

# War, Waste, and Polluted Pastures

An Explorative Environmental Study of the  
Impact of the Conflict in north-east Syria

**PAX**

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## Colophon

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Cover image discription: Oil waste is dumped a dugged canal behind the Suwaydiyah oil facility, flowing into local creeks, April 26, 2020. Abdullah Mohammed

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# 1. Introduction

With the war in Syria soon entering its tenth year, and its economy in shambles, the destructive legacy for Syria's environment is already taking a toll on people's lives and livelihoods in the north-east of the country. Despite the fact that in this part of the country, the most intense period of the war ended after the so-called Islamic State (IS) lost control of its territory in early 2017, ongoing hostilities, whether by Turkish-backed Free Syrian Army (TFS) after the October 2019 incursion in the north-east, regime actions or IS remnants, continue to affect the security and well-being of Syrian civilians.. What does the environmental dimensions of the conflict mean for Syrian civilians trying to rebuild their communities?

The reverberating effects of the armed conflicts on north-east Syria's (NES) natural resources and environmental health will pose significant challenges for the future of the region. Access to clean water, soil and air, fertile land, and the removal of toxic remnants of war are essential for sustainable rehabilitation work, the remediation of affected areas and building back better and greener for the people living there. Both agriculture and oil exploitation are important elements of the economy in this region, and the war has left a legacy of pollution from the oil industry and damage to water and agricultural infrastructure<sup>1</sup>, while deficient environmental governance has given rise to concerns about health risks from poor solid-waste management and storage.



A waste collector walk amidst a dump near the Rmeilan oil fieds, northern Syria. April 19, 2020.

The COVID-19 situation has exacerbated health risks from the lack of access to clean water sources, due to pollution and the deliberate shutdown of water pumping stations by the TFSA, while local authorities and humanitarian organisations have struggled<sup>2</sup> with the appropriate storage and incineration of medical waste. The continued security threat from the so-called Islamic State, Syrian government forces and Turkish-backed Syrian armed groups results in the de facto authorities spending revenues on weapons and salaries for military forces, even as funding is needed to rebuild public services, and for sustainable redevelopment and clean-up and remediation efforts. In return, people and communities lack perspective on economy recovery and a sustainable future in their own land.

To understand the direct and long-term impacts of the conflict on the environment and people's health and well-being, PAX initiated this research building on information from field visits, conversations with local government representatives and information from local partners. The aim is to map the most pressing environmental problems in this region that need to be addressed in post-conflict analysis and reconstruction work by the relevant authorities, local and international organisations and donors supporting recovery and reconstruction efforts.

Following on from PAX's wider environmental monitoring work in Syria<sup>3</sup>, our latest research findings in this report show the specific environmental dimensions of the armed conflict in this region, how they can affect the health and livelihoods of the population, and what kinds of actions are needed to address these problems.

The findings are also a reminder of the need to urge the international community to strengthen the environment, peace and security agenda in order to address the environmental dimensions of armed conflicts. Throughout the conflict cycle—from military planning to operations, humanitarian response, remediation and reconstruction—states and international organisations can and should do more to prevent, mitigate and minimise harm and protect the environment and the people who depend on it. Growing attention is being paid to the environment, peace and security agenda, whether through resolutions in the UN Environment Assembly (UNEA)<sup>4</sup>, draft legal principles by the International Law Commission on the protection of the environment in armed conflicts<sup>5</sup>, the updated military guidelines of the International Committee of the Red Cross /Red Crescent (ICRC) for protection of the environment<sup>6</sup> or debates in the UN Security Council.<sup>7</sup> These elements all contribute to greater awareness of how wars and armed conflict, in combination with growing changes in our environment due to the climate crisis, affect the lives and well-being of people, global biodiversity and nature itself.

This study is a call to action to support communities and their environment affected by armed conflicts. Natural resources and public health affected by conflict pollution, the loss of biodiversity and limited ability to build resilience in the face of the growing impact of the climate crisis are all posing serious challenges for the population. The research and the methodology applied are also a demonstration of what environmental data and information can already be collected during and after armed conflicts through open-source information, Earth observation and ground reporting.<sup>8</sup>



Young workers at a makeshift oil refinery near Tal Hamis, April 15, 2020



# 2. Methodology

The data collection and analysis for this scoping study are based on three sources: open-source information from traditional and social media sources; remote sensing and Earth observation using satellite imagery; and consultation with local partners, who relied on volunteer reporting. Our findings further build on assessments and findings from previous work in this area in earlier studies and from input provided by civil society partners. We will focus on four main areas of concern, namely the formal and informal oil industry, solid-waste management, agriculture and water security. The immediate and long-term impacts of the conflict on these four key areas could result in acute or chronic exposure to pollutants, and degradation of soil and water sources that communities depend on for household or economic activities and the capacity for green recovery efforts.

## Political and media landscape

The region is currently under control of the Autonomous Administration of North-East Syria (AANES), a system of self-governance set up by the Movement for a Democratic Society (TEV-DEM), an umbrella organisation of political parties that is mainly controlled by the Partiya Yekîtiya Demokrat (PYD). Security and defence are provided by the Syrian Democratic Forces (SDF), a US-backed fighting force dominated by the Kurdish-led People's Protection Units (YPG) but also including other Assyrian, Yezidi and Arab militias. There are still some regime-controlled areas in NES, mainly in Hasakah City and Qamishli, while the Turkish-backed Syrian National Army has also occupied areas previously held by the SDF since October 2019.

Outside of regime-controlled Syria, the media landscape has grown and embraced freedoms not found under the restrictive rules on speech. Despite challenges, there is an unprecedented amount of content in social media, traditional media and open-source media covering problems across Syria. An analysis is given below of the pervasive issues presented and discussed in Arabic and Kurdish media in NES. The data were collected from Arabic, Kurdish and English websites and social media (with a focus on Twitter and Facebook). PAX has archived all the links in case a website went off-line, and links to the archives are available on request.

## Remote sensing

The findings of this research are built around various Geo-Information Systems (GIS) and remote sensing tools and methods used to study specific impacts of the conflict on the environment. Optical imagery was used to map oil infrastructure and pollution, and land cover categories and to study changing patterns in vegetation and agriculture in the last five years. Spatial patterns of burning dynamics over the past two years were measured with the aid of NASA's Moderate Resolution Imaging Spectroradiometer (MODIS), the European Space Agency (ESA) Sentinel-2 satellite and Visible Infrared Imaging Radiometer Suite (VIIRS) products. A more detailed look at changing land cover was done focusing on landfills and their expansion since 2015 to quantify units and to visualise the most immediate area of influence or impact from the perspective of air pollution and water pollution.

NASA Landsat imagery was obtained through the US Geological Survey's Global Visualization Viewer (GLOVIS) and Earth Engine platforms. The Shuttle Radar Topography Mission (SRTM) digital elevation models at 30 and 90 metres were obtained through the Consultative Group for International Agricultural Research (CGIAR) data sets and Google Earth Engine. ESA Sentinel-2 data were obtained through the Sentinel Data Hub and Earth Engine. High-resolution imagery from commercial providers such as Airbus, MAXAR and Planet Labs was used for the landfill study.



Satellite image of the Aljwadea solid waste landfill. February 9, 2020.

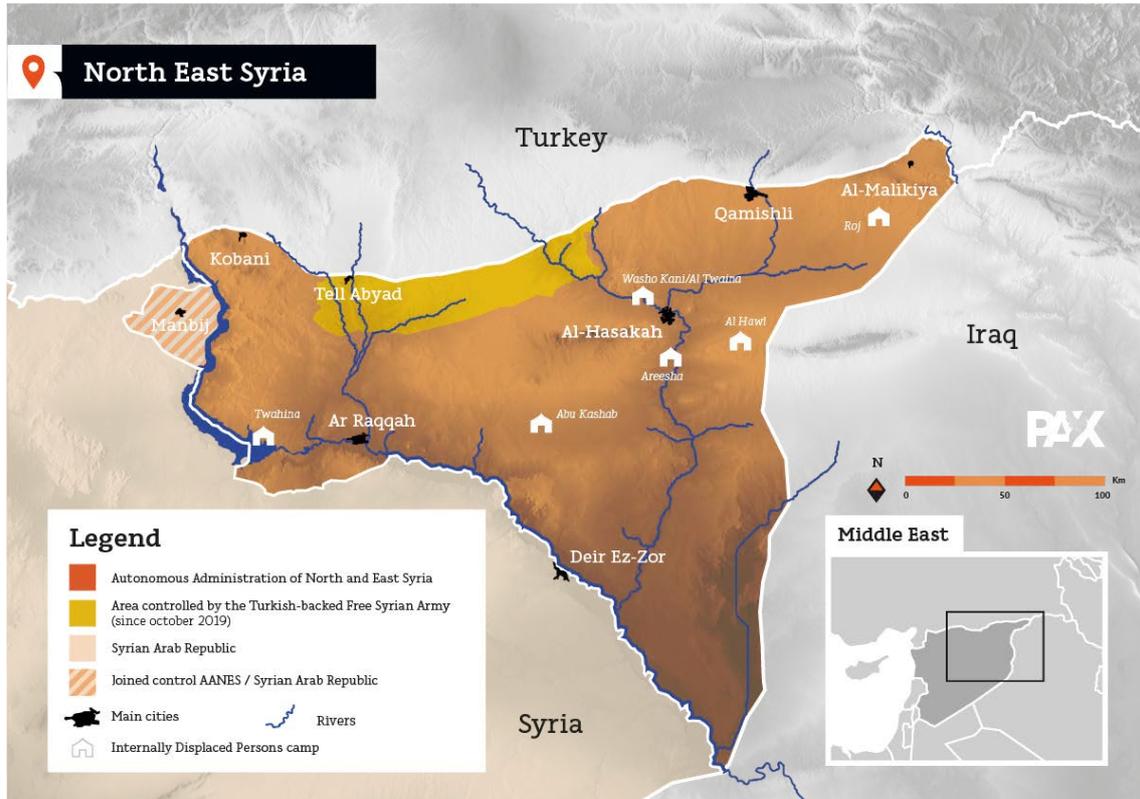
Wider oil legacy pollution from the onset of the conflict caused by the bombing of the oil industry, artisanal refining and open-air storage of oil waste was identified visually using freely accessible satellite imagery from Google Earth Pro, Planet Labs and Sentinel-2 satellites, with additional imagery obtained via EuroSpace Imaging and Airbus. Verification of sources of pollution from solid-waste landfills was done either by PAX field visits dating back to November 2018 or by a local photographer, who travelled to different locations to identify and document the local environmental conditions.

## Study area

North-east Syria is defined as the territory located on the right bank of the Euphrates River. It also includes a small part of the catchment area of the neighbouring Tigris River. In general the terrain is low-lying, becoming hillier and less flat in the north. Elevation ranges from 200 to 500 metres above sea level (MASL). There is only one geological feature with higher elevation—the Abdel Aziz mountains, located parallel to the Sinjar in Iraq— indicating how this plate moved north and folded in the geological past,<sup>9</sup> which also affects the oil resources in the area.

Demographic and settlement data vary according to the source and date. There are over three million people currently residing in north-east Syria<sup>10</sup>, including many internally displaced persons (IDP) and imprisoned members of the Islamic State in large camps.<sup>11</sup> The population is spread over major cities and many smaller towns and villages, as well as larger IDP camps.

An IDP camp overview was compiled from different sources (REACH<sup>12</sup>, UNOCHA<sup>13</sup>). A total of 22 IDP camps were located within NES that were once set-up and running, including informal locations. There are currently six major sites still operational, hosting nearly 100.000 IDPs.





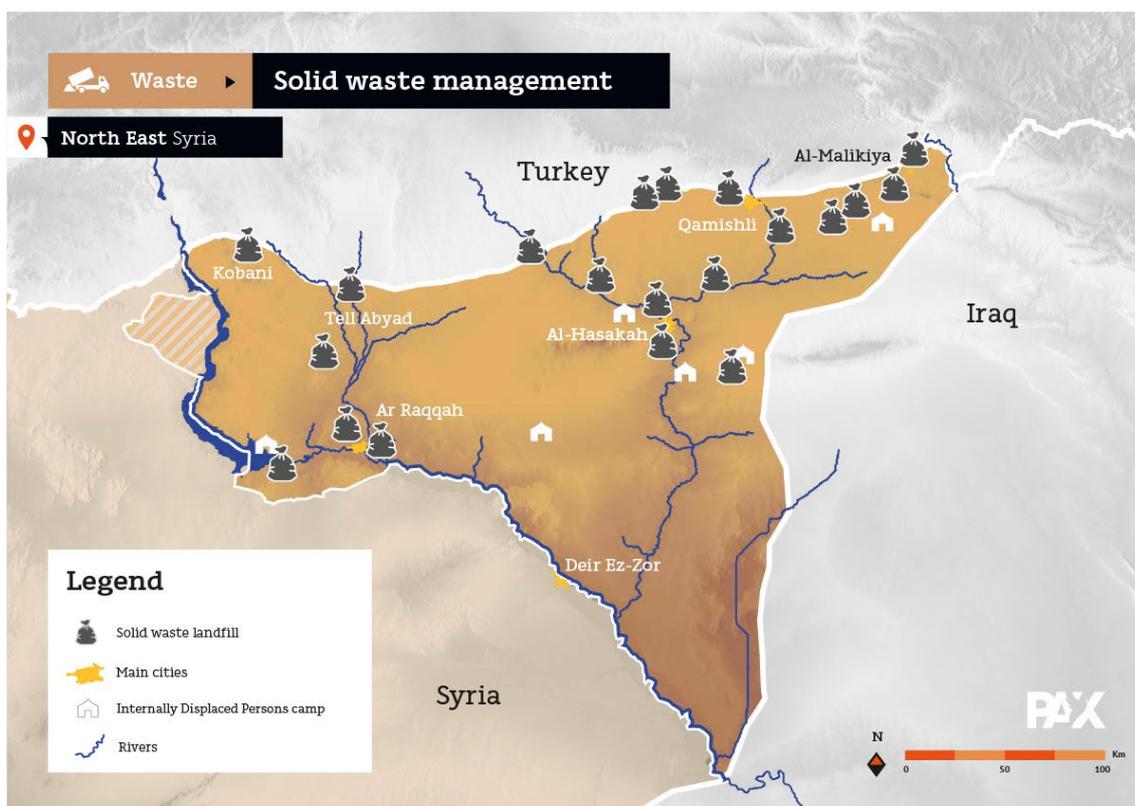
# 3. Solid Waste, Landfills and, Environmental Health Concerns

The collapse of environmental governance during the conflicts has resulted in a lack of enforcement of regulations relating to waste management in all forms, ranging from collection and transportation to safe storage and processing. This can be household, medical or industrial waste.<sup>14</sup> Waste piling up in streets often attracts insects and rodents, which could result in the spread of communicable diseases. Dumping waste in unsafe landfills can impact groundwater from the leachate it generates, attract waste pickers who may then be exposed to hazardous materials, or lead people to start burning solid waste, which negatively affects air quality and is associated with an increase in respiratory diseases among nearby communities.<sup>15</sup> These problems were present prior to the conflict in Syria<sup>16</sup>, and became a significant environmental health risk after the outbreak of the war.<sup>17</sup> Due to the limited UN engagement in NES as it is not government-controlled, there is limited data on the scale of the problem, with the exception of reports by Urban Syria on Hasakah and Qamishli, which are part of an EU-funded project on the urban profiling of a range of Syrian cities.<sup>18</sup>

## Public reporting

Due to shifting territorial control and alliances, and the historically cross-border nature of waste and utility services in Syria, solid-waste management has had varying degrees of success and failure. Reports by NGOs, the United Nations and various local bodies in Syria show a push to provide funding and contracts for clean-up and garbage pick-up in NES territory controlled by the Syrian regime and the SDF.

People living in north-east Syria, like in many other areas of Syria, suffer due to the nature of waste management in the country. Due to mismanagement and a lack of resources, waste dumping sites are often close to residential areas or IDP camps, and sometimes serve as a source of income for those near them. In an attempt to reduce the amount of garbage, many of these sites burn the waste to get rid of it. Due to the proximity of these sites to camps and residential areas, pollution adversely affects local residents, who have to deal with the dangerous fumes and runoff produced by these open burn sites. Additionally, solid-waste sites serve as a source of income for women and children and are used for livestock feeding.<sup>19</sup>



Although these sites are often in rural areas, even residents of the city of Qamishli regularly complain about the pollution and smell, and there are reports of increased cases of cancer and disease in the city due to the uncontrolled burning of garbage.<sup>20</sup> Despite repeated complaints and reports about these dumps for years, they continue to be popular dumping sites. Although aware of the dangers, people working in these solid waste sites depend on the income from the materials they find. Children working at these sites, often without shoes or gloves, complain of injuries that require medical care.<sup>21,22</sup>

"This is the one thing we can do so we can buy bread and food. Sometimes we step on the glass that goes into our feet or scratches our hand, and it costs 1100 Lira for the procedure [to fix it], 500 for the anesthesia [sic] needle, the rest for the doctor to put in stitches."

Efforts made by local administrations have varied in effectiveness and face many difficulties. Despite these efforts to provide municipal collection services for garbage in towns, complaints by residents about trash piling up continue to be common on social media and local Arabic media. Municipal employees in the town of Kirkilkeh have also complained that despite the efforts to collect garbage and multiple warnings issued to residents, garbage is still being thrown out of windows and balconies in towns in Hasakah Governorate.<sup>23</sup> During the recent Nowruz (Persian new year) celebrations in north-east Syria, images uploaded to social media also showed people burning tires and piles of garbage.<sup>24</sup> These activities were widespread and the images showed large groups

of people, including children and the elderly, celebrating next to these fires and thereby being exposed to large amounts of toxic fumes. Plastics and similar materials have often been burned as a fuel of last resort in Syria, where many residents will burn plastic bags and other materials for heat.

Residents of Hasakah have complained about the effects of burning waste,<sup>25</sup> with reports of minor illnesses, disease and poor air quality being common complaints from as early as 2012,<sup>26</sup> when residents complained about water pollution from the garbage in the water. Complaints about the lack of public services in towns have been an issue for trust between residents and the local administration.

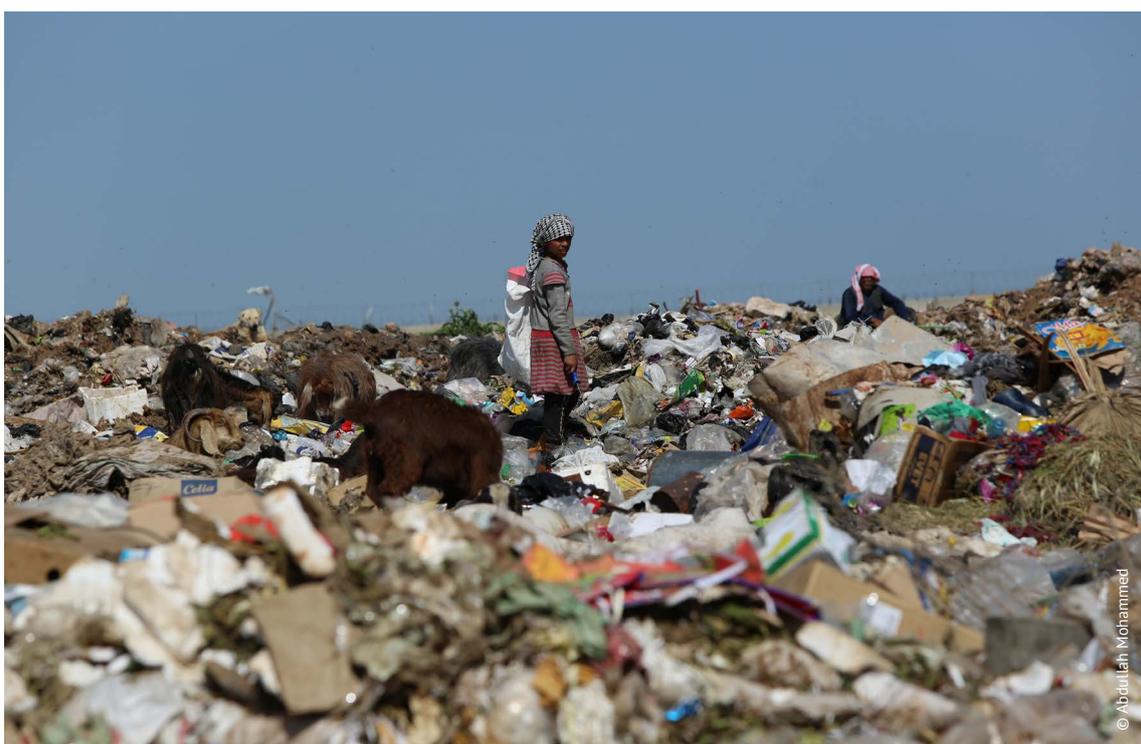


A woman standing next to burning waste at landfill south of Hasakah, April 22, 2020.

There are also growing health risks from medical waste in Hasakah, due to a lack of sufficient waste incinerators, and an absence of preventive measures and monitoring. This has led to the increased exposure of medical personnel, waste pickers and communities near waste dumps to contaminated material and to risks from the open-air burning of medical waste.<sup>27</sup> These problems were compounded with the outbreak of COVID-19, which led to an increase in special medical waste from treatment of COVID-10 patients in the region.<sup>28</sup> Local communities have called for support in the collection and storage of medical waste around Raqqa.<sup>29</sup>

Unable to drink from local sources of water due to contamination from multiple sources, including refuse, people are reliant on water delivery trucks that sell barrels of clean water to residents.<sup>30</sup> This limits when people can use water and puts a strain on the already limited water resources in the area. Residents of Qamishli who live next to an irrigation channel in the city have complained that the garbage is piling up and not being cleaned up, blaming the lack of government services.<sup>31</sup> Although a programme to clean up this river has existed since 2015, an image shared on Facebook shows large amounts of garbage build-up. Government officials have blamed residents for the build-up, saying they are not disposing of their garbage properly.

Most notable among the spread of diseases in Syria has been the surge in leishmaniasis, a disease often said to be caused by the insufficient removal of waste and pollution. Cases of leishmaniasis, along with other diseases, have been reported widely across Syria and have been attributed to a lack of proper waste disposal. In the village of Hajin, as well as many other parts of Deir Ez-Zor Governorate, residents have complained that a failure to bury corpses properly,<sup>32</sup> combined with garbage and a general lack of sanitation, has led to an increase in flies and insects, which they say have caused the thousands of cases of leishmaniasis. Without proper guidance or protocols on how to treat the disease, hospitals, pharmacies and other sources of medical care have each come up with their own treatments for leishmaniasis, further complicating care.



Children at the Qamishli landfill, April 17, 2020

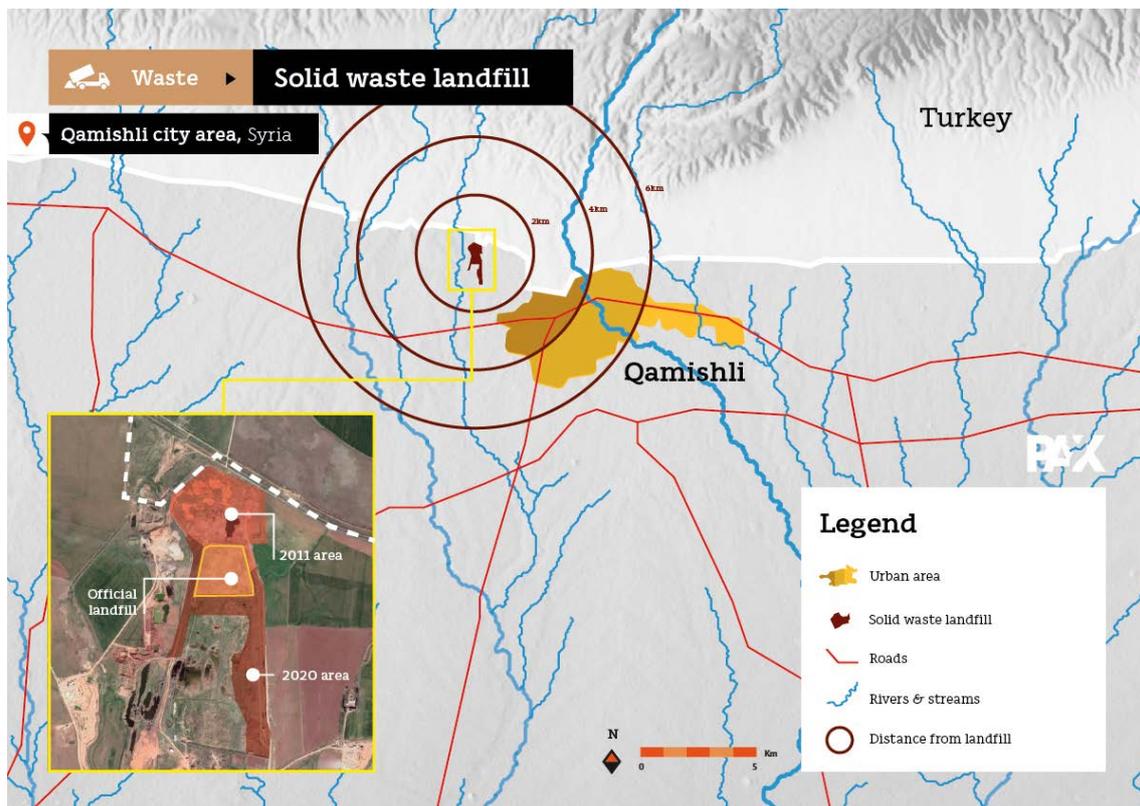
The above issues seem to be a widespread problem, especially in more rural parts of north-east Syria, which is exacerbated by weak infrastructure and the unmanaged nature of villages. Many villages in rural Deir Ez-Zor and Hasakah suffer from flooding. Villages like Amuda (Hasakah) have reported polluted water flooding dirt roads,<sup>33</sup> further damaging poorly maintained dirt roads and spreading sickness.

Waste is often a problem due to pollution in waterways, as the eastern Syrian infrastructure is not built to handle flooding due to heavy rains. In February 2020, flooding from heavy rains destroyed

four bridges near the town of Tel Berak,<sup>34</sup> making transportation between towns impossible until the bridges were repaired.

## Remote sensing findings

In our research we identified at least 21 solid-waste landfill locations in NES, totalling over 300 hectares. The main area we focussed on was the Hasakah region and the findings are not representative for the whole of the SDF controlled area, as more smaller landfills in Deir ez Zor are not included. Concerns about environmental health risks, in particular from waste burning, around several of those locations were raised by civilians through public reporting. A detailed analysis was performed for five locations using Planet imagery with 3m resolution to detect and quantify any expansion of these landfills over the last five years. Other attributes which can facilitate or accelerate groundwater and soil pollution were also analysed, such as the surrounding land cover, if there are populated areas within a range of three kilometres, where the leaching water flows to, if the sites are above aquifers of importance which could be polluted and whether there has been flooding detected inside the dump. These are issues that should be complemented with field work.

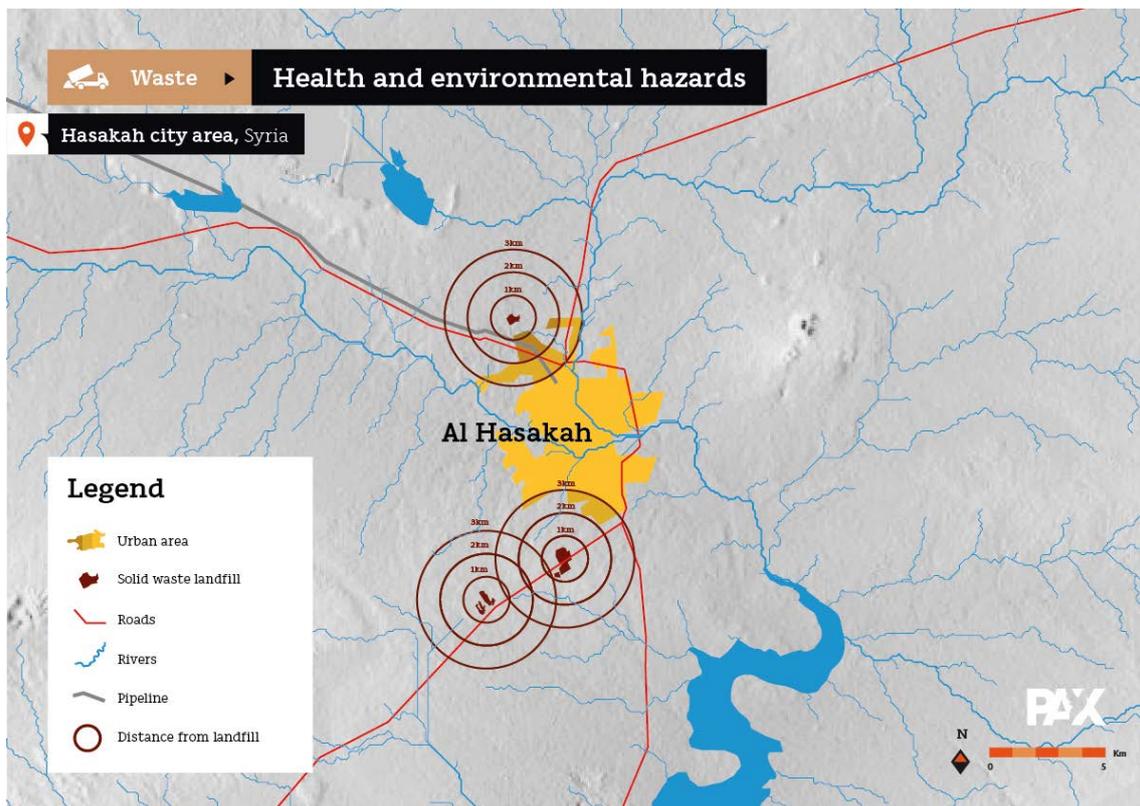


In general, all the locations have shown evidence of growth and more dumping activity within the landfill. Some of these locations started out as formal sites, and informal growth has happened since. The following table shows the growth observations and the legal status of the landfill.

For example, the Tepke landfill, located next to the road between the Faysh-Khabur border crossing and the town of Derik, has shown recent expansions on either side of the dump of two hectares, where children are working as waste pickers.<sup>35</sup>

In conclusion, the current landfills pose various kinds of threats to the population and the environment. More than half of the dumps are located near populated areas—of the five studied in detail, three have settlements at a distance of around one kilometre. The primary hazards to public and environmental health here concern open-air burning and air pollution to which nearby communities could be exposed. Another hazard is increased waste-picking activity, where vulnerable populations including children have access to these locations and risk exposure to various hazardous chemicals, pollutants and other public health risks from materials and diseases at these sites.

The secondary impacts related to solid-waste leachate concern the pollution of surface water and groundwater resources used for direct consumption or field irrigation. Some dumps are within old quarries—practically pits—with internal flooding. This increases the potential for groundwater pollution. In general the landfill locations drain or infiltrate directly into streams or agricultural fields. In a few cases there are water reservoirs that could be receiving pollutants. Three locations are within aquifer units of importance<sup>36</sup>, also creating a potential hazard for these groundwater resources. A full overview can be found in Annex 3.





# 4. Pollution by the Oil Industry

Oil is the most significant natural resource, and oil extraction and exports are a key source of revenue for the Autonomous Administration, while also providing Syrians with jobs and livelihoods linked to the oil sector, be it the extraction, processing or transport of oil or related industries. Prior to the conflict, crude oil was extracted from the oil fields in Rumeilan and exported through a pipeline leading to the Homs refinery. Syria's total oil extraction before the conflict was an estimated 400,000 barrels per day at its peak.<sup>37</sup> The region is rife with pumping jacks, oil stations, pipelines and storage facilities, and its oil made the region important to Syria. Soon after the escalation of the conflict, exports came to a halt. Fighting took place near and around oil facilities, inflicting damage and resulting in the loss of lives and expertise.<sup>38</sup>

The collapse of services and maintenance further worsened conditions for the oil industry itself, with frequent leaks and dumping of oil waste, while artisanal refining spread like a cancer throughout the region. Thousands of small roadside burners appeared and hundreds of clusters of artisanal refineries were set up around towns and villages.<sup>39</sup> This has also led to disturbing levels of exposure of civilians, including many children, to noxious fumes and toxic waste produced at these refineries.<sup>40</sup>



An oil worker is resting at a makeshift refinery, April 15, 2020

The leaks and spills from incidents and makeshift refining can all pose serious environmental and health risks. Hydrocarbons from crude oil and oil-waste spills<sup>41</sup> entering surface water and groundwater contain a range of chemical pollutants including heavy metals such as mercury, lead and arsenic, and cause air pollution from polycyclic aromatic hydrocarbons (PAHs) and volatile organic compounds, particulate matter and sulphur and nitrogen oxide.<sup>42</sup> People working and living near oil facilities face exposure to air, water and soil pollution through various pathways that can cause acute and long-term harm to human health, ranging from respiratory and skin problems to carcinogenic and genotoxic effects, damaged organs and psychological impacts.<sup>43</sup>

For this report we will focus mainly on NES, with future research planned on damage to the oil infrastructure in Deir Ez-Zor. The analysis of the oil industry will focus two main elements: public reporting and our own analysis based on remote sensing.

## Public reporting

With control of the oil infrastructure switching between so many different groups and targeted by various forces, including the international coalition in its fight against the Islamic State, the infrastructure remains in a deplorable condition if it functions at all.<sup>44,45</sup> The oil, which is mainly drilled in eastern Syria, serves as a source of friction between various factions, who must buy it through negotiations or intermediaries in areas primarily held by the SDF.<sup>46,47</sup>

In an attempt to cut off an important source of income for the Islamic State, coalition forces put significant resources and effort into targeting and disabling many of these oil production, refining and distribution facilities, especially later on in the Syrian civil war.<sup>48</sup> While this crippled production, much of the refining and drilling increasingly moved to artisanal facilities.

Although some processing facilities are being repaired or have been brought back into use, a significant proportion of the oil in Syria is still apparently being refined in artisanal refineries. Images of facilities captured from the Islamic State show extensive damage to the facilities in 2018 and video footage of artisanal refineries shows them continuing the work that these facilities once did.<sup>49</sup> These makeshift refineries grew into popularity as early as 2013,<sup>50</sup> spreading across Syria. The refineries vary in quality, but work is primarily done out in the open,<sup>51</sup> with large amounts of pollutants and oil derivatives being burned off or dumped in the surrounding area.

Employees working in these fields realise that these places can cause significant harm to their own health and that of other people,<sup>52</sup> but the economic incentive and lack of alternative work continue to push people to work at oil refineries. In 2017, AP estimated that the refineries and oil wells in the Rumeilan area of Syria,<sup>53</sup> near the border with Iraq in north-east Syria, employed over 2,000 people who made USD 20 a day.

Although local officials have made no efforts to stop the oil refining entirely, they have tried to move activities to less populated areas and to take measures to stop the long-term damage from some oil spills and leaks. Local health officials in Qamishli have complained of hundreds of cases of sickness and breathing problems related to oil spills and leaks, and local officials and oil refiners have attempted to fight runoff by using soil to capture it.<sup>54</sup>

“There is no work, and there is no fuel. We are compelled to work. It [pollution] affects us, it affects animals, and it affects plants. The animals scratch themselves; they have become black. It changes everything.”

People working the fields generally wear little if any protective gear, with some video footage uploaded by locals even showing young children without shoes or gloves protecting their skin as they work around these toxic chemicals in high-temperature situations.<sup>55</sup> Many oil drilling operations are little more than a few trucks, crude pumps and open pools of oil.<sup>56</sup>



Young oil workers at a makeshift refinery at Al Qarraya, Nov 24, 2018

Oil runoff and production not only affect farms and people near these facilities; spills like the 2019 Rumeilan oil spill were significant enough that oil got into farmers' water supply, flooding their fields with oil and unsafe water.<sup>57</sup> Spills also have been reported at oil pumping stations close to the Turkish border, where crude oil from a crumbling oil pipelines was flowing into the Jirih river, adjacent to the Mizgefte dam lake.<sup>58</sup>

Emissions from the processing of oil have been blamed for the rise of cancers in NES, and the total cost to local people and administrations is unknown.<sup>59</sup> People transporting oil have reportedly been targeted by Improvised Explosive Devices (IEDs) as well.<sup>60</sup> The volatility of this industry, along with all the associated costs of transportation and refining and the existence of massive black markets, have led to significant volatility in the price, quality and availability of fuel.

People in Syria rely heavily on petroleum for their day-to-day lives, and their simple homes and tents often require the use of heaters to get through the cold winters of northern Syria. Even in 2020, residents complained about the lack of fuel for heating provided by the authorities in cities like Qamishli.<sup>61</sup> Bakeries and farmers also require petroleum, and while farmers additionally use fertilisers for their crops. The prices of these two products are controlled by the SDF-backed local administration, but a lack of supplies pushes farmers and others to buy from black-market sellers who charge higher prices than that set by the local administration.<sup>62</sup> Fertiliser prices have nearly doubled since 2019, with one ton costing farmers nearly SYP 400,000 (amounting to \$121, with a

February 2020 exchange rate of \$1 = 3300 Syrian pounds).<sup>63</sup> With prices set by the Autonomous Administration, farmer's profits from their yields are often at risk of being swallowed by the high costs of fertiliser and fuel when buying off the black market.<sup>64</sup> Farmers must ensure their inputs are of good quality or face issues with the production and processing of their goods, including products like cotton, which serve as an essential source of income for many farmers.

This situation puts significant stress on people who need fuel to make it through the winter or for cooking. There have also been reports that regime militias like the Fourth Division are imposing additional taxes on goods, driving up prices as groups attempt to extract funding for their own use.<sup>65</sup> Fuel prices can vary widely by region, but even relatively minor changes in the price generate significant complaints by residents, who already struggle to make enough to feed their families and buy essential goods and other necessities.<sup>66</sup> Residents also complained about the lack of gas canisters in 2019, which even the Syrian regime has admitted it lacked for regions like Hama. The price of these canisters reportedly went up 80 per cent in Deir Ez-Zor during February 2020.<sup>67</sup> A gas canister cost SYP 18,000, up from SYP 10,000, and residents had to wait in long queues to get one.<sup>68</sup>



Local oil traders waiting at makeshift refinery, Tel Hamis, April 15, 2020

Although much of the oil refining is carried out in eastern Syria, black crude oil is transported to other parts of Syria.<sup>69</sup> There the oil is refined in similar ways to the east, causing health issues and creating hazardous situations for locals when the refining system malfunctions.<sup>70</sup> To understand the impact these refineries have on people and the environment in Syria, a broader look at refineries across Syria is needed.

## Remote sensing findings

During the course of our research we identified three key sources of environmental pollution from oil activities, namely:

- 1 Existing oil facilities. This relates to the professional infrastructure in place prior to the conflict, including refineries and storage and loading facilities.
- 2 Artisanal oil refining. Most of these makeshift refineries, also known as 'roadside burners' or 'backyard burners', were in use in 2013–2017; they have developed and become more professional over the years.
- 3 Oil-waste storage pits. The waste products, mostly tar, from the oil refining have often ended up in local large, open-air, unlined waste pits.

## Existing professional facilities

Throughout the conflict period, the existing oil infrastructure has not been maintained or monitored properly due to a lack of staff, while repairs suffered from the lack of proper equipment. The results are clearly visible in the area: leaking pumping jacks, and spills around pipelines and storage stations. This report will look at some of the largest polluters, while acknowledging that there are hundreds of smaller spill sites at pumping jacks and wellheads in the area being studied. This warrants more in-depth follow-up research.

There are two main facilities that have been dumping oil waste in the surrounding area, contributing to the pollution of rivers, groundwater and soil. In June 2020, PAX published its report 'A River of Death', containing an analysis of problems around oil spills and dumping of waste at Gir Zero, the main oil storage facility in NES.<sup>71</sup> The spills, either from leaking pipelines or the systematic

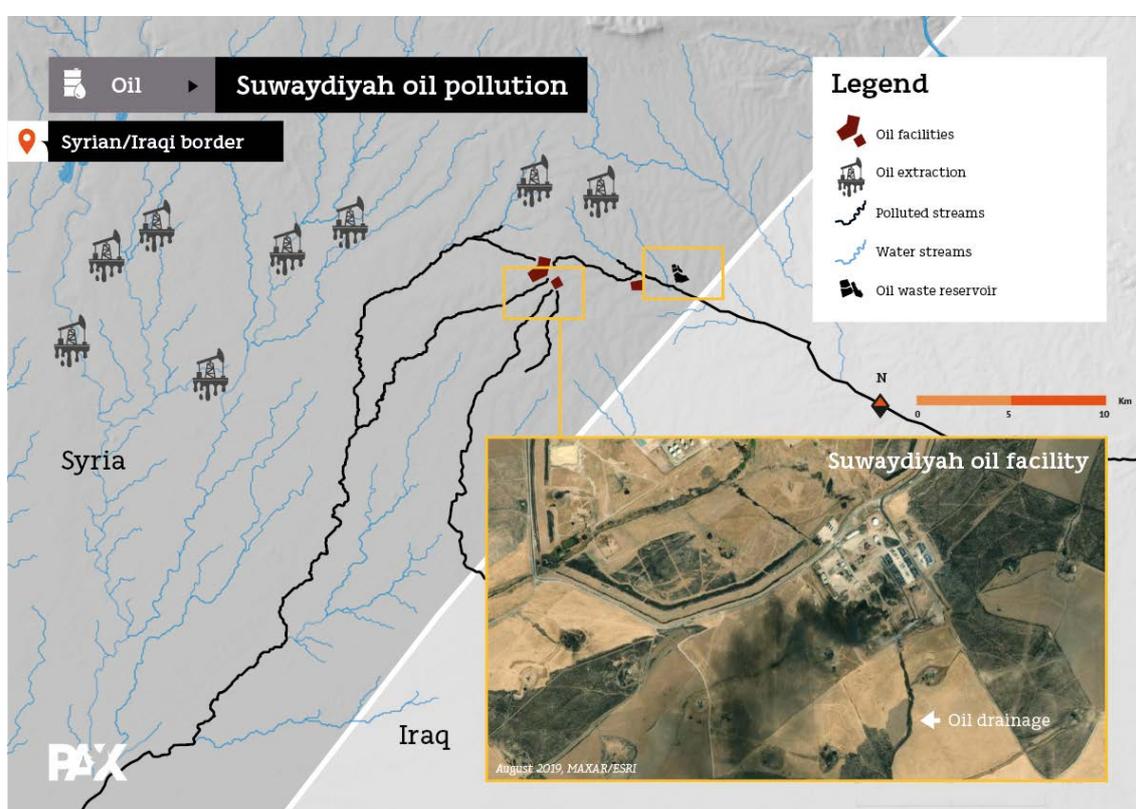


Oil waste is flowing from the Suwaydiyah refinery, April 26, 2020

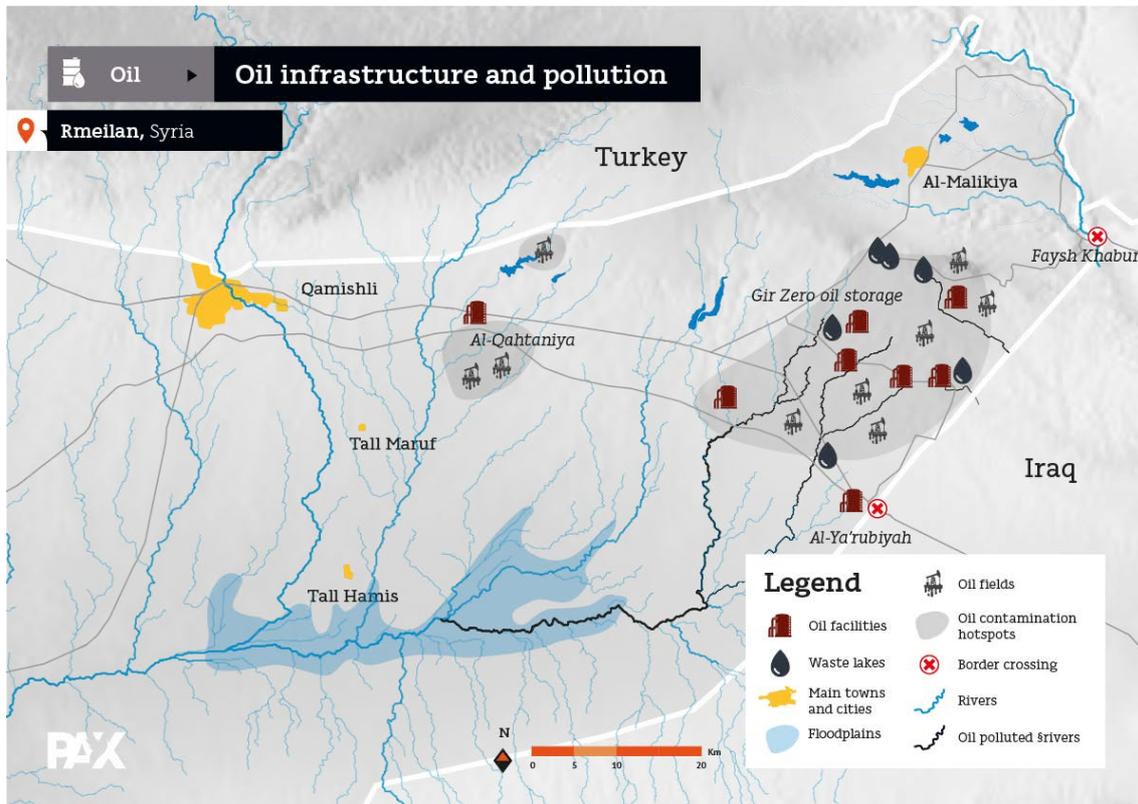
dumping of oil waste in local rivers, spurred serious health concerns among local communities next to the polluted river. The problems are exacerbated by the seasonal rains that flood the polluted rivers, contaminating nearby agricultural lands.

Follow-up research indicated that more facilities have been dumping oil into local waterways. The other main facilities are the As Suwaydiyah oil and gas plants, both close to the border with Iraq. Photos taken by local partners show that oil flows into a canal dug from the facilities to nearby creeks that seems to function as a valve releasing oil waste. There are indications that these oil spills have resulted in oil spilling into Mosul Lake after heavy rains in late 2018.<sup>72</sup>

Satellite imagery shows how additional oil tanks have been placed on the premises of the Suwaydiyah oil facility, and that canals have been dug at both the Suwaydiyah gas and oil facilities for dumping oil waste in nearby creeks.



Apart from the main refineries, there are hundreds of leakages and spills visible around pumping jacks that are scattered throughout the Rumeilan oil fields. The spills at most of these pumping jacks are fairly small, staying within a radius of a few metres. However, at dozens of locations larger oil spills and spills into nearby creeks and rivers can be seen through visual mapping using publicly available high-resolution imagery dating to 2020. For the Rumeilan oil fields alone, including some of the smaller fields north-west of the town of Rumeilan towards the Turkish border, visual identification using high-resolution imagery in the period 2016–2020 showed over 530 oil spills, with about a 90 per cent accuracy rate. Ground verification would still be needed to determine the accuracy and size, but the number is indicative of the magnitude of the problem.

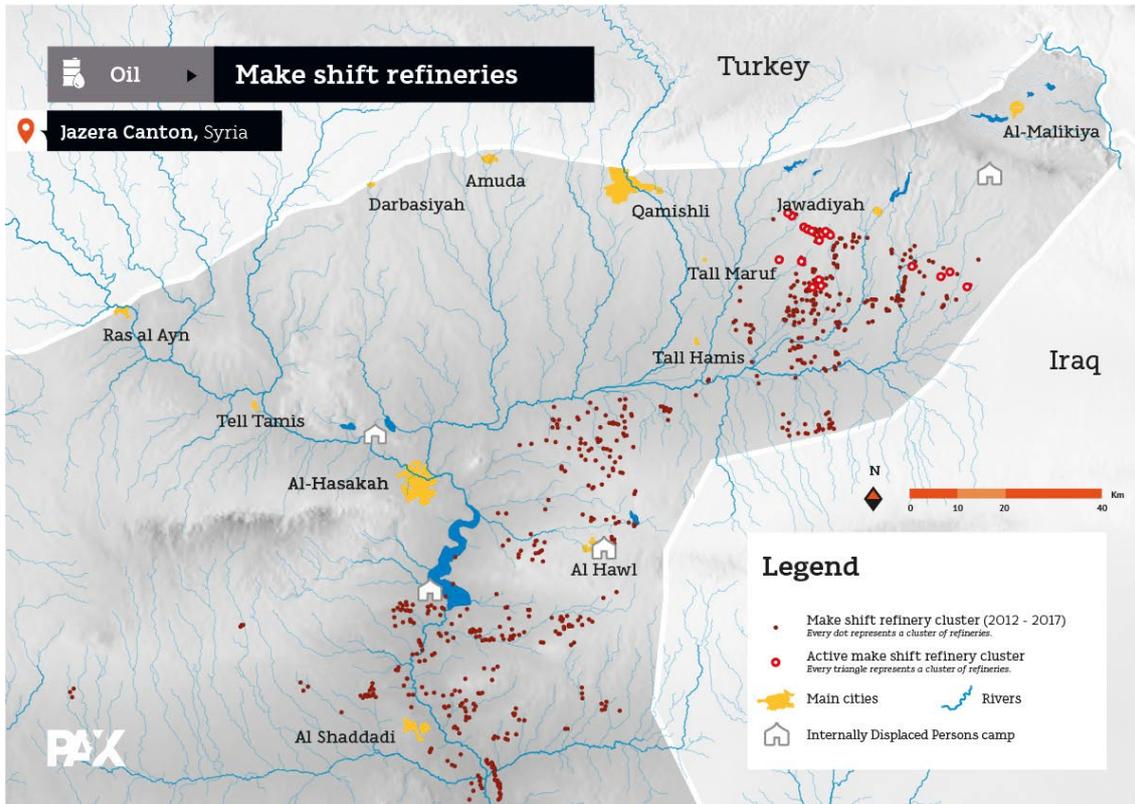


## Makeshift oil refining

With the armed conflict impacting oil pipelines and refineries, the region witnessed an increase in roughly constructed micro crude-oil distillery points, better known as makeshift or artisanal oil refineries. The refineries started out as fairly small, mostly consisting of small oil barrels and a ditch with water to cool the oil vapour. They were built along the roadside to provide fuel. Over the years improvements were made, with larger tankers being introduced with more capacity, and what are called 'vacuum burners', a more mechanised, safer and more controlled way of distilling the crude oil using air pressure.

Due to concern from local communities about the impact on human health and the environment, the Autonomous Administration shut down most of the smaller refineries in 2017, but a few clusters with makeshift refineries are still operational today. Most of these locations have semi-professional burners, reducing the risk of explosions. These locations are regulated by the Autonomous Administration, and the people in charge pay taxes on the oil sales.

We mapped the locations of the sites currently in operation or in operation in the past, using field visits and Earth observation. Older locations that have since closed and been removed were located using Google Earth Pro historical imagery from MAXAR of the Hasakah, Deir-Ez-Zor and Raqqa Governorate. For this report, we focussed on the whole of Hasakah and northern parts of Deir ez Zor only.



Currently operational sites were identified using both NASA VIIRS data and Sentinel-2 infrared sensors showing heat and smoke plumes. Our findings show thousands of refineries in the period 2012–2017 and we have mapped these clusters. Each cluster contains at least two and at most over 100 refineries. In total 340 clusters developed throughout these in this period. The exact number of refineries that were in use between 2012-2017 is likely over 15,000. Our research shows 19 clusters still active in the Al Jazira region around the Rumeilan oil fields, with roughly between 170 and 200 makeshift refineries in use. It is expected that more active makeshift refineries are to be found in Deir-ez-Zor in areas not covered by this research. Based on the findings from our 2016 report on this governorate, the total numbers in the whole of north east Syria is likely to be over 30.000 refineries. A full overview can be found in Annex 2.

## Oil waste storage

The absence of a well-functioning and regulated professional oil industry has not only resulted in widespread artisanal refineries and leakages from facilities; the oil waste generated by all these facilities has also become a huge problem. The waste is mainly a by-product from the oil refining, which results in bitumen/asphalt as a residual product. Because of the lack of proper processing and storage facilities for the waste, the oil waste (mainly consisting of bitumen) has ended up being stored in open-air storage pits, visible on satellite imagery as huge asphalt tar lakes and unlined reservoirs. These open-air waste pits will pose long-term risks for groundwater and surface-water sources, as well as for wildlife.<sup>73</sup>

Other oil refining by-products, such as waste water, are also collected in large reservoirs, or often just dumped into local creeks. Larger spills have also occurred at open-air crude-oil or waste facilities in the oil fields east of Hasakah, ending up in streams, agricultural fields and ultimately in bodies of water and in the soil. Based on high-resolution imagery and ground verification, our findings show at least 25 bitumen pits and oil-waste reservoirs in the Hasakah area spread over eight locations. Some of these pits have been emptied in the last two years and new ones were established at other locations. The continued spills and dumping of oil are already polluting hundreds of kilometres of local rivers and creeks and affecting groundwater in this region, posing serious environmental health risks for local communities, livestock and wildlife.





# 5. Water and Services

With a history of droughts and controversial water projects, Syria has seen its fair share of issues related to water security. Dams have mainly had a mixed history of success in Syria, and have often been a source of conflict with its neighbours and danger to its citizens. In 2002, the Zeyzoun Dam in Hama collapsed, killing 20, destroying hundreds of homes, displacing thousands and leading to a need for international assistance.<sup>74</sup>

More recently, the Tabqa dam in north-east Syria switched control between multiple groups during the civil war but was eventually captured by the SDF from IS. The dam was damaged and at risk of breaking, but was later repaired and it continues to function today.<sup>75</sup> It is no surprise that in this ninth year of civil war, Syria's water security continues to decline.

## Public reporting

In the last two years, Syria has experienced record rainfalls, damaging roads, villages and infrastructure in eastern Syria. Four bridges around the village of Tel Berak in the Hasakah Governorate were damaged by flooding. This incident made travel between 66 villages difficult until the bridges were repaired.<sup>76</sup>

Similar problems have affected border crossings like the Semalka border crossing that connects the Autonomous Administration to Iraqi Kurdistan, a vital route for trade in north-east Syria.<sup>77</sup> The route continues to use a floating bridge, which is affected by snow, frost and flooding.

General issues with urban infrastructure, or the lack of such infrastructure, are a source of many complaints from residents. Cities like Hasakah and Qamishli experienced rainfall that exceeded 50 per cent of normal annual rates earlier this year, causing flooding in cities and towns.<sup>78</sup> Residents of Qamishli complained of the condition of the roads, still unpaved in many areas, which had become extremely muddy and filled with rainwater, making even minor journeys difficult.<sup>79</sup>

Residents of cities dealing with muddy roads and flooded streets also complain about the polluted water that builds up in these areas. Water pollution has been a long-standing issue, with little assistance from the local authorities. Already in 2012, residents of Qamishli complained of significant problems due to pollution of the water supply.<sup>80</sup>

Despite these issues of poor water access and flooding, high rainfalls have benefited farmers across Syria and have provided relief from some of the water shortages that farmers have suffered from in the past decade. In 2019, the Southern Hasakah Dam was recorded as holding nearly 419 million cubic metres of water. Near the end of January 2020 the dam held over 435 million cubic metres of water.<sup>81</sup>

Water levels this high allowed the Water Directorate to release 12 billion cubic metres of water for 12 days straight, which irrigated 12,000 hectares planted wheat, a significant area of wheat in a country suffering food shortages and in which many fires destroyed fields in 2019.<sup>82</sup>

Water pollution is often attributed to oil production, improper handling of waste, or—in refugee camps—a lack of proper sanitation and sewage channels. Open sewage channels can spread disease in normal conditions, but when hit by floods and rain, they often spread dirty and unsanitary water over the entire area.<sup>83</sup> The most significant case of flooding to affect IDP camps involved the al-Arisha camp near the Hasakah dam, built near old artisanal oil refineries that also flooded the camps itself, resulting in the spread to toxic waste from the refineries into the water and soil, while prior to the flood displaced people, including many children were exposed to the oil waste littering around.<sup>84</sup>

Damage to water infrastructure has had a severe impact on access to clean water. In Hasakah City, 35 per cent of the public water network is partially damaged, and only 52 per cent is (partially) operational, with further problems around sanitation networks that could result in more pollution of groundwater and surface water from unregulated waste disposal.<sup>85</sup> In Qamishli, while 83 per cent of the water network is undamaged, pollution from industrial sources and solid waste is affecting local surface water and groundwater, while heavy rainfall in winter resulted in flooding of the sewage systems, further impacting water quality and environmental health.<sup>86</sup> Problems with surface water were further compounded by pollution of Jaghjagh River with untreated wastewater, leading to increased levels of ammonium that make the water unfit for use in growing food crops.<sup>87</sup>

Displaced people have complained of polluted water in their camp's water supplies, blaming it for the deaths of children and the increase of disease among people in these IDP camps.<sup>88</sup> Residents of these camps have also attempted to dig wells, only to find the water undrinkable. Water quality in areas formerly controlled by the Islamic State has suffered significant issues as well.<sup>89</sup>

One hundred people were reported to have been poisoned by contaminated drinking water in the al-Thakhnah neighbourhood of Raqqa.<sup>90</sup> In addition to the lack of clean water available locally, many residents are forced to buy their water from water trucks, which bring in clean drinking water every week. For residents of Tel Hamis in the Hasakah countryside, five barrels of water cost almost SYP 500; that price has probably increased considerably since then due to the fall in the value of the Syrian lira.<sup>91</sup> Residents of the town also complained about the lack of essential utilities and services like electricity.



A girl at a water tank at the Ras a Ain IDP-camp after fleeing from Turkish-backed armed groups. November 4, 2019.

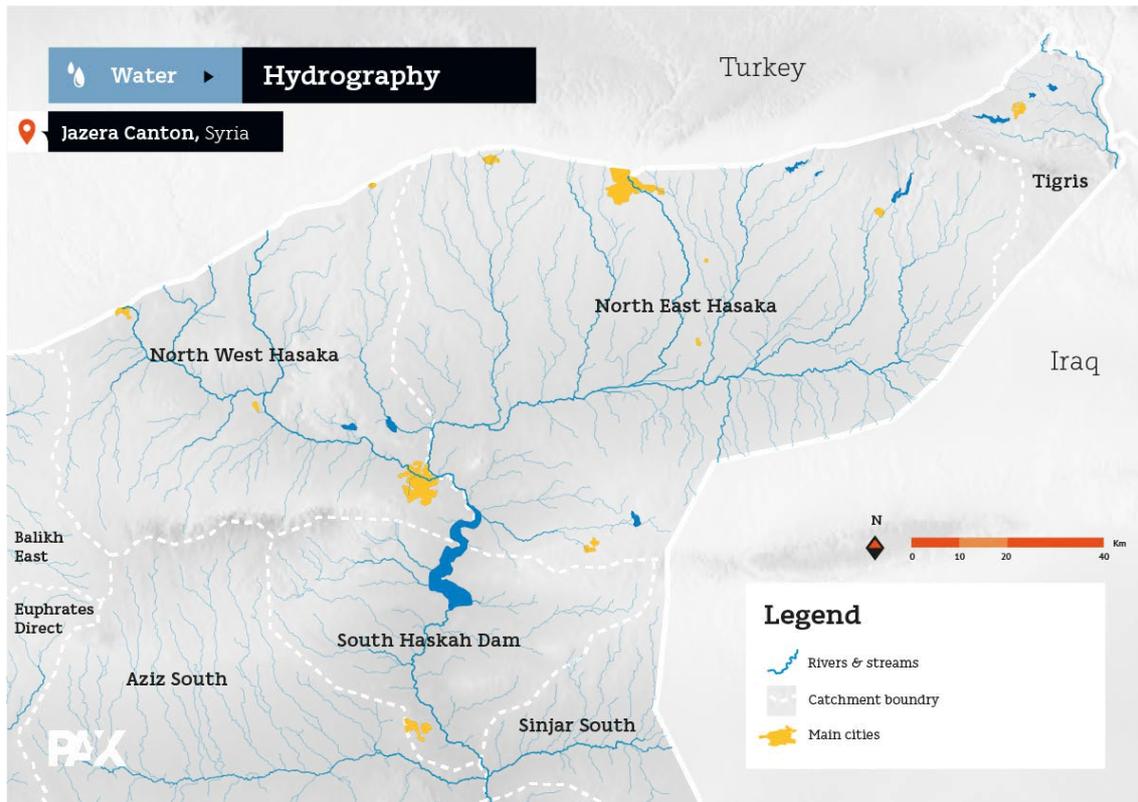
Conflicts between the Turkish-backed Syrian National Army (SNA) and the SDF have also affected access to water, with some accusing the SNA of firing at workers and shelling water pipes leading into SDF-controlled Hasakah in a dispute over electricity supplies to areas controlled by the SNA. In 2019, residents of Qamishli experienced water supply outages and limited access when the water did run.<sup>92</sup> The local administration attributed the problems to increasing population density and blamed the Syrian regime for manipulating water supply lines in areas it controlled.

Oil spills have often ended up in the waterways of north-east Syria, with spills from the Rumeilan oil fields flooding farmers' fields in 2019.<sup>93</sup> Farmers complain that the dangerous water quality is only made worse by oil entering the food system and water supply. Aid organisations like UNICEF that can access these areas have worked to improve water quality and provide clean drinking water for residents. In February 2020, they donated nearly 150 tons of sterilised calcium hypochlorite to help keep drinking water clean in Hasakah's 20 water-pumping stations, although complaints about water quality continue unabated despite these international efforts.<sup>94</sup>

## Remote sensing

To understand the impact of the conflict on the natural and built environment, it is crucial to understand the hydrology as well as the geological conditions. Water determines many processes aboveground and belowground. Because it is known that topography and gravity drive water downwards, it is rather straightforward to perform accumulation analyses.

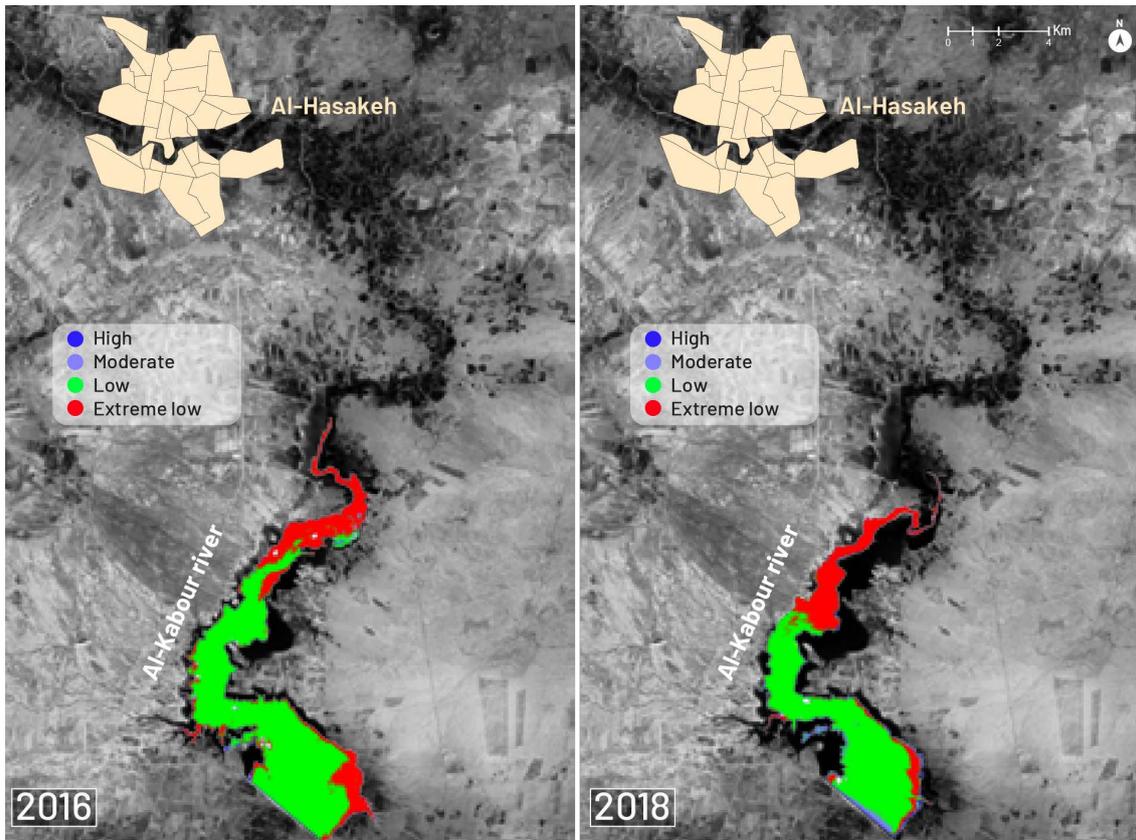
The representation of the ground elevations in GIS is done through a Digital Elevation Model (DEM). This elevation model serves as the basis for delineating the catchment and drainage network. Catchment areas or watersheds are essentially the slopes or land draining into one and the same body of water. The highest points of the terrain where water takes a particular direction towards a body of water are called water divides or catchment boundaries.



When detailing the hydrological structure of NES, six catchment areas can be identified. The first and most western catchment area consists of the slopes that drain directly into Lake Assad and below the dam, near the city of Raqqa. The second catchment area with three subcatchment areas is Balikh River. The largest and most complex is the Khabour watershed with six subdivisions. The Aljije catchment area is smaller and very arid—but it still has large floodplains or saltpans that get seasonally flooded. 17 per cent of the study area consists of slopes that drain directly into the Euphrates and only 2 per cent drains into a separate river system—the Tigris River.

When tracing the potential runoff from polluting sources, it is helpful to understand how conflict damage can impact water and natural resources, biodiversity and people's livelihoods. Built systems or water infrastructure can also be mapped and integrated into the geographical analysis. Pollution can eventually reach water supply systems, and they can also deteriorate or be damaged by deliberate attacks or due to the lack of maintenance.

Pollution sources that pose hazards to water resources include oil spills and leakages from oil extraction and storage, landfill leaching and agricultural activity whereby fertilisers end up in bodies of water, causing eutrophication. The decline in the trophic state of Al Khabour River, which flows into the Hasakah reservoir, is likely linked with an increase in chlorophyll A, which could be caused by external pollutants such as industrial waste, fertilisers and agricultural pesticides. Below is an analysis made by iMMap for their Urban Analysis mapping of Syrian cities showing an increase of Chlorophyll A in red in this aforementioned area.



*Trophic status of Al-Khabour River has been measured by the Sentinel 2A satellite data for the period between 2016 and 2018. Decrease in the trophic status of the river as a result of increased Chlorophyll-a concentration may indicate the presence of external pollutants.*

Water that drains from agricultural and/or productive land often has a high concentration of nutrients. When these nutrients flow into bodies of water and accumulate there, they cause a peak in productivity (algae). Bodies of water have natural productivity dynamics and when these are altered, there is often no way back to the original conditions. Eutrophication is an undesirable process because the algal blooms deplete water oxygen, killing all or most of the life in the water. In some cases the algal blooms themselves might be toxic.



# 6. Agriculture and Forestry

Agriculture in Syria suffered from water shortages and mismanagement of infrastructure long before the start of the civil war. The north east is considered to be the breadbasket of Syria, with crops such as wheat, barley, lentils and cotton grown using rain-fed and irrigated agriculture.<sup>95</sup> Faced with a lack of fertiliser, pesticides and even clean water, agriculture has had to cope with considerable obstacles in producing food for local areas.

## Public reporting

An essential source of food and income for locals, agriculture employs people across the region and the Autonomous Administration has been heavily involved in regulation and price setting for farmers in most areas of north-east Syria.<sup>96</sup> In 2016, they were able to stop farmers from using Jaghjagh River due to contaminants in the water supply.<sup>97</sup> Farmers complained about significant potential losses, saying that they could lose millions of lira from this blocking of their access to the river's water. To reduce costs to local farmers, the Autonomous Administration has subsidised fertiliser for farmers, which continues to be difficult for farmers to obtain.<sup>98</sup> Farmers have also faced increases in the price of fertiliser, which went up from SYP 240,000 per ton to SYP 400,000 per ton in 2020.<sup>99</sup>



Farmer working in the field at Qasr Dib, a small village near Derik/Al Malakiyah. May 24, 2020

Fuel and fertilisers have always been difficult to access, and although prices are set by the Autonomous Administration and the goods then distributed to farmers, the farmers have pointed out that the amounts given to them do not come close to meeting their needs. Farmers openly talk of buying from the black market to meet the needs of their farms.<sup>100</sup> Farmers are given about six barrels of fuel per 100 dunums, but they estimate they need at least 15 barrels per 100 dunums. In the 2019 farming season, they paid SYP 35,000 per barrel on the black market.<sup>101</sup>

**“We recorded significant losses due to pests last year, and the authorities provided no support. So this year, we cultivated smaller areas because of the lack of support.”**

While some farmers are unable to afford the resources needed to fully maximise yields, those who can start the growing season face a multitude of problems in ensuring their crops and livestock can survive to the end of the season.<sup>102</sup> Waterways used for irrigation are often open to the air, and suffer from poor upkeep, with some filled with garbage dumped in them.<sup>103</sup>

Besides the risk of contaminated water due to waste, one of the most significant risks to agriculture continues to be the local oil industry, which is still operating with crude artisanal refineries and wells. Water has been poisoned by oil spills, which not only ruins the soil but directly enters into farmers' water supply.<sup>104</sup> Due to the small scale of these oil processing facilities, many of them are built right next to farms and agricultural areas.<sup>105</sup>

Farmers also must deal with invasive species and wild animals, with farmers in al-Malikiyah (sometimes referred to as Dayrik) saying that in recent years wild boars have destroyed entire fields of chickpeas.<sup>106</sup> Local media reported that the problem has spread to many villages on the Tigris River. Water hyacinth, an invasive aquatic plant species, has long plagued Syria, and the Syrian regime, along with the Lebanese government, has approached the FAO to develop ways to fight it.<sup>107</sup> The plant often fills waterways in Syria and requires clean-up efforts to remove it.<sup>108</sup>

Syria has also witnessed a sharp increase of wildfires that have been affected both agricultural land and forests, in particular in 2019 and 2020. According to the Food and Agriculture Organisation, the increase linked with increased temperatures and winds, as well as started ‘maliciously’ 109 that burned 85,000 hectares of crops in 2019 alone. In non-government controlled western Syria, many of these fires were attributed to Syrian regime attacks either targeting fields,<sup>110</sup> or hitting them in unguided attacks.<sup>111</sup> Many fires could not be accounted for,<sup>112</sup> but stopped by White Helmet firefighters.<sup>113</sup> Although farms in eastern Syria do not suffer regime attacks, farms under the Autonomous Administration, like in the rest of Syria, have suffered heavily from fires. However, the local authorities have refused any outside assistance in fighting fires in north-east Syria, saying that their ability to fight fires was sufficient and outside assistance was not needed.<sup>114</sup>

Many people were forced to evacuate their homes to avoid these fires,<sup>115</sup> which started in June 2020, and some people died trying to fight field fires. In one fire that burned 200 hectares, ten people, including members of the YPG, died fighting the fire.<sup>116</sup> Fires elsewhere on the same day injured and killed a dozen people, destroying trees and fields.<sup>117</sup> These fires were almost a weekly occurrence, with hundreds of thousands of hectares destroyed. Fires regularly destroy massive volumes of crops, with fires destroying 40,000 square metres of wheat in north Hasakah. Farmers usually fight fires with blankets if water trucks are not available.<sup>118</sup>



Locals fighting the cropfires that hit the harvest near Derbesiyah, December 9, 2019

In the past, faulty equipment has also caused fires; harvesters and equipment in poor condition can start fires that destroy fields.<sup>119</sup> The Autonomous Administration has also blamed recent offensives by the Turkish-backed SNA in Afrin and Hasakah, saying that groups have stolen crops in the areas they took over, or targeted fields outside of their control to stop farmers from working.<sup>120</sup> Areas controlled by rebel groups and the SNA have also suffered from fires, and groups have released media footage showing members fighting those fires.<sup>121</sup>

The ICRC has also worked to provide farmers with free wheat and barley seed, distributing 600,000 kilos of free wheat and barley seed to 3,000 farms in Hasakah Governorate.<sup>122</sup> The Syrian Ministry of Agriculture and Agrarian Reform, controlled by the Syrian regime, reported on a countrywide level that 1.35 million hectares of wheat were planted in 2020 and 1.505 million hectares of barley. These planting season figures amounted to 75 per cent and 100 per cent of the planned implementation respectively. Although these numbers seem promising, further research into the veracity of these figures is needed.

In a country suffering from decades of corruption, where infrastructure has been destroyed, facing ecological disaster on multiple fronts, and after years of civil war where nothing was off limits in the Syrian regime's mission to suppress all dissent, the long-term survival of not just agriculture but all sources of income and essential services continues to be threatened.

## Deforestation

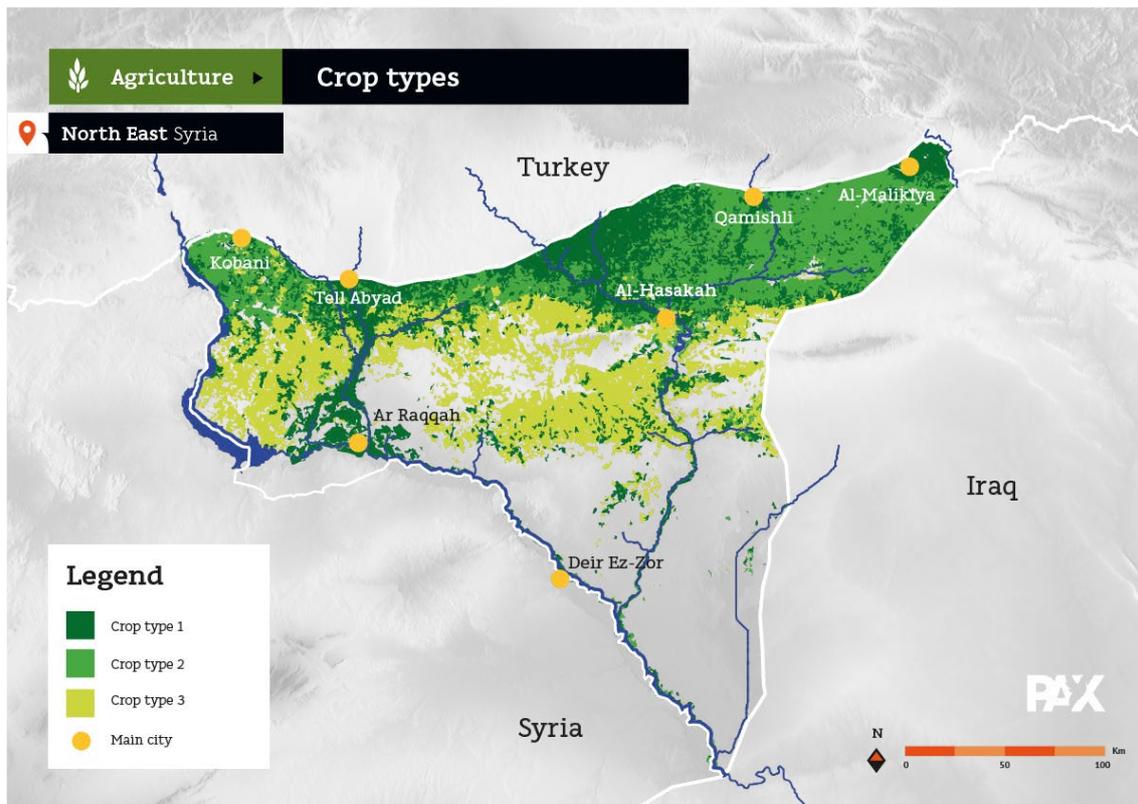
Although most of Syria's forests are located in the west of the country, and heavily affected by conflict-linked deforestation<sup>123</sup>, the northeast has also had its fair share of tree-cover loss. Prior to the conflict, local authorities aimed to restore biodiversity and wildlife in various areas in the region by investing in reforestation projects. The Raqqa province alone had over 17,000 hectares of forest, most of them planted, with the remaining natural forest located on the shores of Lake Assad, west of Raqqa<sup>124</sup>. Large reforestation projects were also set up between Raqqa and Hasakah city, with the latter growing mainly pistachios and various pine trees. Though experiencing setbacks during the conflict, current planning includes reviving these large-scale reforestation projects.

The remaining forest and tree-covered areas have faced significant logging and damage due in large part to the need for firewood, while heavy fighting and absence of forest management due to unexploded remnants of war also contributed to forest loss. According to local authorities, there were also deliberate attacks on tree nurseries where specific regional species were grown during and in the aftermath of the conflict.<sup>125</sup> When PAX met with representatives of the AANES in 2018, they expressed concerns over the massive logging of trees for firewood throughout the last seven years, as this impacts soil and leading further deteriorating environmental conditions. Though substantial reforestation programs have been established both in cities and for artificial forests, the officials also underscored the challenges, as there was limited protection for tree nurseries and larger tree farms need proper irrigation for them to succeed and be sustained, and that in a region already struggling with water. Various local environmental groups<sup>126</sup> and municipalities<sup>127</sup> have initiated reforestation campaigns on a community level in urban and rural areas for greening cities, strengthen soil and slopes near lakes and as an environmental peacebuilding tool.<sup>128</sup> Local entrepreneurs and farmers<sup>129</sup> are currently seeking opportunities to develop tree nurseries for trade and revive the local economy.



## Remote sensing

Both the agricultural change due to conflict, heat and rainfall, as well as the impact of the crop fires can be visualized with remote sensing. To understand the distribution of land-cover types in north-east Syria, Landsat 8 unsupervised classifications were combined with the Normalized Difference Vegetation Index (NDVI) from 2014 to 2020 to produce a final updated land-cover type layer. This procedure takes into account how land cover has changed during this time frame and what the current situation is. From the land-cover analysis it can be determined that 59 per cent of NES is covered by crops (29,000 km<sup>2</sup>): about 15 per cent of this area is classed as 'most green' based on the observations, and associated with irrigation. 45 per cent consists of crops in 'normal' conditions and the remaining 40 per cent of the mapped cropland is associated with 'drier' conditions. The rest of the study area has natural and non-productive land-cover types such as arid bushes and grassland. 24 per cent of NES is almost completely bare.



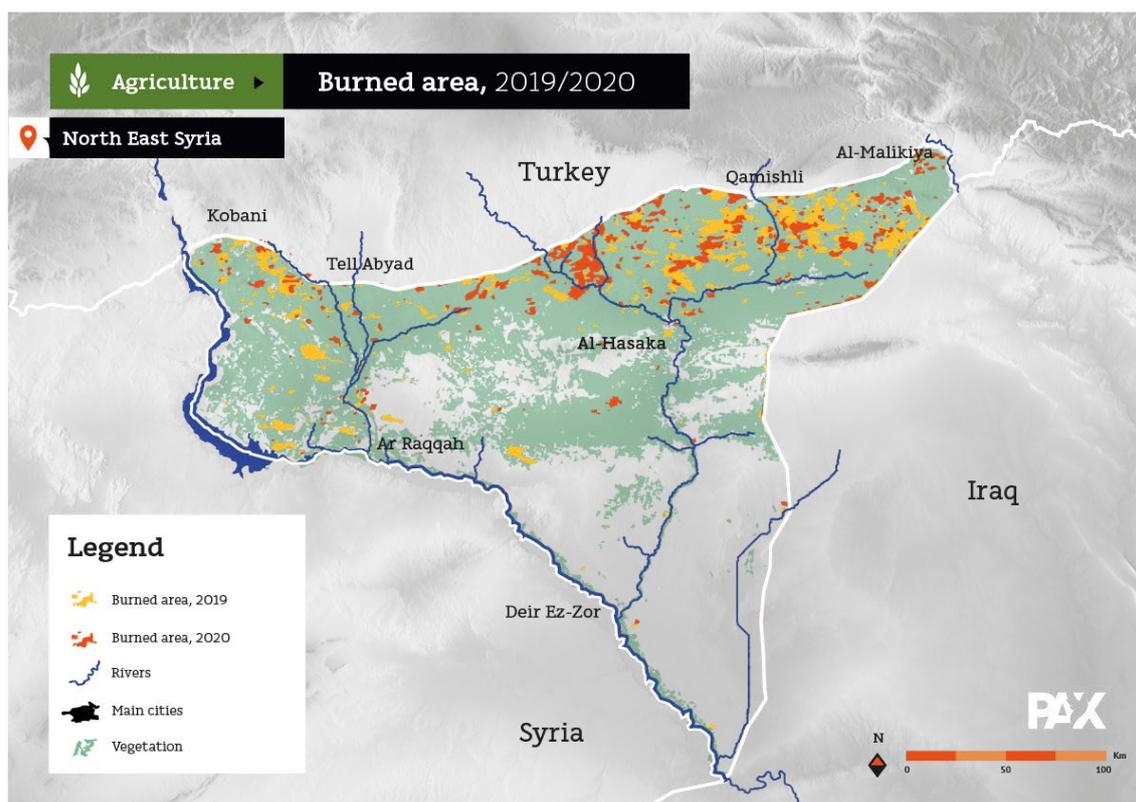
In NES there are three main agricultural classes. They are determined by moisture and water availability in the course of the year or crop season. The other land-cover classes are also mainly determined by water availability, whereby the lack of water leads to bare land or arid vegetation. Bodies of water themselves are another land-cover type.

The findings show a decrease of vegetation growth leading up 2018, but with the increase of precipitation and flow of water from the north, both rainfed and irrigation-based agriculture improved in 2019 and 2020.

<b>Type 1</b>	Groups of crops that appear very healthy - “very green” in NDVI value through the study period. The NDVI shows 2 peaks (crop harvest) per year, the first in late April and the second late summer). There is apparently no water restriction or stress. These crop types are mostly irrigated. They are found mainly along main rivers and some clusters fed by ground water.
<b>Type 2</b>	Groups of crops that appear in a normal health state - moderately “green” in NDVI value, as there is enough moisture to fulfil the crop’s requirements. The NDVI shows 1 peak (crop harvest) per year – late April. These crop types depend on rainfall or precipitation.
<b>Type 3</b>	Groups of crops grown in soils with low moisture or just enough to maintain certain crop types with low water requirements. Typical crops in this class are cereals and grass (managed grasslands). These crop types depend on rainfall or precipitation.

## Crop fires

Since 2018, there has been a significant uptick in wildfires throughout Syria, including the north-eastern agricultural areas. As noted in the narrative section in the beginning of this chapter, the causes are a mix of incidents, deliberate destruction used as a tactic by armed groups and the Syrian regime, and stub burning. The area of burned land and number of fires can be measured using various remote sensing tools. MODIS 64a1 (burned land) & 14a1 (fire) products, together with Landsat 8 and Sentinel-2 images were accessed and processed in Google Earth Engine to quantify the extent of burned land. Existing data from 2019 was taken from a REACH analysis to compare



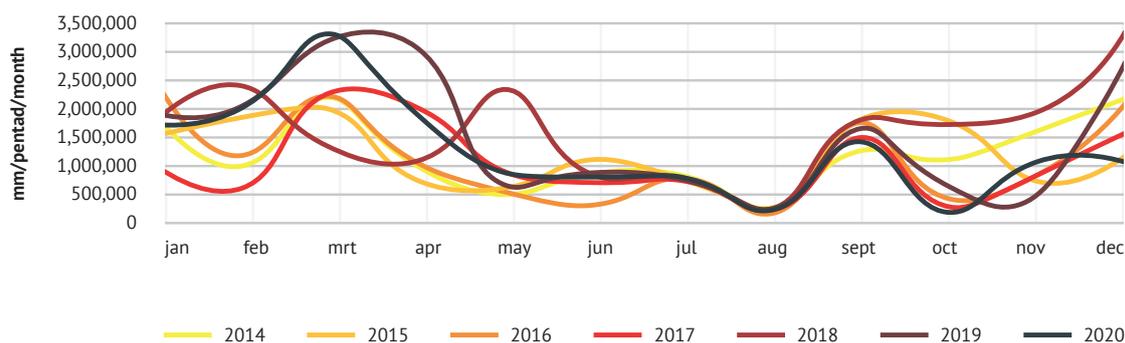
with the following year.<sup>130</sup> In 2020, PAX produced its own analysis of burned land in this region after the Turkish-backed armed groups clashed with the SDF, resulting in increased shelling and fires breaking out in the border areas.<sup>131</sup>

Combining both the data sources and with improved analysis of the fires, our findings indicate that at least 1500 km<sup>2</sup> has been burned in 2019 and over 550 km<sup>2</sup>. Burned areas based on combined sources (MODIS, Sentinel and Landsat derived layers) 2018–2020.

## Precipitation

Where there are no precipitation stations and measurements available, precipitation remote sensing becomes a very useful indication to account for rain activity. Because there are no available measurements, there is a limitation to estimate real water quantities and rates. The remote sensing precipitation is useful as a precipitation signal more than an absolute value. The CHIRPS product was accessed and processed with Google Earth Engine to aggregate monthly values between 2014-2020.

**CHIRPS Precipitation 2014-2020 (mm/pentad)**



Remote sensing measurements of precipitation show how from the end of 2018, there was pattern change and a shift to wetter conditions. Since 2014 it had never rained so much as in 2018 in the months of September to December, with the exception of 2015 only in September/October. With this rain input, 2019 began with normal precipitations throughout January and February, but in March and April – the area received unseen (since 2014) precipitation. 2019 returned to a normal behaviour until November that was rather dry and December being quite wet. This gave way to a very wet 2020 which began quite normal, and was as wet as 2019 in March and became rather normal the rest of the year – with a dry December.

As observed in the optical imagery of Landsat, Sentinel and Planet, 2019 and 2020 were exceptionally wet – 2020 was drier than 2019 in April but wetter in November. Together with the social situation, this had an impact on the land cover and land-use patterns, productivity and even available biomass to burn. The increased rainfall resulted in widespread weed growth in early spring 2019, followed by a heatwave that dried the weeds, and making the land more susceptible to rapidly spreading wildfires.<sup>132</sup> A full remote sensing analysis can be found in Annex 1.



# 7. Conclusion

The environment in north-east Syria has faced serious challenges since the outbreak of the peaceful revolution ten years ago. The ensuing violence by the Syrian regime and later by IS and Turkish-backed armed groups in this part of Syria severely impacted the environmental infrastructure and natural resources through conflict-linked pollution and damage to the ecosystem. The north of Syria is home to much of Syria's oil reserves and large swathes of agricultural land providing food security for millions of Syrians. This research set out to explore the environmental dimensions of the conflict in this part of Syria through the use of remote sensing, open-source documentation and field work. Our aim was to show that a great deal of environmental data and information on related concerns can already be accessed and used for the timely identification of priority areas for humanitarian response, recovery, remediation and reconstruction efforts to address both human-health and environmental issues.

The findings of this report paint a bleak picture of the conflict's environmental legacy. The most visible manifestation is seen in its oil industry, where ongoing spillages, dumping and the widespread practice of makeshift refining have scarred the landscape, with rivers of oil and black plumes of smoke often seen on Syria's horizons. Our findings show over 500 larger and smaller spills from oil facilities and pumping jacks, and nearly 200 makeshift refineries still in operation. Spills and dumping have severely affected creeks and rivers, flowing into a river 160 kilometres long that is used for irrigation. Heavy rains frequently lead to land flooded with oil waste while, after years of dumping, oil is reaching the groundwater and affecting water wells.

Pollution and unsafe working practices involving thousands of civilians, including many children, have left communities in a state of despair about their health and the harm done to their fields and water resources, and they contemplate leaving all together. People living in and around the oil fields feel stuck in a polluted wasteland. Water wells are tainted with oil, the air is thick with smoke while livestock graze in blackened pastures. The COVID-19 pandemic raised further problems, as these communities lacked access to safe water sources for hygiene.

The situation has been aggravated by the limited action taken by the de facto authorities to adequately deal with this problem, caused by limitations in their financial resources, expertise and capacity or because the problems are not seen as a priority. Oil revenues remain the main source of income of the Autonomous Administration, yet repairing and modernising the oil infrastructure as well as clean-up and remediation efforts will come with a huge price tag. Considering the ongoing security threat from both IS and the Turkish-backed armed groups, it is unlikely that the authorities will be able provide a sustainable solution without external support.

Weak environmental governance also contributed to escalating problems with solid-waste management and related water infrastructure. Our resource shows that of the 20 landfills we identified with solid waste, five are close to urban areas where waste burning, waste picking and leachate all pose direct or long-term health risks, affecting air quality, groundwater and surface waters. The water infrastructure in two major cities is still in need of repair, while extreme weather events with heavy rains increasingly result in flooding of cities, towns and villages. There is limited capacity to restore infrastructure and build back better in a way that takes into account the

climate challenges of the future. In particular, water flowing from the Autonomous Administration's neighbour Turkey and hydro-politics, for example in the form of dam building, could pose problems around access to water in the near future.

Water, conflict and climate-security risks are also seen in the agricultural sector. Natural disasters such as droughts and heavy rains, compounded by the war, have all impacted land use and crop yields. Lack of enforcement of environment regulations has led to an increase in the industrial waste, pesticides and fertilisers being dumped into rivers, affecting the water quality and irrigation. Land use has also been affected by farmers fleeing from violence or lacking proper equipment to take care of the land, while at the same time facing droughts and floods that have affected harvests. Increased rainfall in the last two years combined with early heatwaves resulted in higher fire risks in crop fields, both from incidents and from stub burning. Outbreaks of fire were also caused by shelling in border areas and deliberate arson tactics used by armed groups and criminals. In total, 2050 km<sup>2</sup> of burned land were detected in 2019 and 2020, a significant uptick compared with the previous decade.

This initial explorative study of the many environmental issues in north-east Syria should spur action by local authorities, international aid organisations and donors to invest in sustainable solutions for the region. Notwithstanding the political sensitivities around the status of north-east Syria and the Autonomous Administration, a solution to the wide range of environmental problems is needed for its people so that they can rebuild their lives and invest in their future. Activists and volunteers from civil society organisations such as PEL-Civil Waves have already started collecting stories and information from their communities to highlight concerns and urge for action to be taken. These efforts deserve solidarity and support to deal adequately with the wider impact of the conflict on the lives, livelihoods and future of the Syrian people.



Young boy with a lamb on the field near Khazna village, Qamishli. April 9, 2020

# 8. Recommendations

## To the Autonomous Administration of north-east Syria

- ◆ Initiate a wider environmental assessment in collaboration with local and international organisations to build a comprehensive overview and set priorities for intervention
- ◆ Engage with communities to identify concerns about environmental health risks in order to build transparency and accountability concerning the government's activities.
- ◆ Dedicate financial resources and capacity to repairing and modernising oil infrastructure, and cleaning up and remediating polluted soil and affected water sources.
- ◆ Set up a clear environmental legal framework and plans for the implementation of rules and regulations around waste management, agricultural waste, public services and preservation of nature and protected areas.
- ◆ Invest in repairing and building environmental infrastructure, including water infrastructure, sewage systems and landfills.
- ◆ Conduct awareness raising on environmental issues in communities to identify opportunities on a local level for prevention, clean-up and remediation.

## To international organisations and civil society groups working in north-east Syria

- ◆ Integrate work to address environmental health risks and concerns in data collection and survey work in your areas of operation.
- ◆ Collaborate with local and international organisations to share the findings and improve analysis and best-practices around environmental issues in program work.
- ◆ Include awareness-raising on environmental issues in the work stream and strengthen knowledge-building to empower community efforts in resolving these concerns.
- ◆ Implement a 'do-no-environmental-harm' policy in their own operations and humanitarian response work.

## To states and international donors

- ◆ Provide funding for a full independent environmental assessment to be initiated in north-east Syria.
- ◆ Support local and international groups with funding for projects addressing pollution, waste management and wider environmental infrastructure.
- ◆ Consider direct collaboration with local authorities by providing capacity, expertise and equipment to deal with the most acute environmental threats, giving priority to oil-related pollution and environmental infrastructure repairs.
- ◆ Highlight the environmental dimensions of armed conflicts in relevant international forums to strengthen the environment, peace and security agenda, and provide support for regular monitoring and reporting on environmental risks and response.



Environmentalist groups in north-east Syria initiating a reforestation project. Qamishli, April 30, 2021

## Annex 1 - NDVI based land cover change analysis in the Hasakah Governorate, north-east Syria.

NDVI based land cover change analysis in the Hasakah Governorate – Noth East Syria.

Based on the available open source administrative units, the Hasakah governorate has 29,470 km<sup>2</sup>, 43% of the study area of North-East Syria. From the land cover assessment, 24% is defined as natural – agriculturally unproductive land covers.

The rest of the 76% of the Hasakah governorate was classified into one of three crop types. Crop T3 has more relation to drier condition crops and less water availability. Managed grasslands are included in this class. The healthiest and irrigated crops stand out, being classified in the T1 class. If a crop is not irrigated then the water source is precipitation. The rest of the crops (T2) coincide with “rain fed” crops found in other cases and maps in literature.

LC type	km <sup>2</sup>	%
natural	7,911	24
Crop T1	3,974	13
Crop T2	11,476	39
Crop T3	6,829	23

The dimension of the 49,300 km<sup>2</sup> of NES takes size when compared to countries like Belgium (30,500 km<sup>2</sup>) and The Netherlands 41,500 km<sup>2</sup>.

For the study period of 2014-2020, two analyses using NDVI were done over the Crop types in the Hasakah governorate. First, the NDVI value distribution and second, the change of NDVI value. Both are specific per crop type.

The “greenest” or most productive period of the year was identified with MODIS NDVI (8 day product) for a long time series (2002-2019). For this period of April to May, NDVI maps were prepared from Landsat 8 (Figure 1), to capture the “greenest” or highest NDVI value that a pixel could be for that year’s crop season. The years processed were: 2014, 2016, 2018, 2019 and 2020. There is a clear difference between the first and last half of the studied years.

NDVI values range from 0 to 1. In NES the higher values were between 0.6 and 0.7 – according to this index – these values relate to the healthiest and most productive standing vegetation (in that moment). From 0.3 to 0.6, vegetation is considered in normal conditions and below 0.3, it indicates low health or productivity.

NDVI based land cover change analysis in the Hasakah Governorate – Noth East Syria.

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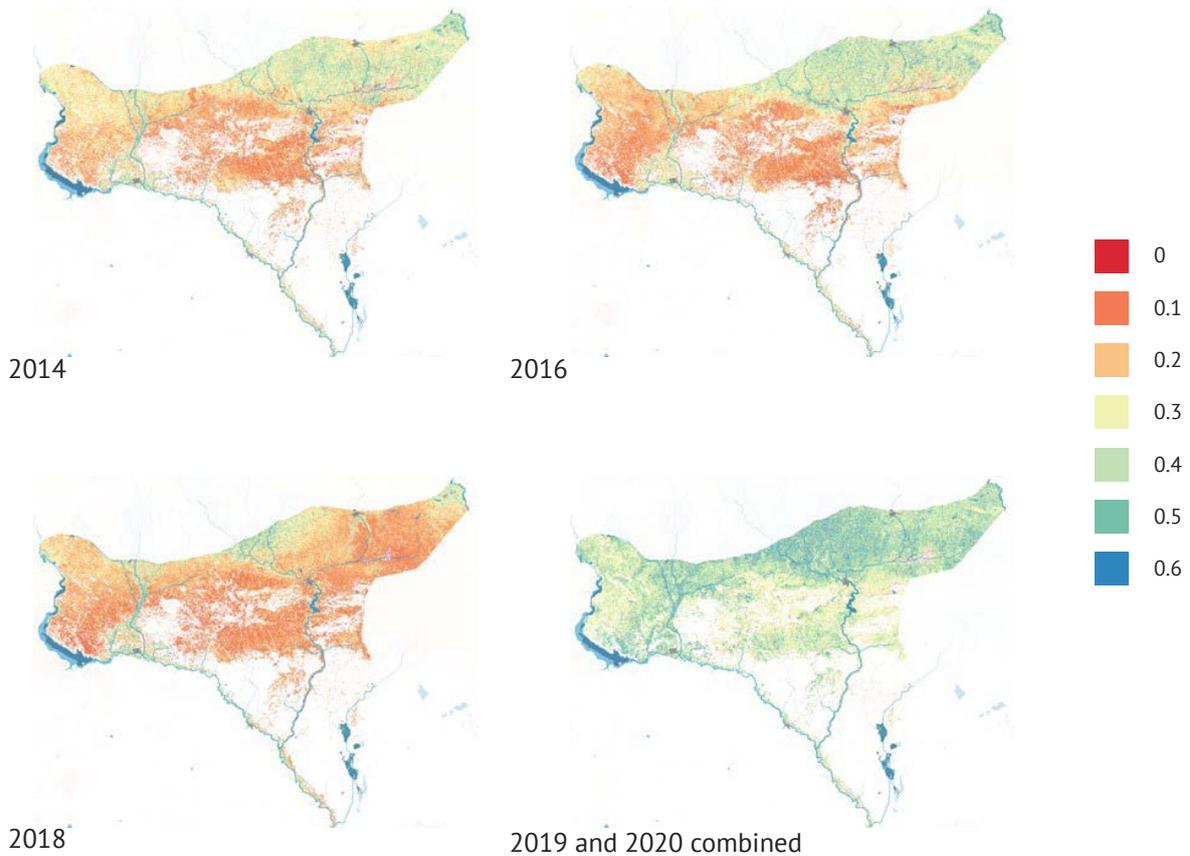


Figure 1. Landsat 8 (April – May) NDVI composites

The NDVI histograms (Figure 2) offer a complete view of the “greenness” per crop type. For example for crop type 2, shows similar bell shapes in 2014 and 2016, but 2018 there is a considerable shift to lower NDVI values and even a higher peak, indicating that in that year, vegetation was not as healthy as before. Many crops could have reached wilting point and died and some other crops could have survived producing lower yield. In the following two years, the NDVI in this crop type increases – indicating better health and productivity – even higher than the first two periods.

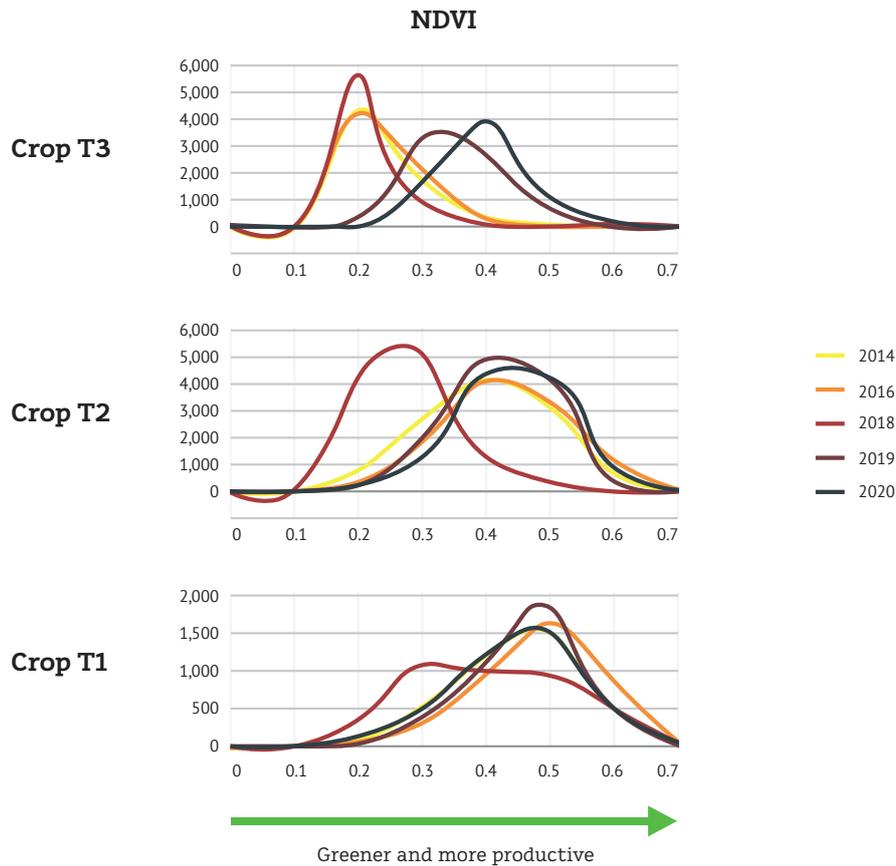


Figure 2. NDVI histogram of the agriculture/crop classes (area in Km<sup>2</sup>).

Crop type 1, shows an interesting pattern in 2018, even though around half of this crop type loses “greenness”, an important part remains “green” (around 0.5-0.6) in the driest period experienced. In 2019 and 2020 the NDVI indicates greater productivity, especially in 2020.

NDVI change can be mostly attributed to available moisture, evidenced with remote sensing products. The second main driver can be related to management factors – determined also by the conflict context (no specific data). The lack of specific data limits the depth of possible analysis. At the end of 2018 precipitation patterns change influencing vegetation dynamics. The change of NDVI can be positive or negative – if the number in the second period is larger, the subtraction will result negative – and otherwise, positive.

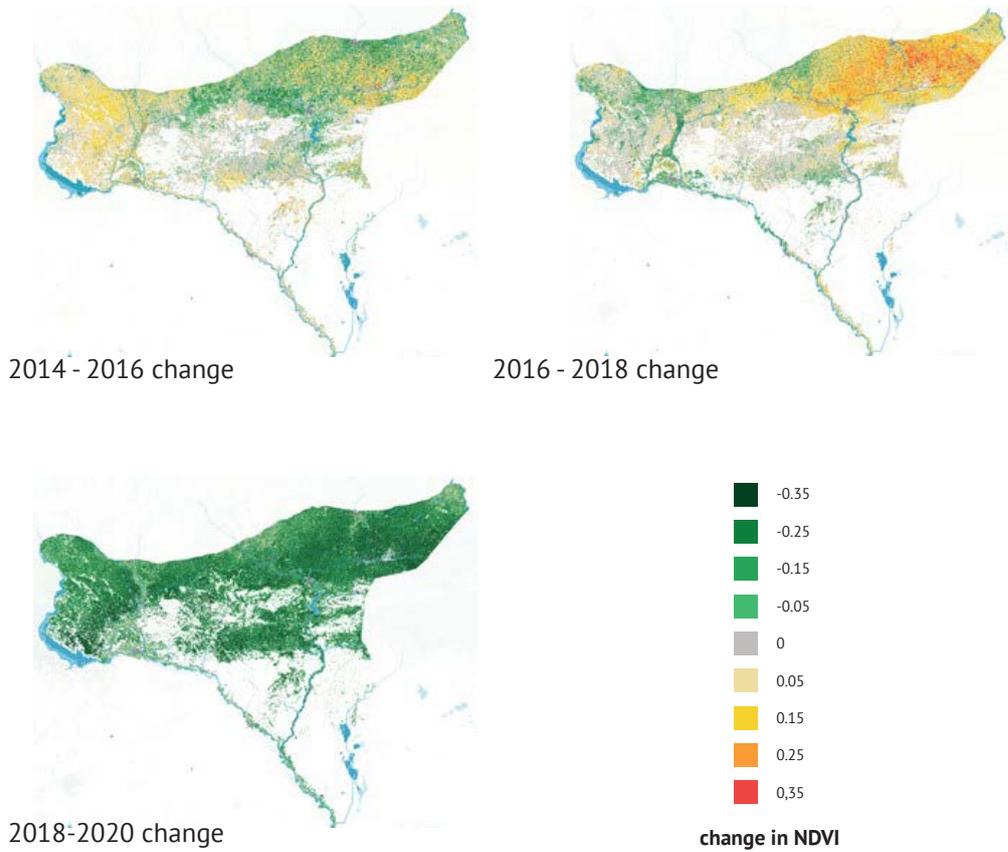


Figure 3. **NDVI change.**

The most dramatic change was between 2016 and 2018, where the whole area of “rainfed” crops in the Hasakah governorate turn yellow, orange and red (legend values). In these locations the vegetation health is the lowest in 2018 (compared to 2016). By 2019 and 2020, a generalized higher vegetation activity and productivity is detected throughout North East Syria. In figure 4, the changes of NDVI in percentages can be further analyzed.

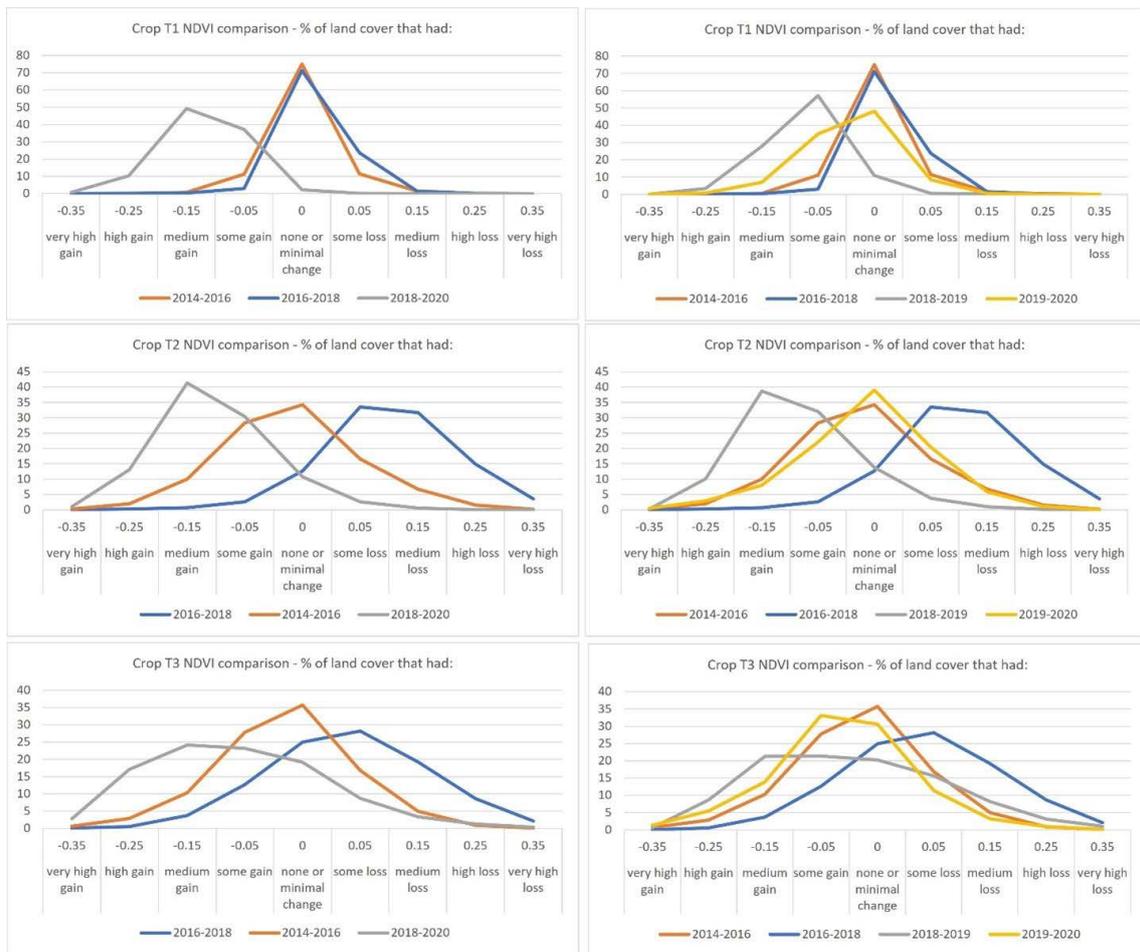
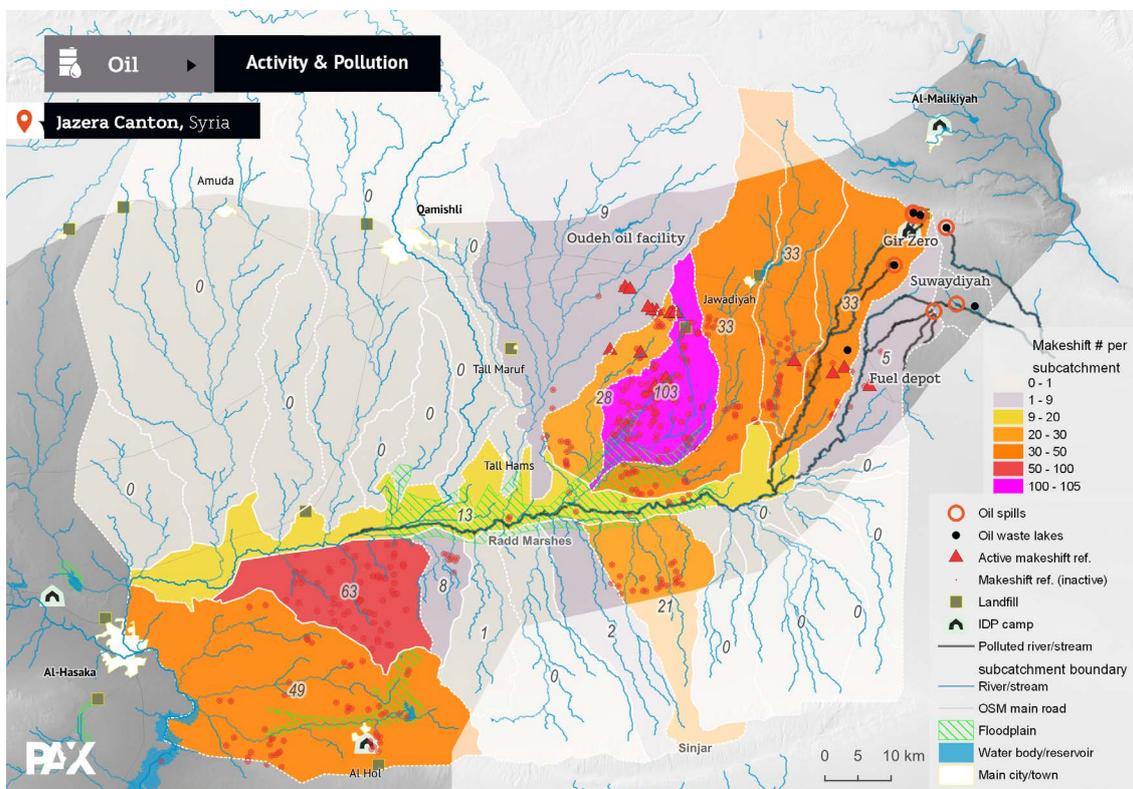


Figure 4. % of NDVI change

## Annex 2 - Pressure of oil related activities – a watershed perspective.

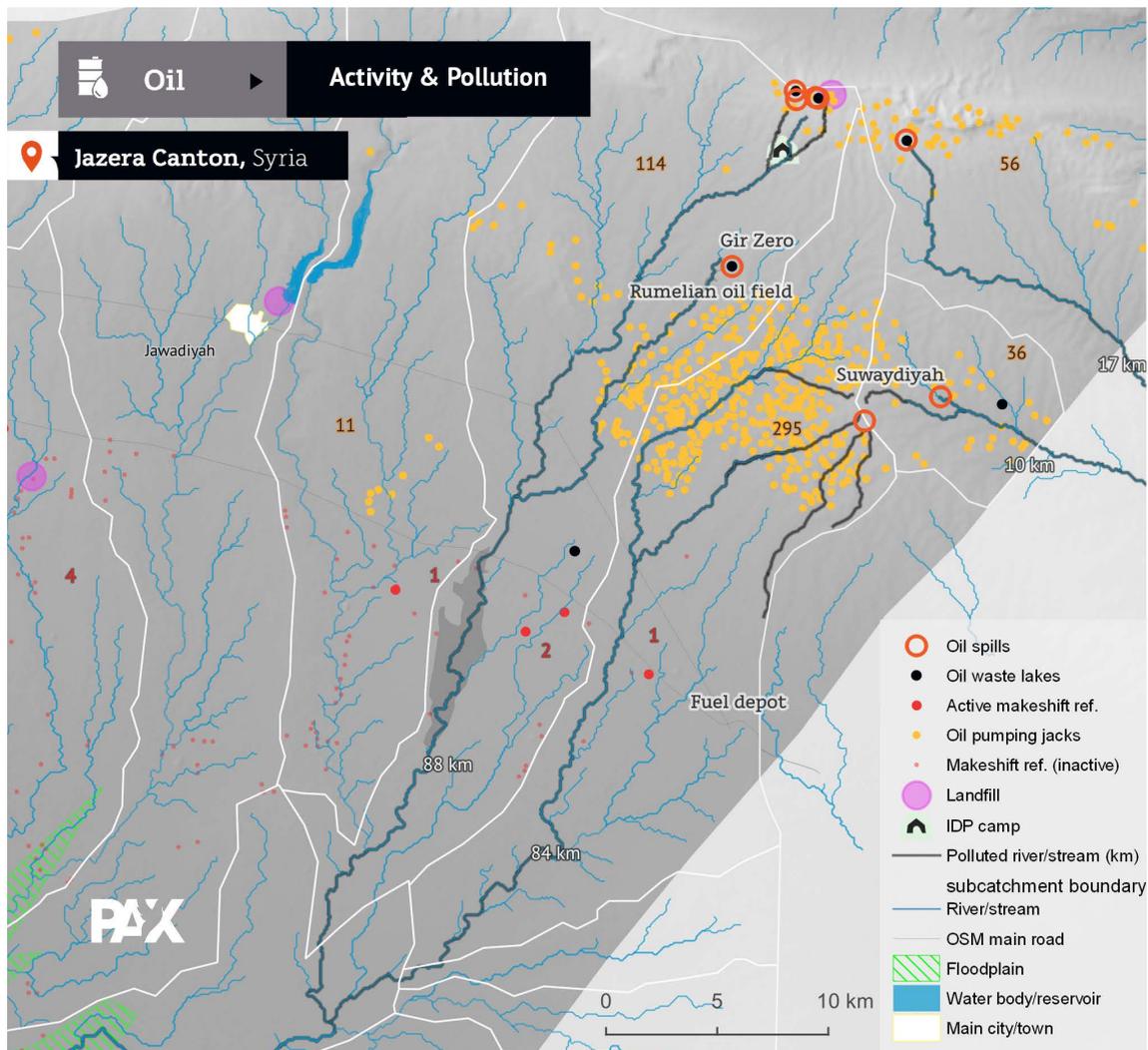
A closer look was done to the north east - upper Khabour catchment, to account for the location and distribution of the elements that pose environmental pressure and potential pollution. Mapping the active and inactive makeshift refineries and rest of oil installations and facilities is a good indication for the oil related activities. Counts are grouped per hydrological unit. For example, for the total clusters of makeshift refineries mapped in NES, 55 per cent (378) are inside the most north-eastern catchment area of north-east Syria. This catchment is subdivided in sub-catchments and a second (more detailed) count was performed. These calculations and sub-catchments can be seen in the following map.



It can be safely assumed that where there are more counts of these installations, there is a higher associated potential of environmental and health hazards. Most of this north-eastern catchment area drains into the Radd Marshes, considered in the UN-ESCWA and BGR inventory, to be an area where groundwater surfaces. This water surfacing and storage process makes these lowlands wet and fertile and a good place for agriculture. But it is also a place where surface runoff and subsurface water flows meet, making this area a potential accumulation zone – a hotspot for pollution from the catchment area. Further studies are needed to draw conclusions and assess the dimensions of this potential problem.

Another cluster of makeshift installations is located on the northern slopes, where 103 points were counted within one sub-catchment area. In a makeshift-refinery density map, this location would have the highest density. It also seems to have quite some agricultural activity.

With a closer look to the Rumelian oil fields, more detail of potential oil impact can be mapped and quantified. The sub-catchments with the most pumping jacks clusters, have 295 and 114 clusters respectively. The active makeshift refineries are also accounted per sub-catchment unit as well as the length of polluted river and streams. A larger spill can be seen in a narrow floodplain where agriculture takes place, over 1000 hectares of cropland have been polluted. Around the Gir Zero facility, at least 15 to 20 hectares of oil around the stream were evidenced in a quick assessment with open source high resolution imagery. More work has to be done in detecting and mapping oil pollution over land.



## Annex 3 - LC & Catchments

### Landcovers NES

Land Cover class	km2	%
Sand - Bare	11785	24
Dry grass with some bare	1003	2
Dry grass and shrub with some bare	6617	13
Crop type 1 - irrig.	4674	9
Crop type 2	12660	26
Crop type 3	11747	24
Water surface	849	2

Crops	km2	%
Crop type 1 - irrig.	4674	16
Crop type 2	12660	44
Crop type 3	11747	40

### Catchments NES

cod_ctch	NES Catchment	km2	%
1	Assad Lake	5184	11
2	Balikh	6667	14
3	Khabour	23895	48
4	Euphrates direct	8584	17
5	Aljje	4114	8
6	Tigris	903	2

## Annex 3 - LC & Catchments

### Sub-catchments NES

name_ctch	cod_ctch	cod_subc	km2
Assad low	1	11	2543
Assad dam direct	1	12	2641
Balikh c	2	22	875
Balikh e	2	21	3800
Balikh w	2	23	1995
NW Hasakah	3	32	4397
Aziz south	3	31	3674
NE Hasakah	3	34	8417
Sinjar south	3	33	1161
Khabour low	3	35	3794
S Haskah dam	3	36	2452
Euphrates direct	4	40	8584
Aljije	5	50	4114
Tigris	6	60	903

## Annex 3 - Landfills

### Sub-catchments NES

Qamishli	From the original dumping in the quarry (17 ha) it extends to a south grass plot (9 ha)	Formal/Informal?
Derik / Malikayah	most activity within the plot - small expansion 2 ha in 2018	Formal
Hasaka (south)	has grown 40 ha, several informal dumps appear road side	Formal/Informal
Tel Arqam/Halaf	has grown (0.8 ha), road has adjusted around perimeter and slides are detected	Formal
Derik south / Tepke	appeared recently- 2x ha core	Informal?

### Sub-catchments NES

Location name	area ha	dump type	internal flooding	drains to-	Surrounding matrix	Neighb. Pop.
Qamishli	26,2	quarry fill & grassland	yes	infiltrates -> channel	grass - agriculture & quarry	yes
Derik / Malikayah	8,1	dump	no	agriculture, stream -> small dam	grass - agriculture	yes
Hasaka (south)	50,8	dump and road side	no	stream headwaters, large dam	bush - natural	none but, recent expansion yes
Tel Arqam/Halaf	3,2	dump hill	no - but slides	agriculture	grass - agriculture	yes
Tal Abyad	2	previous agriculture	no	infiltrates	grass - agriculture	yes
Tell Tamis /Tal Tamer	4,4	side of quarry	no	infiltrates	grass - agriculture	yes
Darbasiyah	4,4	not clear - NA	not apparent	infiltrates -> stream	grass - agriculture - urban	yes
Hasakah north*	15,4	old quarry	not apparent	infiltrates -> stream	grass - agriculture - urban	yes
Tall Maruf	1,6	previous agriculture	no	infiltrates	grass - agriculture	yes
Jawadiyah	18,4	quarry fill	yes	infiltrates -> stream/dam outlet	grass - agriculture - urban	yes
Jawadiyah south*	1,91	previous agriculture	no	infiltrates -> stream	grass - agriculture	yes
Dasirbayah east / Khanik	6,3	quarry fill / east part	not apparent	infiltrates -> stream	grass - agriculture	yes
Derik south / Tepke	8	apparent quarry	not apparent	infiltrates	grass - agriculture - rocky hill	no
Raqqa N1	13,4	apparent quarry	yes	infiltrates	grass - agriculture - suburban	yes
Raqqa N2	43	Brick factory / quarry?	not apparent	infiltrates	urban - agriculture	yes - wall to wall
Ain Issa south	4,4	quarry (sand?)	in stream - flow	in stream	grass - agriculture	yes
Sheran	4,3	old quarry	possible	infiltrates	grass - agriculture - rock outcrops	yes
Raqqa South	51,1	enclosed dump (old?)	not apparent	infiltrates	grass - urban - suburban - agricult.	yes
Hawi IDP - Tchembe	35	open area road side	no	infiltrates	grass	yes - 4km
Tell Brak	10	old quarry	not apparent	infiltrates	urban - agriculture	yes

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