used on other things.
- The already-tenuous profit margins of farms have been further tightened by higher diesel and fertilizer prices, according to KI interviews with farmers in the region.
- The price of fodder increased due to fewer grazing areas and higher barley prices, which has had a negative impact on the livelihood of shepherds through the uneconomical sell-off of underweight livestock.
- Less agricultural production has lowered demand for agricultural labor, reducing the working hours and wages of agriculture workers in the region.
- Subsidized diesel, borehole drilling, and irrigation canal repairs were the most-cited items listed by farmers KIs when asked about ways to immediately improve the water security of their farms.
- Sustainable irrigation methods (for example, drip irrigation) and the provision of water collection containers should also be considered as longer-term methods to combat water security in the region.

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INTRODUCTION

The agricultural sector is one of the primary contributors to Syria's GDP, and is second only to oil in export revenue. In 2007, output from the agriculture sector comprised around 20% of GDP[1] and is also an essential employment sector in Syria. According to the latest (2019) ILO estimates, 10% of the Syrian labor force is employed in the agricultural sector,[2] with livestock comprising about 20% of rural employment.[3] Further, close to 75% of rural households grow food for personal consumption, and more than a third of rural households use their personal food production to meet over a quarter of their food requirements,[4] highlighting the importance of the sector in both the formal and informal household economy.

Agricultural production in Syria has been hugely impacted by severe and sequential droughts[5] causing smaller harvests, and in some cases complete crop failure. This has been further compounded by the years of conflict in Syria (2011 – present); conflict has meant damage to crops and infrastructure, displacement of farmers and laborers, fewer subsidies and increasing costs and reduced accessibility of imported and domestic production inputs (including fertilizers and machinery). Pre-conflict, Syria's extensive number of droughts – occurring for varying lengths almost every two years since the 1960s.[6]

In the northeast, which has the reputation of being the 'breadbasket' of Syria, with large areas of arable land and generally good water supply from the Euphrates river, drought in the region has even more far reaching, national impact, particularly during the 2006—2009 seasons, when drought forced many people reliant on agriculture to relocate to major urban centers.[7] Low levels of rainfall in 2018, and another drought measured in 2021, have continued to affect the health, livelihoods and food security of citizens.[8]

Attempts to measure the effects of the current drought on agricultural production in northeast Syria has been limited in scope.[9] This report aims to build on current evidence, by providing an analysis of year-over-year (2020 to 2021) changes in vegetation water content, measured using satellite imagery. This metric serves as a proxy for the water stress level of significant vegetation, and so can provide a way to judge

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[1] Agriculture, forestry, and fishing, value added (% of GDP) - Syrian Arab Republic

[2] World Bank - Agriculture and Rural Development Indicators

[3] Food and Agriculture Organization of the United Nations (FAO). 2017. Counting the cost Agriculture in Syria after six years of crisis.

[4] ibid.

[5] In this paper, "drought" is synonymous with low rainfall, more precisely known as meteorological drought.

[6] Quarterly Journal of International Agriculture 51, No. 1: 21 – 49. Droughts in Syria: An assessment of impacts and options for improving the resilience of the poor, 2012

[7] The New Humanitarian. Syria: Drought driving farmers to the cities, September 2009.

[8] REACH, Briefing note – Humanitarian Situation Overview in northeast Syria, June 2021.

[9] The only existing measurements were produced in the following: iMMAP. North East Syria Crop Monitoring and Food Security Situation Update, May 2021.

changes in agricultural production. These changes are aggregated according to different administrative boundaries in northeast Syria and southeast Turkey, in addition to land use types in northeast Syria, and the proximity to canals in Ar-Raqqa governorate. Findings are supported by key informant interviews with landowners, farm workers, and shepherds throughout northeast Syria.

The results indicate the largest decline in vegetation water content occurred in Hasakeh governorate and dry farming areas in the region. Irrigation farming areas in Raqqa and Deir-ez-Zor governorates slightly increased from 2020 to 2021. Key informant interviews indicate that, although water levels of all rivers and tributaries decreased in 2021, farmers continued to pump water from boreholes (as much as possible), rivers, tributaries, and canals at normal rates, though at a greater cost due to higher fuel prices and the cost of maintaining pumps. Further, poor water quality appears to be the source of diminished agricultural production around the upper Balikh river and surrounding canals.

The analysis of agrarian communities suggests domestic water scarcity is closely related to water source. Communities that rely on water pumped from boreholes as a domestic water source had 40% less vegetation water content than communities with other primary water sources, and communities that rely on piped water had 40% more vegetation water content than communities with other primary water sources.

In terms of farming, farmers relying on predominantly rain-fed farming tended to request assistance to drill boreholes during drought periods, and farms relying on water pumping are generally in need of fuel assistance. Short term, provision of these services (either assistance for borehole or access to fuel) are important to maintain current agriculture. Longer-term support for sustainable agriculture, such as the implementation of drip irrigation, should be considered to mitigate over-extraction and preserve groundwater supplies. Reduction in water pollution in northern Raqqa should be investigated to maximize the utility of relatively consistently available water sources.

AGRICULTURE IN NORTHEAST SYRIA

In northeast Syria, the predominant crops are wheat in the winter and cotton in the summer.[10,11] Wheat is naturally the most strategic crop due to its positive impact on food security, and was produced in surplus before the conflict, largely due to the development of new wheat seed varieties by the Syrian government's General Commission for Scientific Agricultural Research, government purchasing guarantees, and fuel subsidies.[12] Cotton has been widely grown in northeast Syria and was the country's largest agricultural export before 2011.[13] In addition to

[10] Food and Agriculture Organization of the United Nations, Country profile – Syrian Arab Republic., 2008.

[11] Younes, S.F. Potentials of Cropping Systems' Diversification in North-East Syria, for Enhanced Sustainability in Farming Systems, 2012.

[1212] Aw-Hassan, A. et al. 2014. The impact of food and agricultural policies on groundwater use in Syria. Journal of Hydrology, 51(3): 204-215.

[13] Mohammed, S.A. et al. 2020. Syrian crisis repercussions on the agricultural sector: Case study of wheat, cotton and olives. *Regional Science Policy and Practice*, 12: 519-537.

wheat and cotton, a wide variety of crops are grown to a lesser extent in the region; specifically, barley (generally used for animal fodder), lentils, cumin, and onions in the winter, and maize, tomato, watermelon, melon, cucumber, and onion in the summer.[14]

Farming in northeast Syria is generally categorized as irrigated or rain-fed (dry). Irrigation farming involves watering the soil by overflowing canals (flood or furrow irrigation) or channeling water through hose networks situated between plant rows (drip irrigation), both sourced by water pumped from boreholes, rivers, and tributaries, or channeled through irrigation canals. Dry farming solely relies on rain water, and is generally used to grow less water-intensive crops such as wheat and barley, though about 22% of wheat farms in the region used improved supplemental irrigation systems before the conflict.[15] Livestock production is another significant agriculture activity in northeast Syria

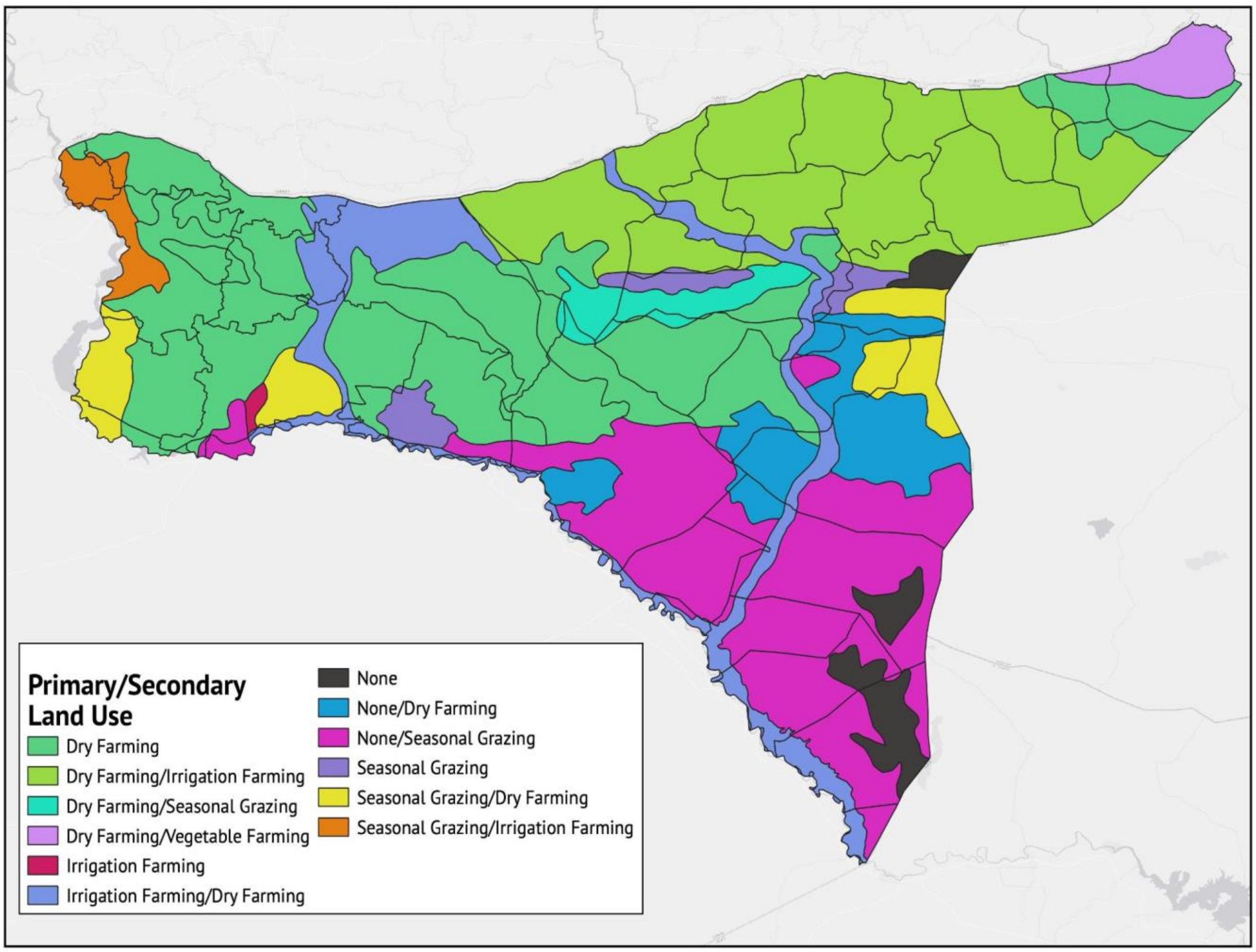

Figure 1: Primary and secondary agriculture land use in the Jazira region

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[14] Younes, S.F. Potentials of Cropping Systems' Diversification in North-East Syria, for Enhanced Sustainability in Farming Systems, 2012.

[15] Yigezu, A. Y., Hassan, A. A., Shideed, K., El-Shater, T. (2011). Economic and environmental impact of supplementary irrigation in rain-fed agriculture: the case of wheat in Syria. Aleppo, Syria. ICARDA: International Center for Agricultural Research in the Dry Areas.

and mainly consists of sheep herding, with smaller populations of goats and relatively few (dairy or meat) cattle and commercial poultry farms.[16] The distribution of primary and secondary agricultural land uses in the Jazira region of northeast Syria are shown in Figure 1.[17]

Agricultural production has declined in northeast Syria over the past two decades. The first major setback were the successive drought seasons from 2006 to 2009, which caused massive out-migration from rural to urban areas.[18] Following this, from 2011, the outbreak of the Syrian conflict has disrupted agricultural production through displacement due to violence, the degradation of and damage to irrigation canals and land.[19,20] Fractured control of regions (for example, opposition and Turkish takeover's in the northwest) led to The breakdown of market linkages, while limited imports and constrained transportation routes have meant more expensive and lower quality agriculture inputs; further, changes in administrative control separated the region from Damascus and any central agricultural planning and programming, particularly access to

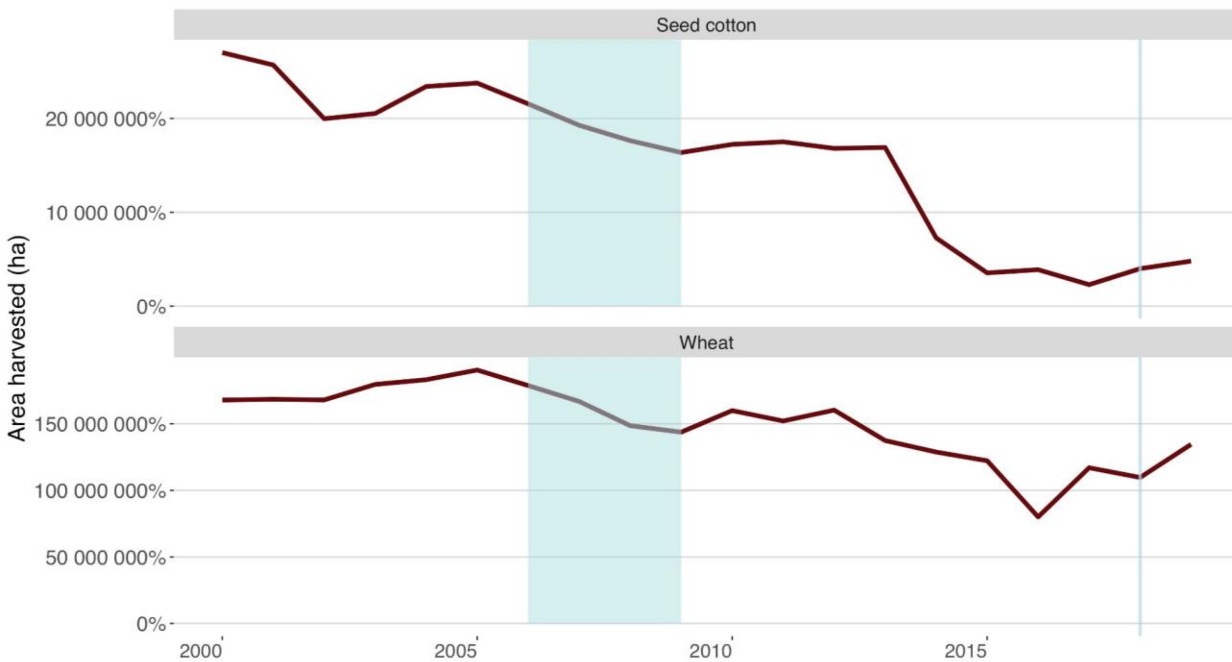

Figure 2: Total harvested hectares of wheat and seed cotton in Syria, 1995-2019. Data obtained from FAOSTAT. Light blue areas indicate drought years.

[16] Food and Agriculture Organization of the United Nations (FAO). 2017. Counting the cost Agriculture in Syria after six years of crisis.

[17] Based on the following land use GIS boundary shapefile: Mathys, Tony. (2017). Soil Dataset for the Jazira Region of Syria, [Dataset]. University of Edinburgh. https://doi.org/10.7488/ds/1724.

[18] The New Humanitarian. Syria: Drought driving farmers to the cities, September 2009.

[19] Global Communities. Resilience through Humanitarian Assistance: Agriculture in the Syria Conflict, May 2018

[20] Bayram, M. and Gök, Y. 2020. The effects of the War on the Syrian Agricultural Food Industry Potential. *Turkish Journal of Agriculture - Food Science and Technology*, *8*(7):1448-1462.

specifically-engineered wheat seeds.[21,22] The FAO estimated that the Syrian agricultural sector has lost an estimated (US) $16 billion between 2011 and 2016;[23] with $7.2 billion losses in crop production and $5.5 billion losses in the livestock sector. Figure 2 shows the number of hectares of wheat and cotton produced in Syria since 2000, with dramatic decreases occurring during the 2006-2009 drought and the first years of the conflict.

DROUGHT IN NORTHEAST SYRIA

Northeast Syria has experienced periodic droughts since the 1980s.[24] The last drought occurred in 2018, and an exceptionally severe drought occurred from 2006 to 2009, which led to a large amount of out-migration to urban centers.[25]

The region is particularly susceptible to droughts since the 1970s, when the government promoted the rapid expansion of large-scale irrigated agriculture, causing over-extraction of groundwater. This propelled the northeast, specifically Hasakeh, into centers of agricultural production.[26] The over-extraction of groundwater from the Khabour basin and lower discharge levels from the main source spring of the Khabour River, Ras al-Ain, caused farmers to abandon land and move onto marginal plots with localized groundwater wells.[27,28] Groundwater levels drop faster during droughts due to lower recharge and increased abstraction; therefore, rainfall shortages have had a multiplied impact on agriculture in the region.

The current rainfall levels are lower than the last drought period in 2018, according to the De Martonne index, a measure of climate dryness using temperature and precipitation data.[29] The index was calculated during wheat sowing and growing seasons (October to May), as shown in Figure 3,[30] with scores lower than 20 indicating semi-arid conditions and scores lower than 10 indicating arid conditions. As expected, changes appear to be most severe in Raqqa, Hasakeh, and Qamishli, with Hasakeh and Raqqa entering arid conditions in 2021. In Turkey, Viransehir and Mardin, immediately north of the border, have also experienced significantly drier climates that placed in them a semi-arid condition, highlighting the regional breadth of the drought.

In addition to lower climatic water availability, water levels in the Euphrates have been greatly reduced due to a lack of rainfall and upstream water constrictions. Specifically, water levels are down four meters since last year, according to

[21] COAR, Need for seed: Damascus increasingly desperate for wheat, December 2020.

[22] Mercy Corps, Hasakeh, Syria agricultural assessment, October 2015.

[23] Food and Agriculture Organization of the United Nations (FAO). 2017. Counting the cost Agriculture in Syria after six years of crisis.

[24] DW News. How climate change paved the way to war in Syria, February 2021.

[25] Kelley, C.P., et al. 2015. Climate change in the Fertile Crescent and implications of the recent Syrian drought. PNAS, 112(11), 3241-3246.

[26] Selby, J. 2019. Climate change and the Syrian civil war, Part II : the Jazira's agrarian crisis. *Geoforum*, *101*, 260-274.

[27] ibid.

[28] Hole, F. and Zaitchik, B.F. 2007), Policies, plans, practice, and prospects: irrigation in northeastern Syria. *Land Degradation and Development*, *18*(2), 133-52.

[29] Temperature and rainfall data gathered from the historical monthly data free available from World Weather Online.

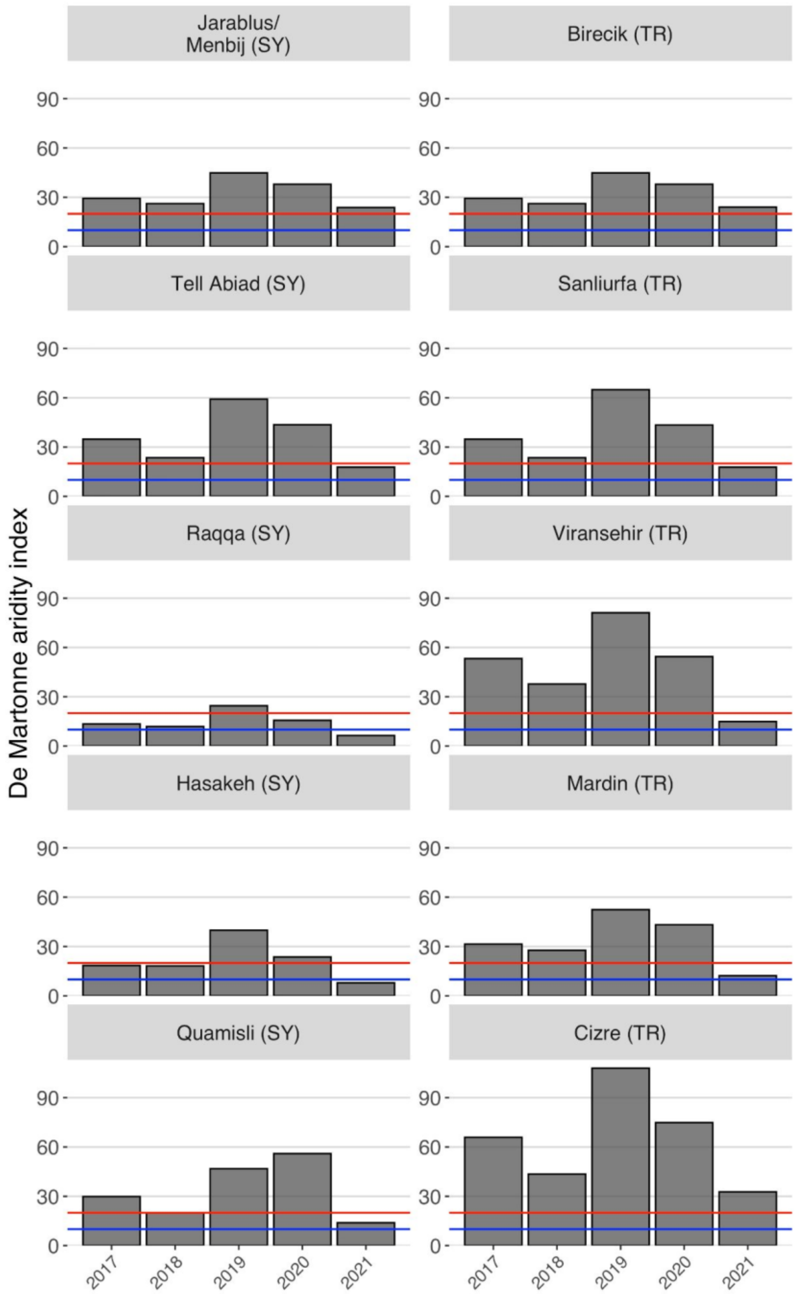

Figure 3: De Martonne aridity index for primary cities across northern Syria and primary cities immediately north in Turkey. The red line (scores ≤20 >10) indicates semi-arid conditions and the blue line (scores ≤10) indicates semi-arid conditions.

key informants in Karama, Raqqa governorate, while water levels recorded at Tabqa dam near Raqqa were roughly 80% below their normal level in May 2021.[30]

The lower water levels have reduced electricity generation and increased the amount of power required to operate water stations; this has been specifically noticed at the Alouk water station along the border with Turkey, an essential water provider to Hasakeh governorate.[31] This extends to smaller scale water pumping for river and canal-fed irrigation farming, which becomes costlier under drought conditions due to the need for longer water hoses and additional pump power.

One farmer in Raqqa subdistrict stated; "The low water levels [of the Euphrates] affected electricity provision, denying those with electric water pumps from being able to pump their water" (transcribed from Arabic).

[30] World Food Programme. (June 2021). Syria Vulnerability Analysis and Mapping (VAM) Bulletin #55: May 2021. https://reliefweb.int/

[31] UN Office for the Coordination of Humanitarian Affairs. (May 2021). Briefing to the Security Council on the humanitarian situation in Syria. https://reliefweb.int/

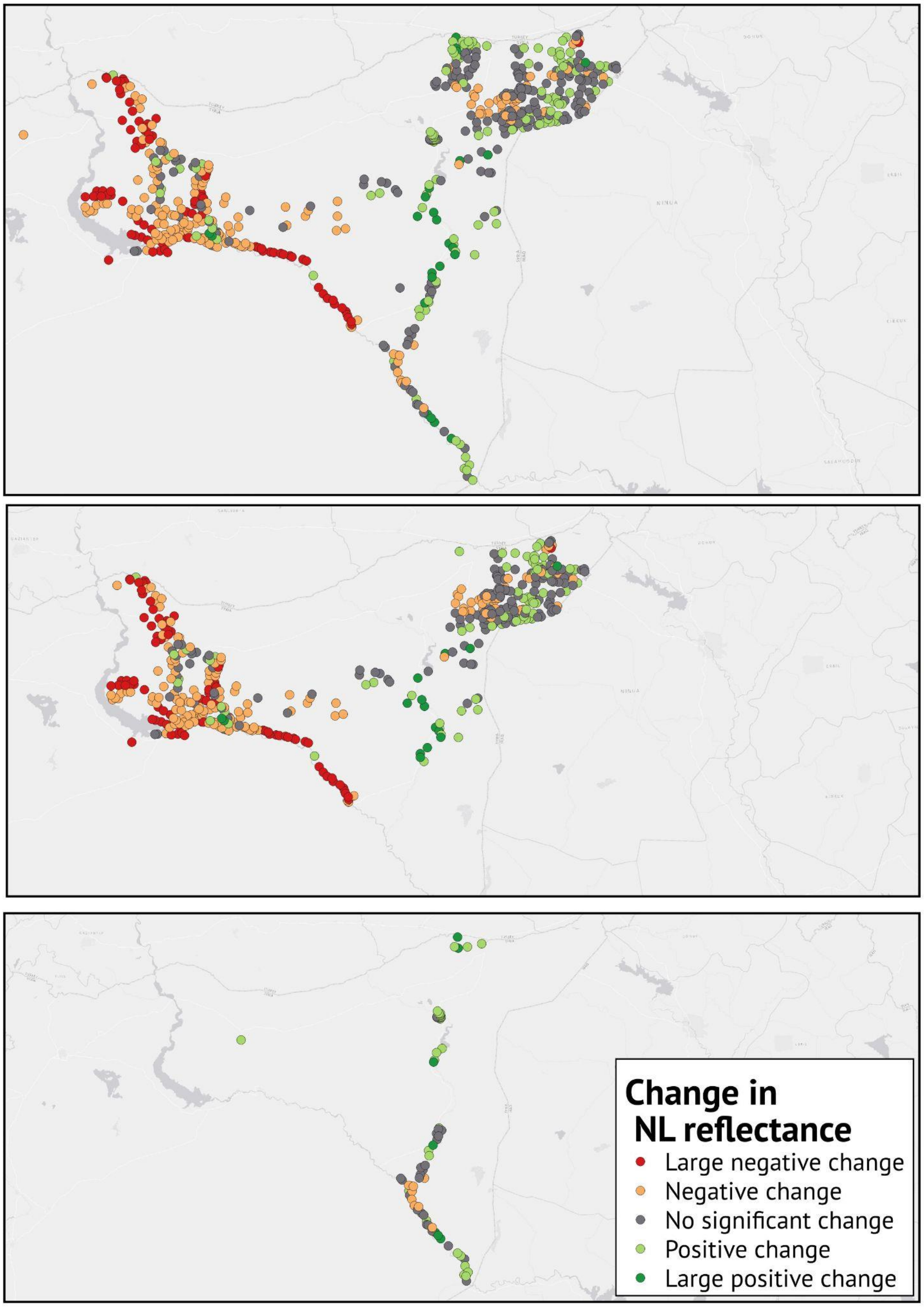

Figure 4: Change in night light reflectance in northeast Syria. The top panel shows all locations within Self-administration control as of May 2021. The middle panel is a subset of those locations where the main network is the main source of electricity. The bottom panel are locations where community generators are the main source of electricity.

EUPHRATES WATER LEVELS

Lower water levels in the Euphrates have also had other negative externalities including reduced power generation for the Autonomous Administration's electricity network, with electricity consumption in the typical community under the Administration's control decreasing by an average of 23% from 2020 to 2021, according to power usage measurements by HAT.[33]

Figure 5: Euphrates River in Karama subdistrict, Raqqa governorate. Local sources informed HAT that last year's water level was near the top of the land along the left side of the photograph. Photograph by HAT.

Interestingly, the growth rates of electricity consumption differed based on their primary power source. As shown in Figure 4, consumption in communities which use the mains network as their primary power source was 26% lower in 2021 than 2020, (according to paired t-tests),[34] while the consumption of communities that used community generators as their primary power source increased by an average of 11% from 2020 to 2021. There was no statistically significant difference in the electricity consumption of communities that used private generators as their primary source of power.

Additionally, key informants in Raqqa informed HAT that the water quality of the Euphrates has worsened as a result of higher concentrations of pollution from upstream sources; specifically, untreated sewage from Raqqa and industrial waste in the Balikh River. The effects of higher concentrations of pollutants increase the likelihood of water-borne diseases and chronic illnesses via drinking water and the consumption of produce from farms irrigated with river water.[35,36]

[33] Measured as the change in April 2020 and April 2021 levels of total night light reflectance within 2km of community (administrative level 4) centre points.

[34] Measured using a subsample of communities according to their main power source, as identified in REACH's Humanitarian Needs Overview assessment (May 2020 & 2021).

[35] Islam, M. et al. 2018. Trace metals accumulation in soil irrigated with polluted water and assessment of human health risk from vegetable consumption in Bangladesh. *Environmental Geochemistry and Health* (*40*), 59–85.

[36] Okafo, C.N. et al. 2003. Occurrence of pathogens on vegetables harvested from soils irrigated with contaminated streams. *Science of The Total Environment 311*(1-3), 49-56.

PART II CHANGES IN VEGETATION WATER CONTENT

METHODOLOGY

Quantitative measurements for vegetation water content were calculated using Sentinel 2 multispectral satellite images.[37] 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.[38,39] Further, the spatial resolution of visible and infrared light bands are 10m or 20m,[40] allowing for detailed analyses on relatively small study areas. Images taken at the end of the growing season (early and mid-May) were obtained for the years 2020 and 2021. The images cover most of northern Syria and southeastern Turkey. Images for May 2020 and May 2021 were

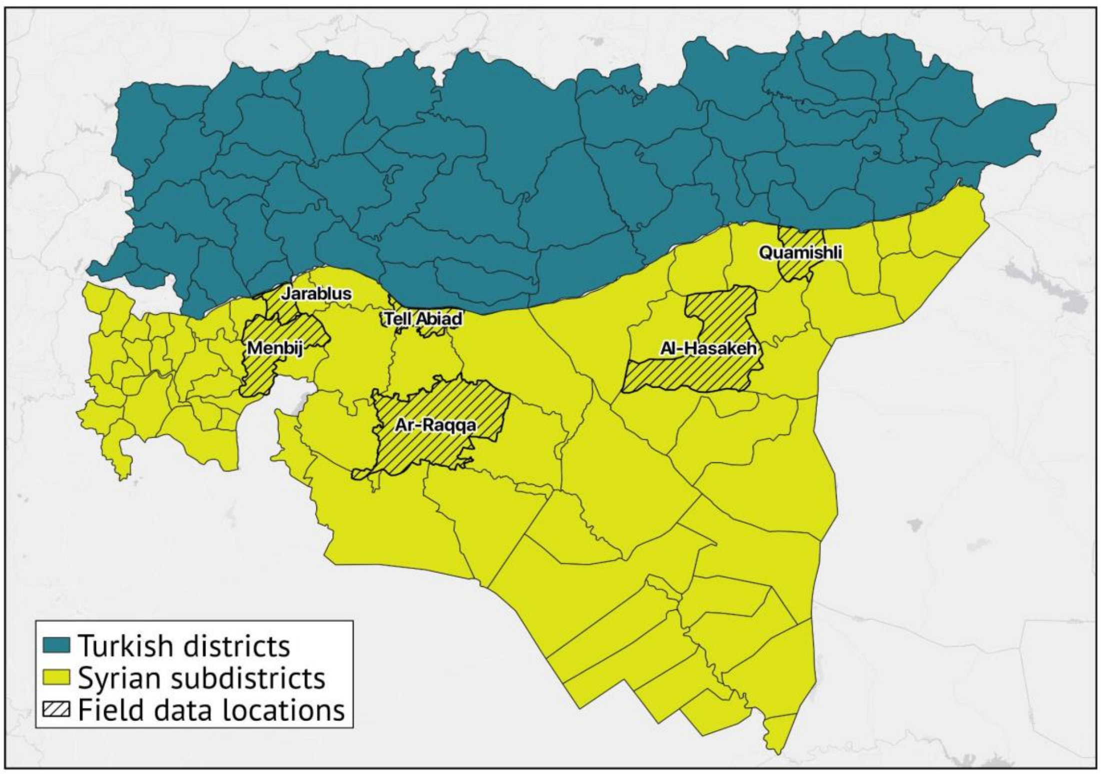

Figure 6: Study area of the subnational satellite imagery analysis. HAT collected data from key informants in the Syrian subdistricts covered by hash marks.

[37] Atmospherically-corrected using the sen2cor package in R. Bands 2 to 8a, 11, and 12 used in the analysis. Band 8 resampled to a 20m spatial resolution.

[38] 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*, *101*(3), 582-592.

[39] Piedelobo, L., et al. 2018. HidroMap: A New Tool for Irrigation Monitoring and Management Using Free Satellite Imagery. *International Journal of Geo-Information*, *7*(6).

[40] Satellite sensor spatial resolution is typically measured as the distance of the side of a square pixel; therefore, each pixel represents the squared spatial resolution on the ground.

collected to calculate the annual change in vegetation water content.

The Normalized Difference Moisture Index (NDMI)[41] is an indicator of vegetation water content. NDMI is calculated using near-infrared (NIR) and short wave-infrared (SWIR) bands from multispectral satellite images to measure plant water content. SWIR reflectance is indicative of moisture-related internal structure and NIR reflectance is solely indicative of the dry matter internal structure. The ratio of the difference between NIR and SWIR reflectance and the total NIR and SWIR reflectance, the formula for NDMI, accurately measures the relative abundance of dry structure in a plant, and is therefore an accurate measure of vegetation water content.[41] NDMI has proven to be useful as a measure of drought in past research.[42,43]

HAT conducted interviews with 27 farmers, 26 farm workers, and 23 shepherds throughout northeast Syria to provide further, qualitative contextual information on the economic and productive impact of the current drought. The maximum geographic scope of the quantitative measurements and subdistricts where informants were interviewed are shown in Figure 6.

SPATIAL ANALYSIS

The analysis centers on measuring the annual change in NDMI from May 2020 to May 2021, aggregated according to several geographic boundaries; specifically, agricultural land use zones in the Jazira region, land surrounding canals in Raqqa governorate, subdistricts in northeast Syrian (districts in southeastern Turkey), and populated places in northeast Syria. Growth in vegetation water content (or NDMI) indicates lower levels of vegetation water stress and a decline in NDMI indicates more vegetation water stress, a proxy for less productive agriculture. Changes in water stress could derive from crop fallowing, as some fields are uncultivated and left to recover while others are cultivated after a season or year of recovery. However, this is likely not a major source of error at an aggregate level because shifting farm fields most often fall within the boundary of the geographic aggregation (e.g. subdistrict).

Significant water bodies such as rivers and large lakes produce NDMI values of approximately zero; however, water-deprived water bodies register high NDMI values as a result of vegetation growing in shallow water, such as reeds. Therefore, significant water bodies were clipped from the satellite images before analysis to avoid imprecise annual change calculations. These water bodies were identified using the boundaries of major water bodies available on Wikimapia. Pixels within these boundaries were removed from the images.

[41] Cessato, P., et al. 2001. Detecting vegetation leaf water content using reflectance in the optical domain. *Remote Sensing of Environment 7*: 22-33.

[42] See: Gu, Y., et al. 2007. 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 34(6).

[43] El-Hendawy, S.A., et al. 2017. 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 Volume*, *182*(1): 1-12.

PART III DYNAMICS IN VEGETATION WATER CONTENT FOR GEOGRAPHICAL AREAS

SUBDISTRICTS

Subdistrict vegetation water content dynamics including bordering administrative units in Turkey were analyzed to assess changes in agricultural vigor throughout the broader region. Large reductions in vegetation water content were observed in all subdistricts in Hasakeh governorate and all measured subdistricts along the northern border. Further, significant negative changes were observed in practically all Turkish districts (*ilçeler*), particularly just north of Qamishli district in Syria. The latter explains the logic of the Turkish government to increase irrigation in the region, though the areas in Turkey exhibited higher absolute levels of vegetation water content per-km^2 than areas in Syria. Positive changes in vegetation water content were observed in several subdistricts along the Euphrates, a surprising finding that will be more clearly explained in the community-level analysis.

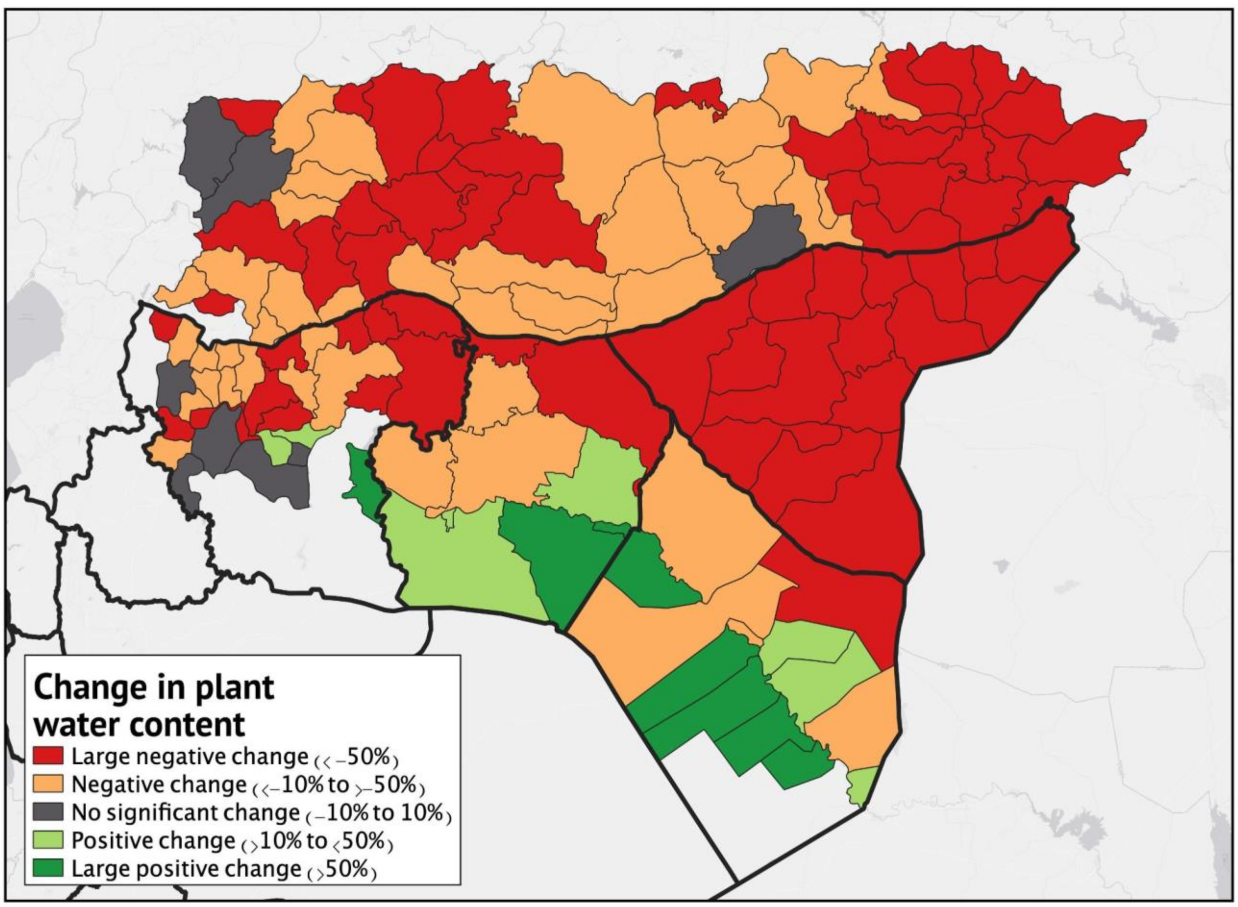

Figure 7: Change in plant water content, 2020 to 2021, in northern Syria and southeastern Turkey.

AGRICULTURAL LAND USE ZONES

Changes in vegetation water content were aggregated according to the combined primary and secondary agriculture land use in the Jazira region (see Figure X)[44,45] to analyze how different agriculture types were impacted by the drought and lower water levels in the Euphrates. Areas where the primary land-use zone is "none" were removed from the analysis, and several seasonal grazing zones were removed from the analysis because current satellite images clearly indicate a significant amount of farming is currently practiced in those areas.

As expected, the greatest reduction in vegetation water content occurred in areas where dry farming was the primary use of agricultural land, where it decreased by at least 50% from 2020 to 2021. Negative changes were observed among all land use types in Hasakeh governorate, including irrigation farming, likely due to extremely low water levels in the Khabour River and significantly diminished groundwater replenishment.

The large decrease in vegetation water content in dry farming areas significantly decreased agricultural production and also had a large negative effect on the agricultural labor force by reducing the working hours and wages of farm laborers. According to

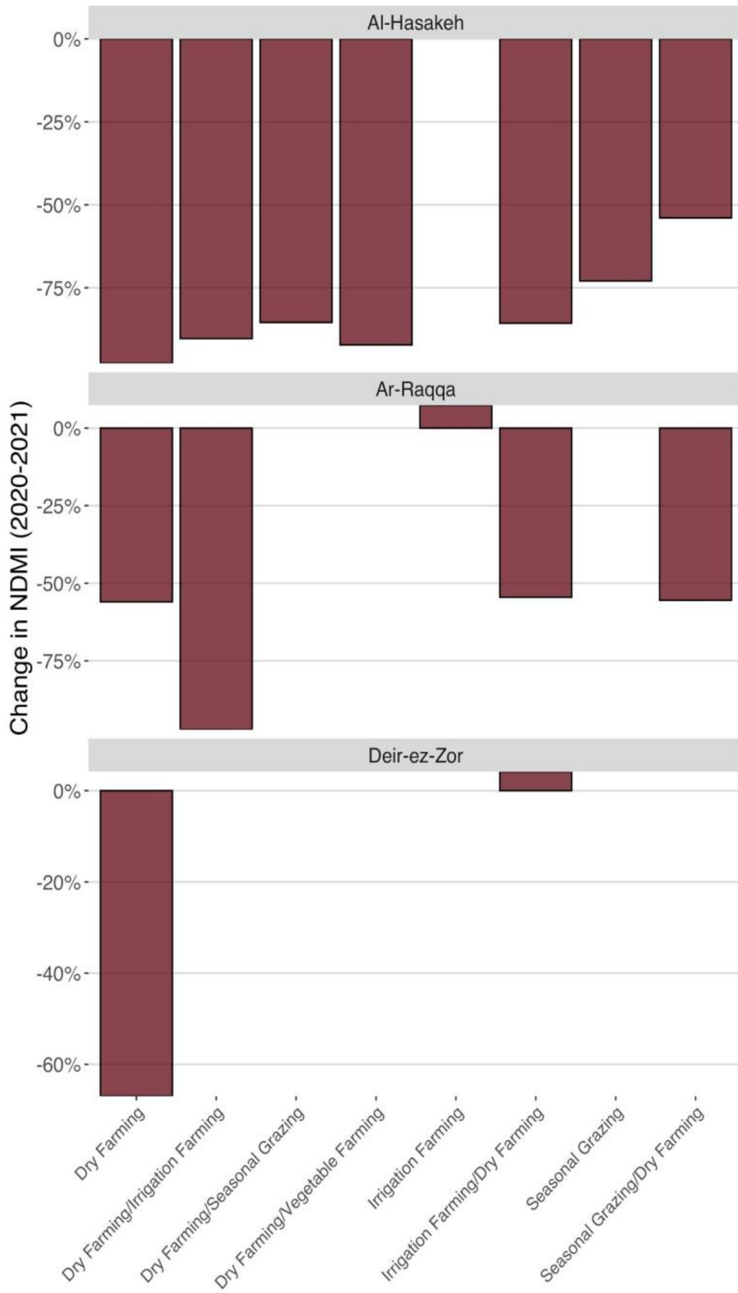

Figure 8: Change in plant water content (NDMI), 2020-2021, in different primary/secondary agriculture land use types in northeastern Syria.

[44]Mathys, Tony. (2017). Land use Dataset for the Jazira Region of Syria, [Dataset]. University of Edinburgh. https://doi.org/10.7488/ds/1771.

[45]Agriculture land use shapefile based on maps in the following report: van Liere, W.J. 1965. "Syria- Classification and rational utilization of soils - Report to the government, Soil Survey of the Jezireh." Food and Agricultural Organisation (FAO)

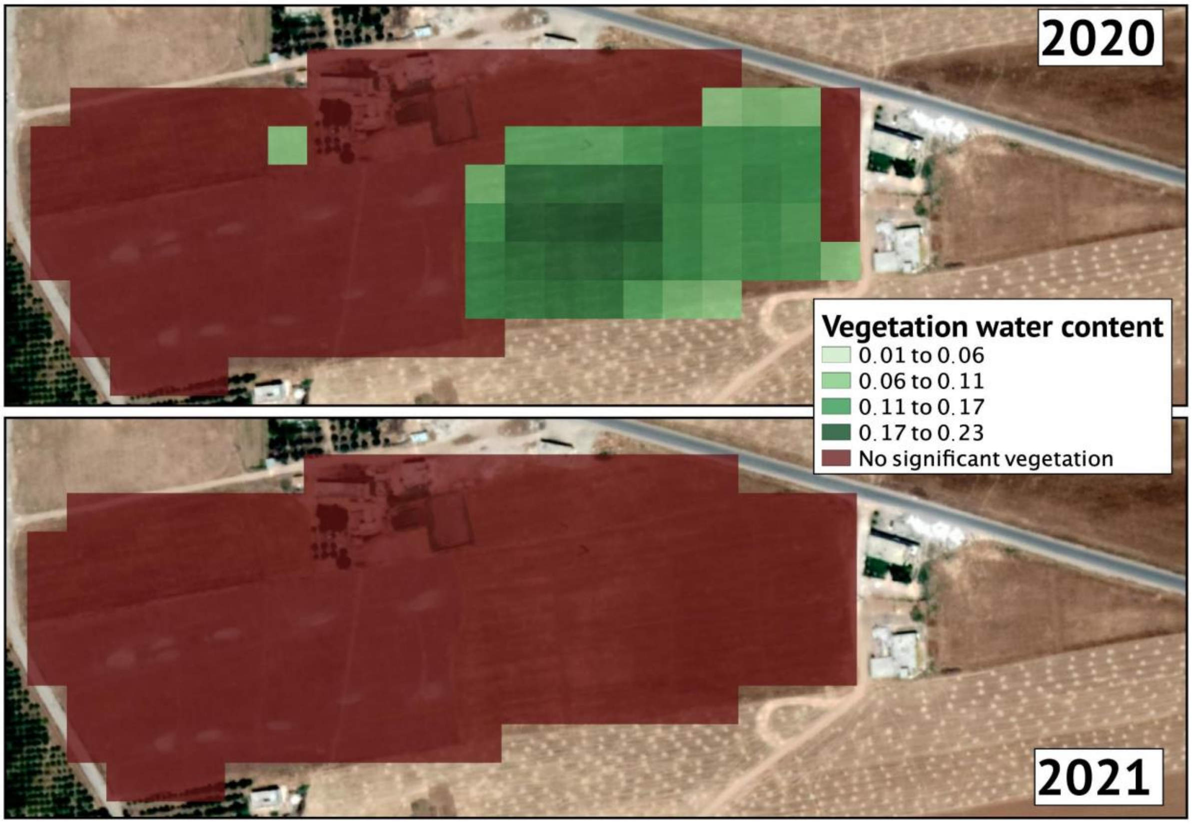

Figure 9: The vegetation water content of the rainfed wheat and barley farm of a landowner interviewed by HAT.

interviews conducted by HAT across northeast Syria, all but one farm laborer (in Jarablus) reported working less this harvest season compared to last year. Further, 17% (3/18) of the laborers reported they could not find work this season, and two laborers from Qamishli stated that they worked 15% (6/40 days) and 20% (10/50 days) of the days they worked last year. Lower labor demand was the reason that 21% (5/24) of KIs reported that wages were lower this season compared to last season.

Despite the lower demand for labor, relatively few KIs reported an interest in migration. About 25% (6/24) of laborers reported willingness to migrate within Syria; two to major cities nearby, two to more productive agriculture areas, and one stating they would move to any place in Syria with economic opportunity. Two laborers expressed interest in emigrating outside Syria to find work in agriculture; one hoped to work in Turkey. Labour opportunities are not generally generated from additional vegetable cultivation because produce from average-sized vegetable farms are typically harvested by the family operating the land.

The vegetation water content of seasonal grazing lands in Hasakeh and Raqqa decreased by over 50% from 2020 to 2021. Less available grazing areas and higher fodder prices have economically strained shepherds in the region. According to interviews with shepherds conducted by HAT (see Table 1), fodder prices were the most

Table 1: Ways drought has affected herding among interviewed shepherds in northeast Syria, June 2021.

Subdistrict	Higher fodder prices	No grazing land	Lower Animal prices	KIs
Hasakeh	100%	67%	100%	3
Jarablus	100%	40%	80%	5
Menbij	40%	80%	20%	5
Qamishli	100%	60%	40%	5
Tell Abiad	20%	80%	20%	5

common way that the drought impacted herding; however, fewer KIs reported higher fodder prices as an issue in Jarablus and Tell Abiad. The lack of grazing land was cited by over half of all KIs except those in Jarablus. Lower animal prices were cited less in Menbij, Tell Abiad, and to a lesser extent Qamishli, but more in Hasakeh and Jarablus.

The cost of feeding a sheep or goat increased compared to last year and differed across northeast Syria. Fodder, hay, or barley prices increased by a multiple of about 10, according to the four shepherds that reported fodder prices in 2020 and 2021. The cost of fodder differed by region across northeast Syria, shown in Table 2, with the cost of feeding each animal per day the highest in Hasakeh and Qamishli, the center of wheat and barley production and the areas hardest hit by the drought. Five shepherds (22%) reported renting grazing land as an additional cost, which is typically free for grazing after the wheat harvest.

Table 2: Average cost of fodder per-head of sheep or goat, according to KI interviews with shepherds, June 2021.

Governorate	Average cost of fodder (SYP, per-sheep/goat)	KIs
Hasakeh	3,100	2
Jarablus	1,850	5
Menbij	1,030	5
Qamishli	2,530	3
Tell Abiad	1,700	5

COPING MECHANISMS

Livestock sell-offs occur when the profit margin of the animal becomes too small or negative, and has occurred during the current drought. One sheep and goat shepherd in Hasakeh sufficiently explained the logic (transcribed from Arabic):

"The drought decreased the number of grazing grounds, forcing us to sell our sheep and keep a small number of goats. The cost of raising goats is higher than the cost of selling them because their cost does not cover the cost of fodder. We have had to sell half of our livestock to secure the cost of fodder for the other half in addition to making an income as shepherds."

Underfeeding animals is another result of higher fodder prices. Another shepherd in Hasakeh explained that "...[the drought] forced us to reduce the amount of fodder in order to be able to feed the herd. For example, we previously used to use 3 bags of barley, now we only use one bag" (transcribed from Arabic). Naturally, animals grow smaller when they are underfed and as a result sell for lower prices. Therefore, the price of sheep should noticeably drop during droughts.

This observability of this process is tested by measuring the affordability of a two-year-old sheep using WFP market price data from January 2018 to May 2021 gathered in Qamishli and Hasakeh cities.[46] Figure 10 highlights the beginning and end of the wheat growing cycle in recent drought years using light and dark blue vertical lines. In Qamishli, sheep affordability sharply increases in the February of both wheat growing cycles, indicating a sell-off. However, sell-offs were not evident in Hasakeh, perhaps due to the presence of other market forces.

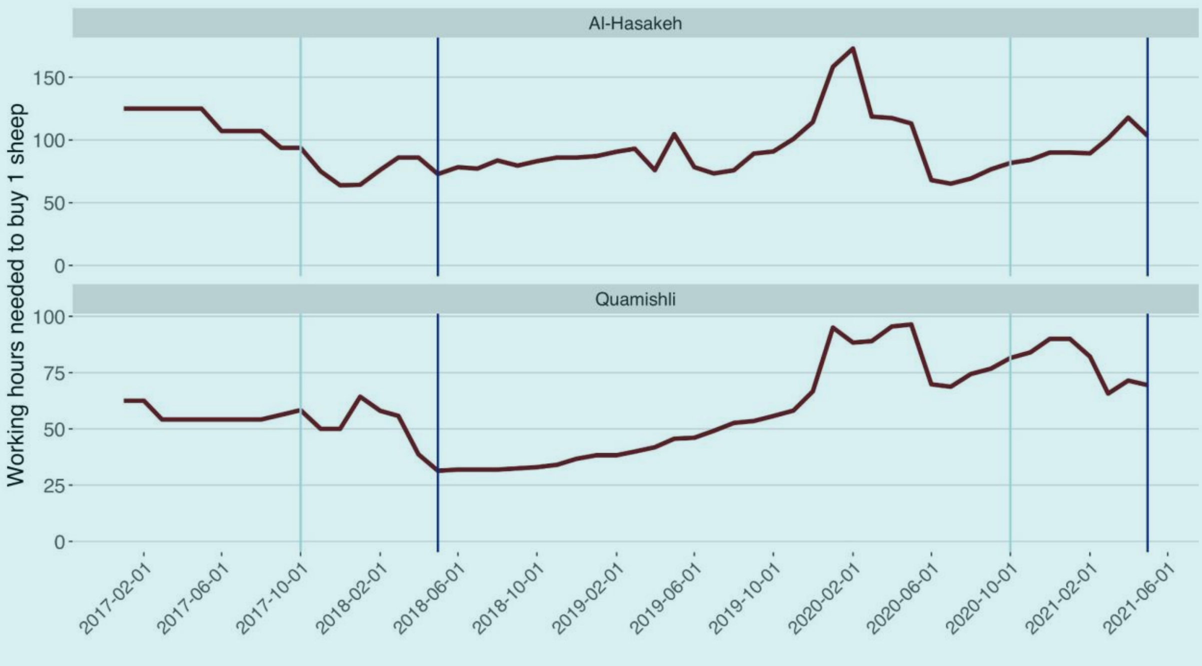

Figure 10: Affordability of one 2-year old sheep in Hasakeh and Qamishli (cities). Light and dark blue vertical lines indicate the beginning and end of wheat seasons during a drought year.

[46] A measure of how many hours the average unskilled daily laborer needs to work to purchase an item, defined by the following: Item price/Average daily wage for an unskilled worker

Vegetation water content increased where irrigation farming is the primary agriculture land use in Raqqa governorate by 7% and in Deir-ez-Zor governorate by 4% from 2020 to 2021. As the community-level analysis will show in the following section, these irrigation farming areas are located near the Euphrates river; therefore, lower water levels in the Euphrates did not significantly hinder many irrigation farmers from extracting the existing river or canal water for irrigation. In fact, according to the farmers interviewed by HAT, farmers that rely on rivers, tributaries, canals, and boreholes continued to pump water, despite reporting lower levels of their primary water source, while all rainfed farmers reported significant productivity losses. In addition, the vegetable prices are higher than last season in Qamishli, Hasakeh, and Raqqa cities, as shown in Figure 11. Higher vegetable prices likely encouraged irrigation farmers to incur the higher cost of production or expand vegetable planting areas.

Vegetable farming requires less land and is therefore manageable when irrigating using surface water. Five respondents (19%) reported that they changed crop types to compensate for low productivity this past wheat season; two respondents, one in Tell Abiad subdistrict and one in Jarablus subdistrict, reported switching to corn because it requires less water and is more in demand. One respondent in Menbij subdistrict reported changing his crop to alfalfa (largely used as a forage crop for cattle) because of its lower cost of production. Two respondents in Qamishli subdistrict reported planting legumes because they can be sold in US dollars (to wholesalers).

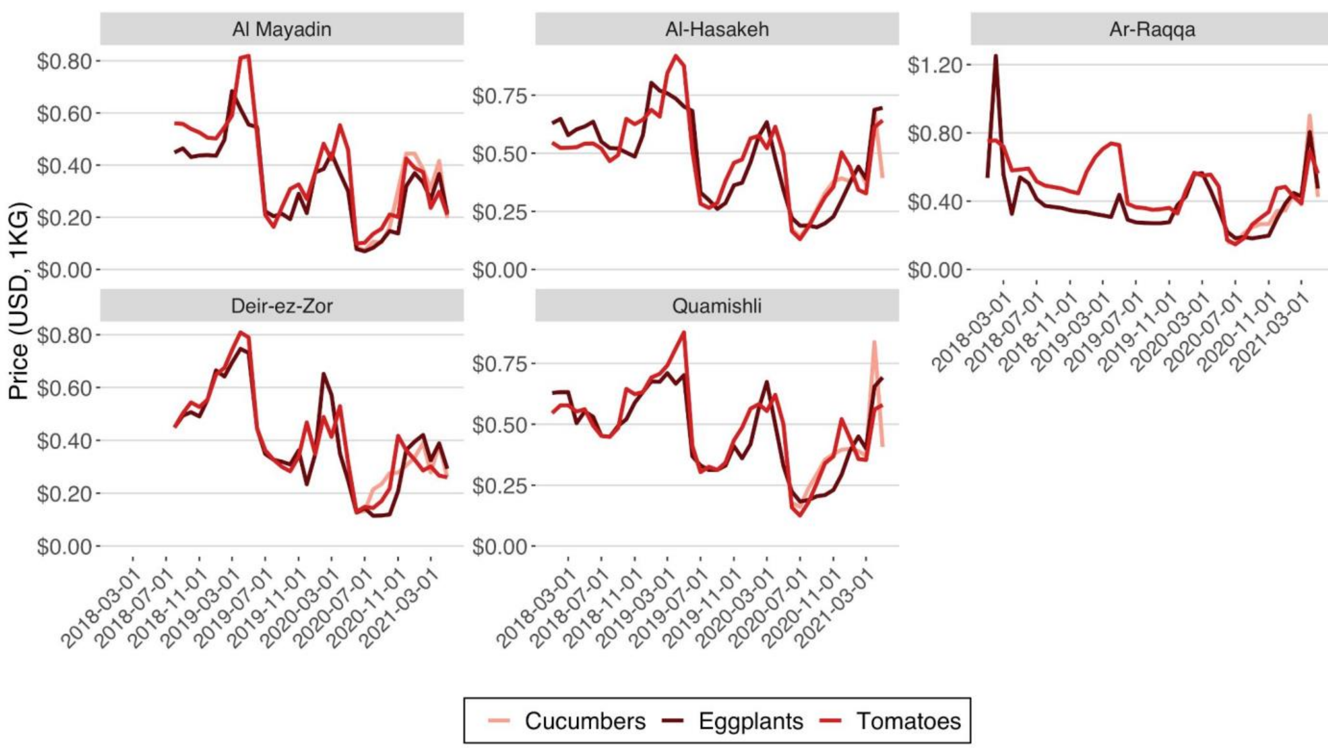

Figure 11: USD-adjusted prices of primary vegetable commodities in urban markets in northeast Syria.

Despite the relative success of irrigation farming in Raqqa and Deir-ez-Zor, coping mechanisms are being used to deal with a reduction in water levels, as shown by responses from farmers who pump water from rivers, tributaries and canals in Menbij, Tell Abiad, and Raqqa subdistricts.

A farmer who relied on the Balikh river in Tell Abiad stated that if the water level of the river becomes too low, then he would "change the water pump's location and lower it to a level where water is more abundant" (transcribed from Arabic).

Only one farmer, located in Menbij, stated they received irrigation water using trucking, in this case from the Sajur River. One farmer (in Raqqa subdistrict) reported that water levels in irrigation canals were significantly lower than the previous year, and that he is planning to drill a borehole as a secondary water source.

ALONG CANALS IN RAQQA GOVERNORATE

Changes in vegetation water content within 2 km of canals in Raqqa governorate were measured to assess the impact of lower water levels on

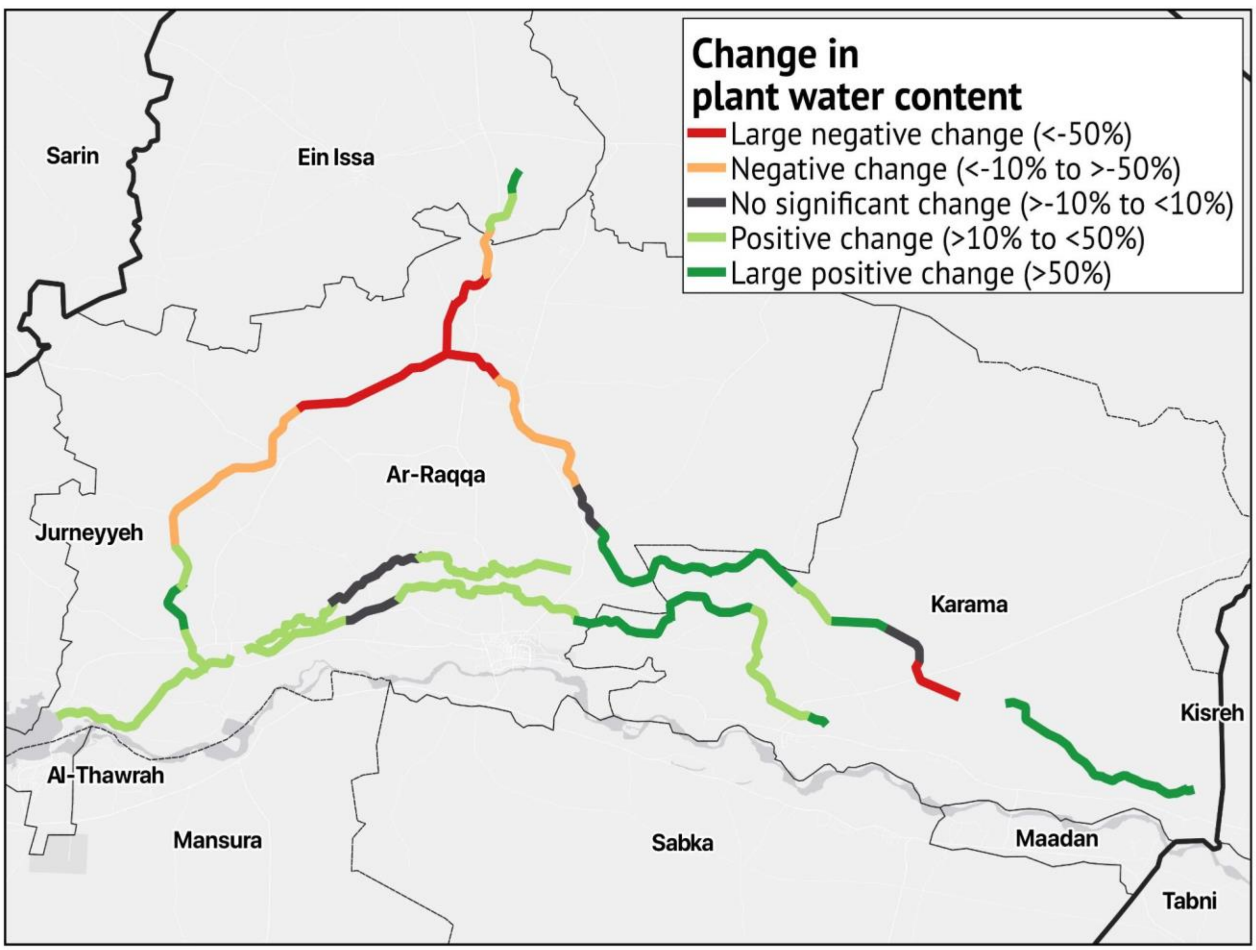

Figure 12: Change in plant water content (NDMI), 2020-2021, within 2km from canals in Raqqa governorate.

irrigation farming near canals and rivers.[47] The distribution of vegetation water content around segments of irrigation canals is shown in Figure 12. Land around irrigation canals closer to Lake Assad and the Euphrates exhibited positive changes in vegetation water content, indicating water levels are sufficient to produce agriculture, though additional water pumping is likely required. One farmer interviewed by HAT in Hazimeh (Raqqa subdistrict), who relies on an irrigation canal within a "red" zone (of large negative change) shown in Figure 12, stated that the irrigation canal water arrived at about half the volume as it did last year (15-20 m^3 to ≅10m^3).

Significant negative changes in agricultural production were observed along irrigation canals further downstream, likely the result of lower canal water levels and a higher concentration of water pollution. Most of the water volume of irrigation canals in the upper Balikh river (center/north Raqqa subdistrict) consists of water imported from Lake Assad and the Euphrates, with a relatively small contribution from surface drainage.[48] As a result, the water quality of irrigation canals in Raqqa subdistrict is not immediately affected by saline agriculture drainage water and highly polluted inflows from the Balikh river.[49] However, because the contribution of these poor quality water sources naturally increases when the Euphrates flow is reduced,[50] the significantly lower water level of the Euphrates this year has lowered water quality in irrigation canals (more so upstream) by causing a higher concentration of agricultural runoff and inflow from the Balikh river.

AGRARIAN COMMUNITIES

Changes in vegetation water content around agrarian communities (a 3 km radius) in northeast Syria were measured to more precisely analyze the spatial distribution of water stress dynamics. Communities assessed by REACH under the control of the Autonomous Administration in eastern Aleppo, Raqqa, Hasakeh, and Deir-ez-Zor governorates were used for the analysis, and were identified as agrarian if the key informant affirmatively answered that one of the community's most common sources of meeting basic needs was cash crop agricultural production, food crop agricultural production, or subsistence agricultural production.[51]

As observed before, vegetation water content grew around communities along the Euphrates, as shown by Figure 13, with most of the decline occurring in the Balikh river basin, along the Khabour river, and in Hasakeh governorate. Vegetation water content increased in communities along the Khabour river likely due

[47] Canal line shapefile obtained from the Syria WASH working group.

[4848] UN-ESCWA and BGR (United Nations Economic and Social Commission for Western Asia; Bundesanstalt für Geowissenschaften und Rohstoffe). 2013. Shared Tributaries of the Euphrates River. In *Inventory of Shared Water Resources in Western Asia* (online version).

[49] The upper Bailkh, the portion running through Raqqa subdistrict, does not flow year round due to extensive groundwater extraction and the fact the Ain al Arous Spring falls dry most of the year. Further, the river is heavily polluted and salinized by the discharge of sewage water from urban areas Turkey (Akcakale and Harran) and Tell Abiad, and agricultural drainage water from the Urfa-Harran region in Turkey (sourced from *ibid*).

[50] UN-ESCWA and BGR (United Nations Economic and Social Commission for Western Asia; Bundesanstalt für Geowissenschaften und Rohstoffe). 2013. Shared Tributaries of the Euphrates River. In *Inventory of Shared Water Resources in Western Asia* (online version).

[51] REACH's Humanitarian Situation Overview of Syria (HSOS) product, May 2021.

to the lower water levels in the Euphrates,[52] and in Hasakeh governorate due to the drying of smaller tributaries and lower groundwater levels. Communities along the upper Balikh river experienced significant negative changes in vegetation water content likely due to lower irrigation canal water levels and a higher concentration of pollution.[53] Negative changes in vegetation water content also occurred in a cluster of locations assessed near Menbij in northeast Aleppo governorate, which according to our KI interviews in the area, appears to rely on boreholes and pumping from the Sajur River.

Changes in aggregate vegetation water content among these agrarian communities, according to WASH and livelihood indicators, were assessed to measure how community-level resources and coping mechanisms related to changes in vegetation water content. The analysis consists of linear regressions measuring the relationship between changes in plant water content within 3 km of agrarian communities and affirmative responses to several WASH and livelihood indicators, such as main water sources and

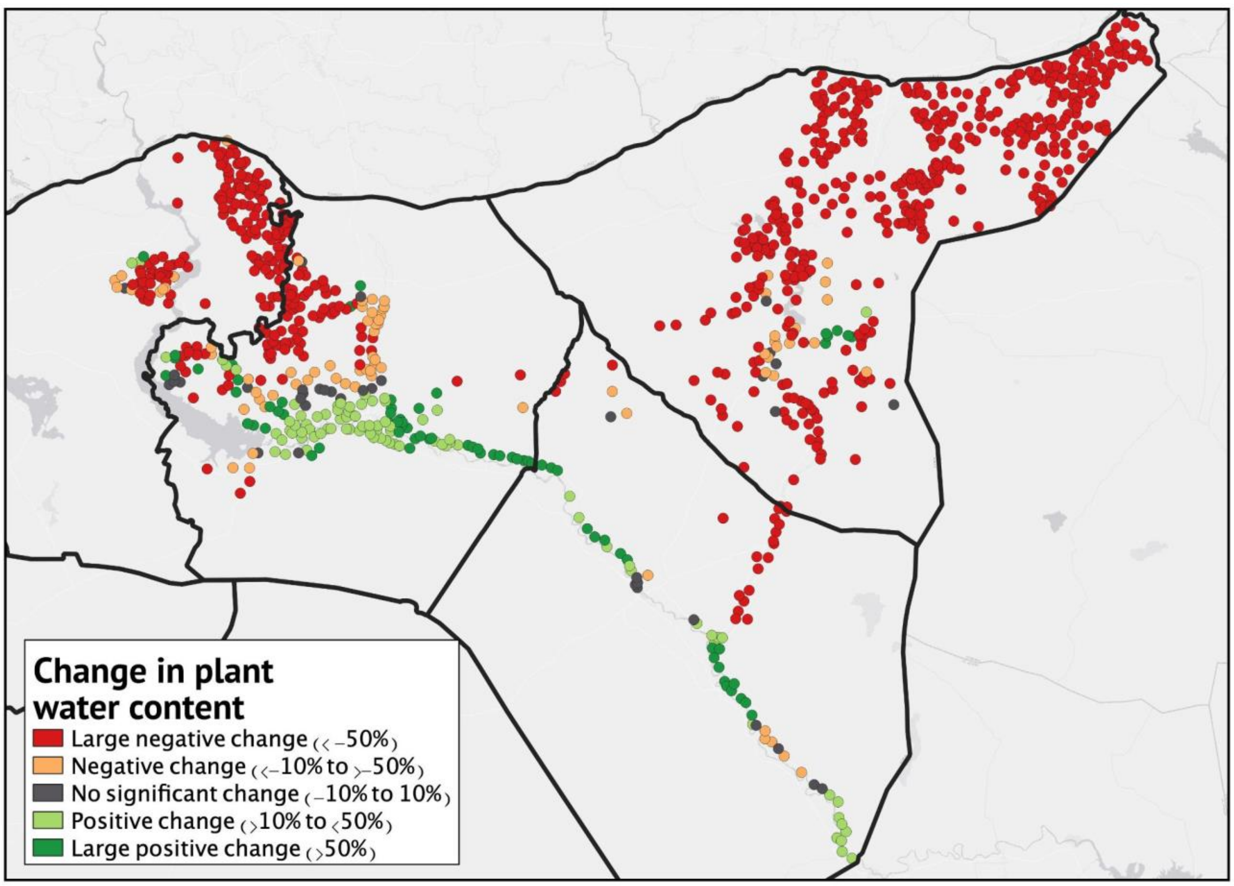

Figure 13: Change in vegetation water content around agrarian communities in northeast Syria.

[52] UN-ESCWA and BGR (United Nations Economic and Social Commission for Western Asia; Bundesanstalt für Geowissenschaften und Rohstoffe). 2013. Shared Tributaries of the Euphrates River. In *Inventory of Shared Water Resources in Western Asia* (online version).

[53] *ibid*.

barriers to accessing agriculture livelihoods.[54,55] The results are found in the Appendix.

The results of the WASH and livelihood indicator analysis indicate that community-level domestic water sources, quality, and access barriers are closely related to local changes in vegetation water content. Significant decline in vegetation water content were observed in communities that experienced agriculture degradation, rely on boreholes for all types of water, have less affordable water, have insufficient fuel to operate water pumps, cope with a lack of water with credit or bartering, and have bad water color, smell and taste. Positive changes in vegetation water content were observed in communities that mainly obtain domestic water from piped water systems and experience less serious water pumping problems, such as a lack of pressure and limited pumping hours.

These results indicate vegetation water content and local domestic water availability are closely related. Specifically, reliance on boreholes as a main domestic water source is a considerable vulnerability, and a lack of community-level purchasing power for fuel and water is indicative of the extent and vigor of locally cultivated land.

[54] Controlling for the population size of the community, categorized into quantiles using May 2021 HNAP community-level population data. Standard errors clustered by District (admin 2).

[55] Please note the HSOS sample is not statistically representative and interpretations drawn from the data are only representative of the non-sample sample collected by REACH. Nevertheless, the large sample sizes are beneficial and regression controls serve to compensate for sampling bias.

PART IV ECONOMIC CHALLENGES CAUSED BY DROUGHT

The drought has exacerbated the already tenuous profit margins of most farms, particularly through higher fuel costs from additional water pumping and higher fertilizer costs, in conjunction with weaker harvests and unprofitable crop sell-offs. The 27 KI interviews with farmers conducted by HAT provided detailed contextual information about strategies used to cope with lower water availability and rising production costs.[56]

Renting land to shepherds for use as livestock fodder is one way farmers have attempted to extract value from failed wheat or barley crops. Only four farmers reported they sold their harvest as fodder; unfortunately, none of them recovered the cost of production in the sale, and all six farmers that responded to the question stated they would lose money *if* they sold their crop for fodder. One farmer in Hasakeh recuperated 50% of the production cost when he sold his crop as fodder, and another farmer in Qamishli recovered only 25% of the production cost. Only one KI that sold his unproductive harvest as a grazing ground relied on irrigation

Table 3: Farmer KI responses to the question "How have you compensated for a lack of fertilizer (if anything)?" in northeast Syria, June 2021.

Subdistrict	Used animal dung instead of chemical fertilizer	Reduce amount	Did not use fertilizer	Bought on credit	KIs
Hasakeh	0%	0%	100%	0%	3
Jarablus	100%	0%	0%	0%	2
Menbij	100%	0%	0%	0%	4
Qamishli	0%	0%	67%	33%	3
Raqqa	0%	75%	25%	0%	4
Tell Abiad	25%	50%	50%	0%	4

[5656] The large majority of whom stated they own the land they cultivate (85%; 22/26).

farming, a farmer Raqqa subdistrict that relied on irrigation water from the Balikh river.

Fuel is a major production cost among farmers that rely on water pumping, which is utilized more during lower rainfall periods. High diesel prices were cited as a major cause of profit loss by almost a third of farmers interviewed by HAT. One farmer in Tell Abiad stated he had to borrow money to purchase fuel while another noted that despite the high costs of fuel, his crops would completely fail without water pumping. Consequently, decreasing profit margins are placing increasing economic stress on many farmers.

Similar issues were also highlighted by farmers who utilize boreholes. Those who use boreholes noted they had sufficient water for the current wheat season by deepening boreholes, which exacerbates groundwater over extraction in the region in addition to adding significant production cost. Rainwater collection was not widely adopted as a way to compensate for a lack of water, as only two of the five farmers relying on rainwater stated that they collect rain in storage containers, and no other farmers reported having rainwater storage containers.

Fertilizer is an additional economic burden for farmers, especially during less productive drought seasons. Only four farmers interviewed by HAT, two in Jarablus and two in Qamishli, reported they could afford fertilizer this past season, with the two in Qamishli stating they could afford to buy fertilizer because they have additional work outside the agriculture sector. Table 3 shows the ways farmers interviewed by HAT have coped with the inability to purchase sufficient fertilizer. The use of animal dung was common in Menbij and Jarablus subdistricts. Not using fertilizer was the approach taken by all farmers interviewed in Hasakeh subdistrict and was the most common coping mechanism in Qamishli subdistrict. Reducing the amount of fertilizer was the most common strategy in Raqqa subdistrict, and no clear strategy was observed among KIs in Tell Abiad subdistrict. Only one KI reported they coped with a lack of fertilizer by buying it on credit, perhaps indicative of poor credit accessibility.[57]

The farmers interviewed by HAT were asked what repairs or equipment would be useful for their farm to become more water-secure. The results are found in Table 4. The need for subsidized diesel is pronounced in farms in Hasakeh and Menbij subdistricts that rely on boreholes for water. Borehole drilling was cited by all KIs that rely on rainwater in Jarablus, Qamishli, and Tell Abiad, along with the farmer in Raqqa that relies on irrigation canal, suggesting boreholes are desired as a secondary water source. Canal repair was cited by all three farmers relying on boreholes, suggesting they view canals as a way to compensate for declining water yields from boreholes. Higher capacity and more efficient water pumps were listed as a useful item by farmers in Tell Abiad that rely on pumping river water as their main source of water.

[57] Based on the result of the community-level analysis (see the Appendix) that indicated greater levels of water stress around communities that reported access to credit as a primary livelihood need than communities that did not report that as a primary livelihood need.

Table 4: Farmer KI responses to the question "What equipment or supplies would help you become more water-secure?" in northeast Syria, June 2021.

Subdistrict	Primary water source	Subsidized fuel	Borehole drilling	Canal repair	Water pump	KIs
Hasakeh	Borehole	100%	0%	0%	0%	1
Jarablus	Borehole	100%	0%	0%	0%	2
Jarablus	Rain	33%	100%	0%	0%	3
Menbij	Borehole	100%	0%	0%	0%	2
Menbij	River pumping	100%	0%	0%	0%	2
Qamishli	Borehole	0%	33%	100%	0%	3
Qamishli	Rain	0%	100%	0%	0%	2
Raqqa	Borehole	0%	0%	0%	0%	1
Raqqa	Canal	0%	100%	0%	0%	1
Raqqa	River pumping	0%	0%	100%	0%	1
Tell Abiad	Rain	0%	100%	0%	50%	2
Tell Abiad	River pumping	50%	50%	50%	100%	2

CONCLUSION

This paper reemphasizes the disproportionate impact the lack of rainfall has had on dry farming areas during the ongoing drought in northeast Syria. This event has reduced wheat production, which has increased the cost of herding by reducing grazing areas and increasing fodder prices. However, the analysis showed that vegetable farmers along the Euphrates and the canals immediately north of the river have managed to grow more produce than last year by accelerating water pumping. Reports of continual water pumping from the Balikh and Sajur rivers and borehole deepening reiterates the well-established concern of groundwater over-extraction in the region. Further, the lack of rainwater collection equipment in rainfed areas should be further explored as a feasible short-term solution in preparation for periods of higher rainfall. The poor agricultural performance of areas along canals in northern Raqqa subdistrict suggest that the quality of the irrigation canal infrastructure and the quality of the water should be investigated.

The report also demonstrates the utility of satellite imagery for the disaggregate spatial analysis of agricultural production, which will continue to be an essential area of interest in northeast Syria considering the climatic changes becoming evident in the region over the last several decades. Smaller geographic areas, communities and land along irrigation canals, were the most informative spatial units because larger units masked significant heterogeneity in agriculture land use, soil type, and water levels and quality. However, the analysis of land use zones within subdistricts offered an informative high-level overview of the changes in the production of specific types of agriculture within administrative boundaries.

Vegetation water content measured using satellite imagery analysis quickly and objectively measures changes in the spatial distribution of agricultural vigor, and therefore should be considered a central indicator used to inform the prioritization of humanitarian agriculture assistance. Northeast Syria's extreme sensitivity to rainfall levels due to its reliance on depleted groundwater stocks also necessitates regular drought monitoring using standard drought indicators,[58] and perhaps an early-warning system to mitigate sharp declines in agricultural production, such as those observed in this paper, when the next drought inevitably hits the region.

[58] Most commonly the Palmer Drought Index: Wells, N. et al. 2004. A self-calibrating Palmer Drought Severity Index. *Journal of Climate*, 17, 2335–2351.

APPENDIX

Table A1. Regression results of WASH and livelihoods indicators and changes in vegetation water content.

Indicator	Option(s)	Percentage point difference in NDMI growth rate ('20-'21)	Sample size (yes/no)
Most common source of drinking water	Community borehole or well for free; Community borehole or well requiring payment; Private borehole or well	Too few affirmative responses.	5/394
	Springs; Surface water, lake, pond, dam, or river	Too few affirmative responses.	2/397
	Private water trucking conducted by private citizens; Combination of water network and private water trucking; Water trucking conducted by authorities or an NGO	-78 percentage points (p=0.000)	180/219
	Piped water network; Combination of water network and private water trucking	77 percentage points (p=0.000)	212/187
Average monthly expenditure for water for a household of 6 people in the last 30 days	Average monthly expenditure for a household of 6 people in the 30 days/ Estimated daily wage for unskilled labour for residents in the assessed community	-0.092 (p=0.000) On average, the NDMI growth rate is 9.2 percentage points lower for every additional hour needed to afford the monthly water expenditure.	n=173
Barriers to accessing sufficient water	Boreholes not providing any not providing adequate quantities of water	Too few affirmative responses.	18/381
	Pumping not frequent enough or insufficient fuel	-30 percentage points (p=0.002)	65/334

	to enable the operation of water pumps		
	Not enough pressure to pump sufficient water	23 percentage points (p=0.013)	124/275
	All households had access to sufficient water	37 percentage points (p=0.013)	95/304
	Water pumps only function a few hours per-day	60 percentage points (p=0.000)	85/314
Barriers to accessing livelihoods related to agriculture for resident population households	High rates of livestock death	Too few affirmative responses.	27/372
	Degradation of agricultural lands/crop damage	-26 percentage points (p=0.015)	161/238
	Lack of access to resources needed for job	25 percentage points (p=0.033)	270/129
Most common source of water for all purposes including cooking, drinking, bathing, washing, etc.	Community borehole or well for free; Community borehole of paid well; Private borehole or well	-49 percentage points (p=0.000)	117/282
	Springs; Surface water: lake, pond, dam, river	Too few affirmative responses.	11/388
	Water trucking conducted by authorities or an NGO; Private water trucking conducted by private citizens	-78 percentage points (p=0.000)	180/219
	Combination of water network and private water trucking; Piped water network	70 percentage points (p=0.000)	193/206
Most common problems with drinking water	Water smells bad Water tastes bad Water has a bad colour	-28 percentage points (p=0.002)	158/241
	Water was perceived to be making people sick	Too few affirmative responses.	8/391
	Water is calcareous	Too few affirmative responses.	28/371

Reported coping strategies of households dealing with a lack of water	Receive water on credit or borrow water; Exchanging goods or other favors in order to receive water; Spend money usually spent on other things to buy water	-48 percentage points (p=0.000)	227/172
Proportion of households with access to sufficient water over the last 30 days	0% of households; 1% to 20% of households; 21% to 40% of households	Too few affirmative responses.	19/380
Humanitarian assistance provided to resident households in the community over the last 30 days	Agriculture supplies; Livelihood support	Too few affirmative responses.	21/378
Priority livelihoods needs resident households	Tools, equipment for production	42 percentage points (p=0.000)	238/161
	Access to credit	-53 percentage points (p=0.000)	104/295

CONTACT

Nicholas Bodanac
Humanitarian Access Team

nbodanac@mercycorps.org

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. Successful humanitarian and development interventions require a nuanced and objective understanding of the human ecosystems in which these interventions occur. To this end, the HAT's most important function is to collect, triangulate, synthesize, analyze and operationalize disparate data and information. Since 2015, HAT analysis has provided a forward-looking template for international interventions in Syria, and facilitated an increasingly nimble, adaptive, integrated, and ultimately impactful international response to the Syrian conflict.

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