Axed & Burned

How Conflict-caused Deforestation Impacts Environmental, Socio-economic and Climate Resilience in Syria

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Cover image: A Syrian man cuts a tree in the northern town of Darkush on January 25, 2013. Beset by a freezing winter and stifling fuel and electricity shortages, Syrian civilians desperate to stay warm in a northern forest have no choice but to cut down trees for firewood. Once a tourist destination for Syrians and other Arabs across the Middle East, the formerly pristine national park to the north and west of the city of Idlib is being systematically stripped bare. AFP /AAMIR QURESHI

Content

Why Addressing the Environmental Impact of Syria's War Matters

The war in Syria has now entered its 12th year, leaving a long-lasting humanitarian impact on the country as hundreds of thousands of people have been killed and millions displaced. Beyond these direct impacts on the Syrian people, the severe destruction of cities, towns, agriculture and infrastructure and the collapse of governance pose serious public-health and socio-economic challenges for communities across the country. In particular, the destruction of natural resources and damage to ecosystems has potentially severe consequences for the lives, livelihoods and future of Syrian citizens, as well as for the country's climate resilience.

The environmental consequences are likely to be long lasting, ranging from conflict-polluted rivers, wells and groundwater, eroded and degraded soils, and human exposure to industrial hazards in bombed areas to damaged water infrastructure and agricultural systems. It is profoundly important to include these dimensions of the armed conflict in Syria in the post-conflict assessment to understand what is needed for clean-up and remediation efforts in conflict-affected areas. Ecological restoration and rehabilitation of Syria's natural environment is needed to support the sustainable rebuilding of society and future climate resilience. Droughts, increased temperatures and water scarcity, caused in part by climate change, are already worsening agricultural conditions and access to clean water. There are concerns that this could increase the risk of wildfires that spread rapidly through forests and croplands, a phenomenon that has been seen frequently in recent years, impacting harvests[1], villagers and orchards.[2]

One particular environmental dimension of the conflicts is the alarming loss of forest cover caused by the war. From the dense coastal forests on the mountain ranges of Latakia, Tartous and Hama to the many nature reserves and orchards with millions of olive trees and fruit trees, Syria has a rich biodiversity of trees and thriving ecosystems. While the forests of the coastal mountains play a greater role in protecting water quality and sequestering carbon, forests and trees throughout Syria are an essential element in combating the growing number of heatwaves in a climate that is becoming warmer and drier. The conflict-linked collapse of forest management is already leading to more widespread forest fires that are destroying towns, villages and livelihoods. Driven by the need for firewood, large parks and orchards are disappearing in and around urban areas, making cities even more prone to the urban heat island effect. Meanwhile, the decline of orchard management—key to Syria's agricultural sector—risks having huge economic impacts, affecting both national food security and the livelihoods of tens of thousands of Syrian civilians.

This report aims to understand the depth and breadth of conflict-linked deforestation throughout Syria. Using spatial-temporal analysis of various sources of satellite imagery and public data sets, this is an initial broad remote-sensing study and environmental open-source investigation of how the war has led to widespread logging and the destruction of forested land. The findings will contribute to the growing literature on the environmental dimensions of war, while also providing a more granular analysis of region-specific deforestation and how this impacts the lives and livelihoods of Syrian communities. Lastly, it will demonstrate that these data are imperative for environmental restoration and rehabilitation efforts, as current and future generations depend upon a healthy environment to rebuild their society, in particular as the compounding impacts of climate change are posing new challenges for a country battered by conflict.

The Environmental Toll of Syria's War

The role of the environment in relation to armed conflicts has long received little attention in conflict analysis. Only recently has growing attention been paid to climate-change-linked environmental degradation and the conflict sensitivity of diminishing natural resources. This shift has been pushed by international organisations[3], the humanitarian community[4] and civil society groups.[5] This long-term policy lacuna was driven by an absence of proper research, the complexity of the triple nexus of conflict-environment-climate and, understandably, prioritisation of humanitarian and economic factors. As a result, there was a lack of proper investment in the restoration of ecosystems, rebuilding environmental infrastructure and the clean-up of conflict pollution, while prevention or mitigation has not been properly incorporated into military planning. Recent developments such as the updated military guidelines of the International Red Cross and Red Crescent Societies (ICRC) on protection of the environment in armed conflict[6] and legal discussions in the UN on this theme have been helpful in norm building and raising awareness.[7]

Throughout the last seven years, PAX has worked on building a systematic approach of identifying and monitoring the environmental consequences of the conflict in Syria through open-source investigation, remote-sensing analysis, field work and collaboration with our Syrian partners and experts. This work has demonstrated widespread pollution from the professional and makeshift oil industry, the collapse of environmental governance, and climate-induced water shortages affecting agriculture and food security.[8] One major environmental aspect that so far has lacked proper analysis and inclusion in policy responses is the rapid decline of Syria's tree cover. Direct targeting of armed forces and militants seeking cover in these forest areas and the use of trees for firewood and charcoal production (both legal and illegal) have resulted in severe deforestation of specific areas in Idlib, Latakia, Tartous and Hama. In other provinces such as Aleppo and Homs, olive orchards and trees in public parks were cut down, while in Hasakah the little remaining forest was used for heating and cooking, yet later on also for peacebuilding through reforestation efforts. With the use of Earth observation, remote sensing and open-source investigation, we set out to explore the extent to which Syria's forests have been affected by the conflict, the drivers of deforestation, the links with Syria's war economy, and potential consequences and solutions.

Conflict Pollution and Environmental Degradation

Since the outbreak of violent hostilities, an estimated 610,000 people have been killed (including nearly 306,000 civilians),[9] many more wounded and more than 12 million displaced internally and in other countries.[10] The war has left towns and cities in rubble, damaged the country's critical infrastructure and laid waste to natural resources. The grave humanitarian consequences of the conflict have been well documented, and ongoing monitoring work by relevant actors has outlined the impacts of conflict damage on Syria's economic resources. In the years since the outbreak, the war has intensified and left a trail of destruction of natural resources in its wake, ranging from damaged oil infrastructure to the burning of agricultural lands and pollution of local waterways with rubble, solid waste and other hazardous materials. New research methods, such as open-source investigation and access to satellite imagery and analysis, have spearheaded innovative and pioneering research into the environmental damage caused by armed conflicts, as researchers now have tools and methods to monitor ongoing environmental issues during the conflict.

In 2015, PAX initiated a first attempt to document the environmental and related public-health impacts of the conflict through innovative open-source research in our desktop study Amidst the Debris.[11] The findings provided a glimpse of how armed conflict resulted in environmental damage through attacks on industrial facilities, oil refineries and critical infrastructure such as water systems and sewage systems, and the wider consequences resulting from the breakdown of environmental governance. The collapse of professional oil refining resulted in the widespread rise of unsustainable coping strategies such artisanal oil refining, which we analysed in our 2016 report Scorched Earth and Charred Lives. The findings underscored the inherent linkages between these polluting practices and their public-health impacts, in particular on vulnerable groups like children. Similar practices are also rampant in the west of the country, as was demonstrated later in open-source research by Bellingcat.[12] Another oil-related dimension of the conflict is the rapid decline in enforcement of regulations and maintenance in the oil industry, which reached a low point in the summer of 2021 with a major oil catastrophe at Baniyas, when a massive oil leak affected regional coastal and marine ecosystems. The offshore fuel infrastructure witnessed earlier sabotage actions, while satellite images showed an increased number of spills from oil tankers mooring near the coast and wastewater discharges coming from Baniyas thermal power plant, as analysed using remote sensing in PAX's 2021 Environment and Conflict Alert.[13] In the meanwhile, communities in Kurdish-controlled north-eastern Syria still struggle with the ongoing dumping of oil waste water and air pollution coming from various oil facilities and the few remaining clusters of makeshift refineries; this is documented in our 2021 report based on field visits, interviews, open-source analysis and remote sensing.[14] With the increase in the felt impacts of climate change, our recent analysis documented the severe problems of water shortages for rural communities in north-eastern Syria, compounded by deliberate blockage of water through dam building in the Khabur river[15] and the blocking of water access from pumping stations in Hasakah, affecting the lives of nearly a million people.

This research also builds on the in-depth investigations and reporting conducted by the many international organisations that have a particular focus on the linkages between environmental degradation and humanitarian response, in particular the work done by the World Bank, UN Development Program (UNDP), the Food and Agriculture Organisation (FAO), REACH, the NGO Forum, Un Ponte Per and many others. Equally important is the growing focus on climate and conflict-linked environmental issues, as reflected in the work of Syrian NGOs such as PEL-Civil Waves, DOZ, Syrians for Truth and Justice, and Syrian experts who fled the country yet continue to contribute their insights and analyses.

Research Methodology

To understand the many forms of tree-cover loss throughout Syria in the period 2011-2022, this research used a variety of research methods and means of data collection to gain insight into forest types, the extent and causes of forest loss, and environmental, societal and economic impacts. Various governmental reports on biodiversity and forest-related policies were analysed, including reports submitted to the Convention on Biological Diversity and the UN Convention to Combat Desertification, and external analyses by international organisations such as the World Food Program (WFP), the ICRC and the UNDP. This analysis helped give a more thorough understanding of the regime's information position and response to some emerging forest-related challenges.

Although scientific, peer-reviewed articles were used wherever possible, knowledge gaps were filled through the review of open-source data. Arabic news sources were included by searching for keywords (in their Arabic translation) such as 'Syria, forests, deforestation, firewood', and 'charcoal production'. Arabic-speaking co-authors of the report contributed to open-source data collection from local news sources throughout Syria and collected information from Syrian social media including Facebook and Twitter posts. Additional information about locations and reports was obtained in collaboration with researchers from Syrian partner organisations, including Syrians for Truth and Justice and PEL-Civil Waves.

Remote Sensing Analysis

Peer-reviewed and investigative-journalism articles were further substantiated via a thorough geographic information systems (GIS) study of tree loss in Syria. The starting point is the Hansen data set on tree-cover loss.[16] We used both the data-set visualisation available through the Global Forest Watch dashboard and the raw data from the European Space Agency's Sentinel 2 imagery (20meter), NASA's Landsat 5, 7 and 8 (30meter) and Planet Scope high-resolution (3meter) resolution imagery.

This study applied remote sensing analysis to detect tree-cover loss in Syria. For the sake of clarity, we use that as an indication of current deforestation. Optical sensors can detect change if the tree cover is gone because tree leaves give a specific reflection from sunlight as they absorb a certain spectrum of colours and reflect others. The loss of tree cover can happen naturally, e.g. through seasonal change, but can also be caused by fires or the cutting down of trees. This research reviews forest-cover loss during the period 2012-2021. It does not track forest regeneration over this period of time, nor can current forest loss necessarily be taken as an indicator of permanent deforestation, which can only be diagnosed through long-term monitoring. Rather, this study should be viewed as a snapshot of forest loss due to a decade of conflict in Syria, and its immediate and potential long-term impacts on economic, social and ecological resilience.

A separate tool was developed for a more detailed analysis on the forest changes. The forest classification itself took place in two stages: first, the data acquisition and then the data processing and analysis. The imagery source was Sentinel 2, accessed through Google Earth Engine. A selection was made of dates and the clearest views as a first step. Once the images were obtained for each study period, these images were classified to give the land cover classes. This second part of the process was performed using the 'R' application (statistical computing software). A land cover classification script was developed by Dr Yifang Shi for PAX. The script runs two classification

models, the Random Forest model and the Support Vector Machine (SVM) model. After performing the classification, a statistical analysis of the results was performed to automatically select the best output. Furthermore, additional statistics related to the accuracy were visualised to aid the process.

After each year had been classified (2014-2021), the resulting forest class was compared year on year, and the areas where forest loss was detected were quantified per period. A final aggregation was performed to obtain the total tree-cover loss in the study area per study period and in total. The first period of analysis was from 2013 to 2016 and the second period was from 2017 to 2021. An initial baseline was established using the forest cover in 2010 for the study area of the western hills/coast.

A similar procedure was applied for a smaller study area in the north (Aleppo), where only the years 2015 and 2021 were compared to quantify the forest loss. To understand and have more detailed information on the canopy loss, this last area was subdivided into two subareas around Mount Kurd and Mount Barsaya. The latter was subsequently divided into seven locations to give even more detail on the clearing and cover loss. In this area, a comparison was made before and after control switched to different armed groups. Finally, to include cases of forests in and around populated places, two more forest patches near the cities of Afrin and Kafr Halab were studied to quantify their cover loss.

Syrian men cutting pieces of wood, which will serve later as a source of warmth during the upcoming harsh winter season. November, 3, 2020, Syria, Idlib City

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As the Hansen data set and our own analysis focused on broad swathes of forest, additional Earth-observation tools were utilised that capture small-scale tree cover loss, mainly by using Google Earth Pro historical Very High-Resolution (VHR) imagery from MAXAR and Airbus for specific areas to identify deforestation over time. This has proven to be a useful tool for spotting smaller areas of tree-cover loss, such as in urban parks and orchards. A case study was done to estimate the changes in the green belt around the city of Palmyra. To detect how the productive land cover has been changing, a combination of Normalized Difference Vegetation Index (NDVI) and image classification was applied. As NDVI is most sensitive to the 'green' (cover with active photosynthesis), it noticeably fails to capture drier and woody cover, mostly related to orchards visible in higher resolution imagery. Image classification improved the green belt's mapping capturing these units. Additional remote sensing research with Landsat 5 data was used to identify the start of a reforestation project on the shores of Lake Assad at Jabel, close to the city of Raqqa.

Besides the land cover studies, the NASA's Fire Information for Resource Management Systems (FIRMS) Visible Infrared Imaging Radiometer Suite (VIIRS) fire data were quantified from 2012 to 2021 for the study area to determine the changes in yearly burning activity. The whole study area of west and north-west Syria was divided into several parts to make more sense of the fire point quantification and provide input for the discussion of the results. The main division is between the northern part and the western part. The second division is given by the administrative units or governorates and the third division is given by the flat and hilly terrain where general productive and extractive activities can be differentiated—as well as their relations with fires and burning. Conflict-related fires could occur more randomly.

Carbon sink loss estimation data were obtained using NASA's 'Global Aboveground and Belowground Biomass Carbon Density Maps',[17] a product that gives a general estimation at 300m spatial resolution of the carbon stock present in 2010. These data were combined with the results for the areas with tree-cover loss identified in this study to give an initial estimation of the above-ground biomass lost up to 2021 in the western Mountain range.

The illegal logging of Cilician Fir (Abies cilicica) in the Cedar and Fir reserve of Slunfeh, Latakia 2018.

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The State of Syria's Forests

Located east of the Mediterranean Sea in the Mashreq region of the Middle East, Syria has a gradient of climates. Along Syria's western coast, a Mediterranean climate supports forested coastal mountains bordered by fertile land used for farming and various forms of agriculture. East of the Coastal Mountain Range, Syria opens up into a mix of semi-arid rangeland and arid desert areas that cover nearly two-thirds of the country, intersected by the Euphrates River providing a fertile corridor for Syria's agricultural industry. This variety in ecosystem types is supported by a vast annual rainfall gradient ranging from 1,000mm along the western coast to as little as 100mm in the south.[18]

Dominant Species in Syria's Coastal Forests

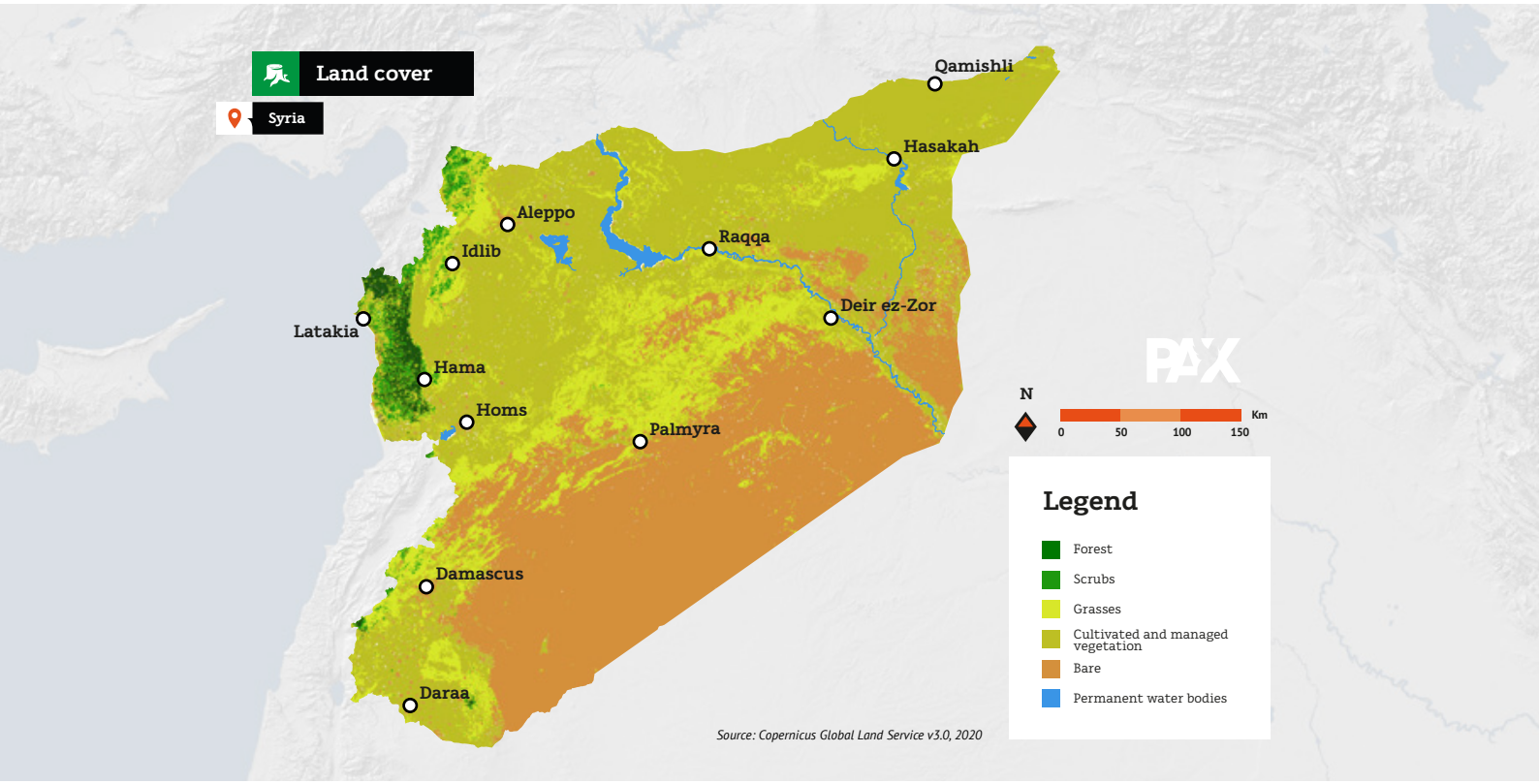
Over a century ago, forests covered between 15 per cent[19] and 32 per cent[20] [21] of Syria's land. Yet rapid industrialisation and population growth took a heavy toll. Today, approximately 2.6 per cent of Syria's land area is forested[22]; 76 per cent of the forested land is in the coastal region due to its cooler temperatures and greater precipitation.[23] [24] Syria's coastal mountains support coniferous forests, where dominant species include the regionally endangered *Cedrus libani* (Cedar of Lebanon) at high elevations of 1,100-1,300 metres, and the endangered *Abies cilicica* (Cilician fir) at 1,300-1,500 metres. At warmer, lower elevations, *Pinus brutia* (Calabrian pine) can be found, as well as Cupressus sempervirens (Mediterranean cypress), and *Pinus halepensis* (Aleppo pine). Many of these forest types are in various degrees of degradation. Broadleaf forests include *Quercus calliprinos* (Palestine oak), *Q. cerris* (Turkey oak), *Q. infectoria* (Aleppo oak), and *Castanea sativa* (sweet chestnut). Lastly, common riparian (or riverside) species are *Platanus orientalis* (Oriental plane), *Alnus orientalis* (Oriental alder), *Salix alba* (white willow), *Tamarix spp.* (different species of tamarisk or salt cedar) and *Populus euphratic*a (Euphrates poplar).[25]

Locations and Dominant Species of Syria's Forest Reserves and Protected Areas

According to Syria's fifth national report for the UN Convention on Biological Diversity[26], there are 31 protected areas across Syria, of which 16 are composed of or include forest ecosystems. These reserves protect a variety of tree species and genera with high biodiversity and habitat value, including genera such as oak, cedar, fir, pistachio and pine, and locally rare or threatened species such as *Pistacia atlantica* (Atlas pistachio), *Crataegus aronia* (spiny hawthorn), *Ficus carica* (native fig) and *Malus trilobata* (the Lebanese wild apple). The forest reserve of Abu Qubais alone (on the eastern side of the coastal mountains in the governorate of Hama), is known to support at least 503

different plant species, 16 mammal species, 89 bird species, and 20 different lizards and amphibian species. The protection and buffering of these nature reserves from harvest or degradation, as well their connectivity to other healthy ecosystems, are critical for the preservation of rare and endangered flora and fauna in the face of climate change and other threats.

Although Latakia has one of the largest areas covered in forest in Syria, forest reserves in Latakia make up a total of only 15,610 hectares, compared to other governorates where a greater percentage of forests are protected, such as Hama (45,365 hectare) and Homs (79,000 hectares).[27]



Forest Ecosystem Services: The Value of Syria's Forests

Forest ecosystems play a critical role in the provision of goods and services for the surrounding communities and society as a whole. Their services range from clear socio-economic benefits from orchards, timber, water purification and soil stabilisation to carbon storage, climate regulation and the sustenance of rich biodiversity. It is vital to include all these elements in any conflict assessment and reconstruction planning for Syria, and they deserve closer scrutiny to understand their relevance.

Wood Products

Wood product exports from Syria's natural forests, for which Calabrian pine is particularly important,[28] were valued at USD 18.4 million in 2010; this dropped to USD 548,000 by 2019.[29] The export of wood constitutes a relatively small proportion of Syria's total exports, at 0.1 per cent and 0.05 per cent of total pre-war and post-war exports, respectively. Non-wood forest products in Syria include oleoresins, used in making traditional soaps, resins and pharmaceuticals[30], in addition to mushrooms, herbs and other products of the forest, which have been valued at USD 4 per hectare in Syria's forests by Croitoru and Liagre.[31]

Watershed Protection

However, a valuation that only considers timber revenues tends to vastly underestimate the value of Mediterranean forests. In the case of Syria, wood products are estimated to contribute only around 8 per cent of the forest's total value. Rather, the forest's role in watershed protection is by far its most economically valuable role in Syria, at an estimated USD 130 per hectare.[32] This equates to an overall estimated value of more than USD 16.6 million annually in watershed services for Syria's natural coastal forests prior to the conflict.[33] Watershed protection services provided by the forest include moderating flooding, stabilising soils, mitigating erosion, and filtering natural and anthropogenic pollutants.[34] Despite their high water requirement, trees' capacity to alter soil characteristics has been found to increase soil moisture around trees even in dry climates.[35] This increased soil moisture contributes to year-round flows in waterways, as groundwater is transported through underground flows into streams. Furthermore, the forest's capacity to clean and filter water significantly decreases the costs of purifying water to a standard suitable for drinking. Deforestation, and the increase in soil erosion, sedimentation and water pollution that often accompanies it, can lead to a need for more extensive and complex water treatment technologies, which can be double the cost of conventional filtration.[36]

Biodiversity

Syria's various forest types and its climatic gradients support vast biodiversity, both within and outside of protected reserves. Similar to diversification in stock portfolios, a diverse array of plant and animal species, stand ages and structures, microclimates and refugia can play an important role in increasing ecosystem resilience to climate change by increasing the likelihood of ecosystem resistance or resilience to disturbances.[37] Many plant and animal species have also developed special relationships of partial or full interdependence, such as important pollinator species that require a specific plant on which to lay their eggs, or fruiting trees that require certain bird species to eat their fruit and disperse the seeds. Forests also provide in-stream (aquatic) habitats, such as when logs or branches drop into streams to create cold water pools for fish spawning, or through the production of essential nutrients for a variety of aquatic and terrestrial forms of wildlife.

Climate Change Mitigation

Forests can play a valuable role in mitigating the local impacts of climate change by sequestering carbon in trees, the forest floor and soils, cooling local air temperatures[38] and contributing to inland rainfall through both cloud-seeding particles and evapotranspiration of moisture to the atmosphere.[39] The preservation of forest biodiversity and connectivity (as opposed to the isolation of forests as smaller patches that are further apart) is critical in maintaining resilience to climate change and other stressors.[40]

Forest loss can therefore decrease domestic production, increase water pollution and treatment costs, cause significant soil erosion, soil dehydration and losses in soil productivity, decrease biodiversity, increase vulnerability to ecosystem collapse, and increase the likelihood of extreme flooding and streams drying out.

Governance of Syria's Natural Forests

Proper management of forested areas is a necessary instrument for maintaining healthy ecosystems, monitoring changes to the environment and preventing illegal logging. As often happens with conflicts, the collapse of governance is one of the main causes of environmental degradation, and one that can have long-lasting implications for both communities and biodiversity.[41] Understanding the capacity and regulatory framework applied by local authorities is also key in addressing any challenges born from conflict and can be a tool for environmental peacebuilding.

Governance in Regime-held Areas

Understanding what contributes to forest loss requires looking into Syria's existing legal and policy framework for forest management and protection, and how it is enforced by both the state and, in conflict and post-conflict areas, by non-state actors. According to the Syrian Forestry Law of 1953, forest cover is the property of the state. The law commits 99 per cent of Syria's forests (as of 2005) to government ownership and grants these forests (at least officially) a large degree of protection.[42] Governance of forests has been the responsibility of the Ministry of Agriculture and Agrarian Reform (MoAAR) since 2001. The most recent Forest Law, No. 6 of 2018,[43] confirms the continued role of the MoAAR, and its Directorate of Forestry. In 2017, a decree was issued by the government that sets additional penalties for people found uprooting and selling timber from fruit trees without a licence.[44]

Although not directly responsible for forest management, the Ministry of State for Environment Affairs is responsible for providing the legislative framework and institutional support for environmental work in Syria,[45] and thus may be another important stakeholder in forest management. Until 2016, the Syrian government had assigned the role of the Minister of Environment Affairs when forming official cabinets; the last person to hold this role was Minister Nazira Farah Sarkis. However, in 2016 this position was deemed to have been ineffective and the role abolished.[46] Websites associated with the ministry have been shut down and only archived copies of those websites exist.[47]

Syrian men cut down trees for firewood used for heating and cooking on December 3, 2016 in the rebel-held town of Hazrama, on the outskirts of Damascus.

© Sameer Al-Doumy / AFP

Although Syria does not have an official cabinet-level position covering the environment, the functions have been taken over by the Ministry of Local Administration and Environment, run by Hussein Makhlouf, cousin of the infamous Syrian businessman Rami Makhlouf.[48] Belal Al-Hayek, listed as the Ministry's director[49], currently holds the title in the Convention on Biological Diversity national focal points page for Syria, but also holds various other positions on the page and is listed as the secondary contact for many of the other positions.[50]

Syria is a member of the Global Environment Facility (GEF); however, it has not received the nearly USD 18 million in funding meant for projects planned since 2001, as detailed in the report on GEF funding in 2018, and has been excluded from regional projects without notice.[51] The funding that Syria did receive has been spent on climate-change and biodiversity projects.

Governance in Opposition-held North-West Syria

Opposition-held areas have at times seen attempts at local forest governance and protection, but in general local military factions have been fully involved in the deforestation. For example, the 'Free Police' (الشرطة الحرة) in opposition-held Idlib note that they forbid the burning or logging of forests and have issued many statements. The Ministry of Agriculture in Idlib's opposition 'Salvation' government has issued statements on the cultural and religious importance of trees, while calling upon local military factions to undertake meaningful forest protection.[52] Meanwhile, according to local loggers, the logging continues with the knowledge and implicit consent of military factions in Idlib, and in some cases with the direct involvement of military officials in the sale of firewood in return for a percentage of the profits. Hay'at Tahrir al-Sham, which controls much of the Idlib governorate in northern Syria, taxes the rampant fuel-wood trade in Idlib and northern Latakia, part of its larger monopolisation of fuel and energy sectors in the area.[53] Nevertheless, all military factions deny any role or culpability in ongoing forest loss.[54]

In 2018, a recently-established local council in Afrin, at that time retaken from the Kurdish People Protection Units (YPG) by the Turkish-backed Free Syrian Army, passed a law in collaboration with local civil and military police that protects local forests from logging.[55] However, an article from the following year revealed that this law had not yet been implemented, and logging for fuel and trade continued unabated as a source of livelihood and funding for both local residents and military factions.[56] This was despite orders even from a few military leaders that military members were to cease all participation in logging activities.

In Dara'a, near the Jordanian-Syrian border, forests were managed temporarily by the Free Dara'a Governorate Council, which encouraged tree nursery production and unsuccessfully attempted reforestation of forest, fruit and olive orchards before the area was retaken by the Syrian regime.[57]

Governance in the Autonomous Administration of North and East Syria

Under the rule of the de facto authorities of the Kurdish-led Autonomous Administration of North and East Syria (AANES), efforts have started to deal with forest management, as some areas were heavily affected by logging for firewood. One notable exception to deforestation is Jebel Abdelaziz, west of the city of Hasakah, where a large afforestation project planted tens of thousands of trees on hillsides towards Raqqa. These remained largely untouched during the conflict, as local citizens acknowledged and protected the forest's value, with only minor incidents of illegal logging that did not affect the area as a whole.[58] In the other areas, logging was rampant, as many areas switched

control. Some of the larger reforestation projects around Raqqa, started around 1991, faced massive logging during the occupation under ISIS. Under the current AANES rule, attempts are being made to restart tree nurseries and reforest areas through local committees.[59] This is largely done through both commercial and state-owned nurseries, some that are part of AANES and one that is still run by the Syrian regime.[60] There are also many smaller initiatives undertaken by local communities, farmers and NGOs.[61] At some locations, such as the Tabqa Nature Reserve, an island in Lake Assad, the Syrian Democratic Forces (SDF) announced support for the local city council in its reforestation and protection efforts. The island's pistachio, pine cypress and olive trees were largely cut down under ISIS rule, as trees were lost to lack of irrigation and subsequent logging for firewood.[62] Forest management responsibilities have been taken up by various entities, with orchards and fruit trees falling under the Economy and Agriculture Commission, and wider nature reserves with trees becoming the responsibility of the Health and Environment Commission. However, a clear regulatory framework is not publicly available.[63]

Syrians sit at a shop selling firewood in the rebel-held town of Kfar Batna, in the eastern Ghouta region on the outskirts of the capital Damascus, on January 27, 2017.

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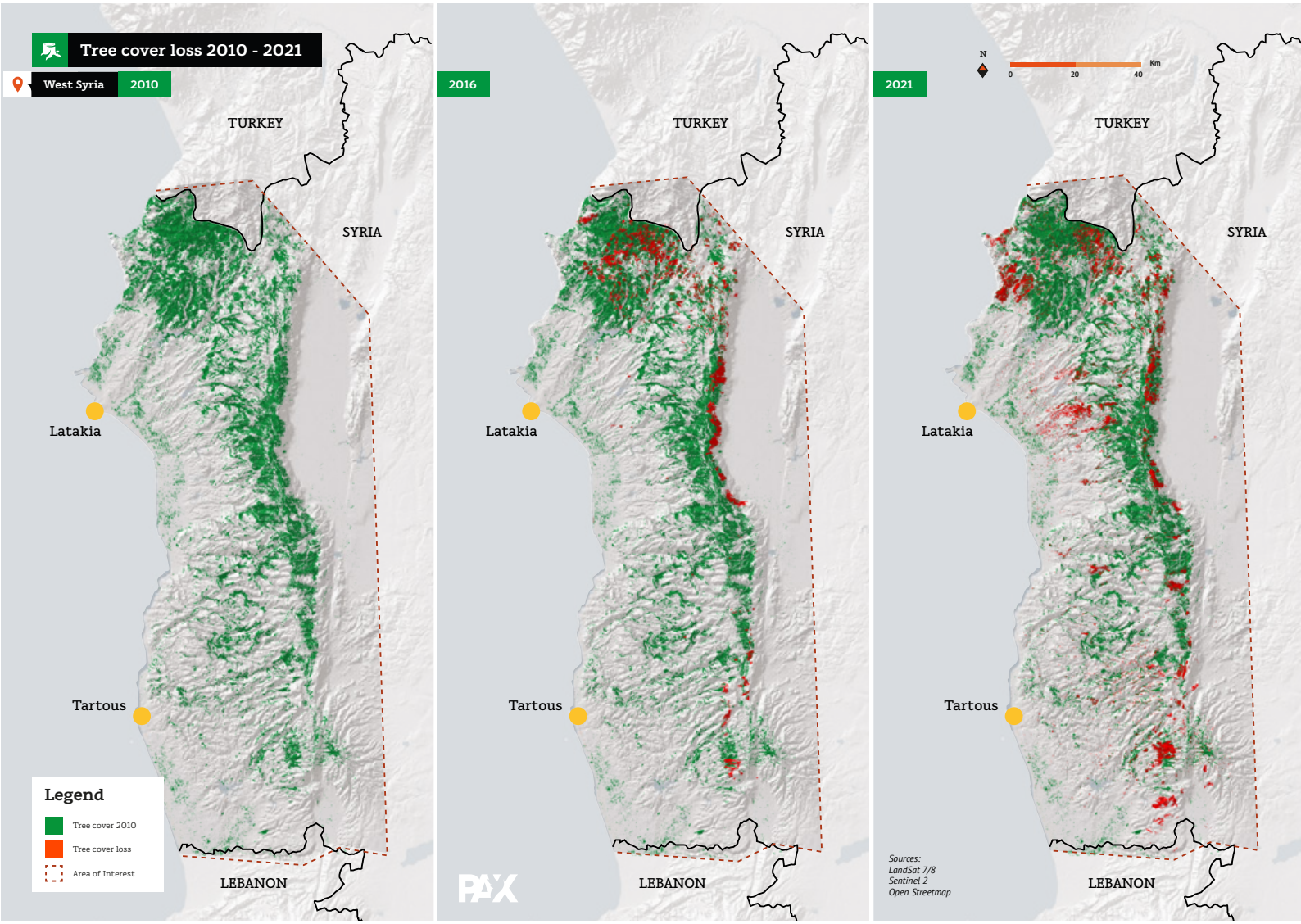
Impacts of War on Syria's Natural Forests and Reserves

The lush green forests of the western provinces contain most of Syria's natural tree cover, and have suffered the most degradation caused by the war. The hills of Idlib and Aleppo, home to massive olive and fruit orchards, were also affected by the movement of millions of internally displaced persons (IDPs) and fighting between regime forces and rebel groups. Urban forests in and around some Syrian cities faced severe degradation due to the sieges by the regime, when people struggled to keep warm during the harsh winters. Throughout the war, local news reports emerged indicating how rapidly increasing energy prices, bombardments, wildfires and charcoal production all contributed to the thinning or even complete deforestation of forested areas. By combining local news reports, governmental documentation, scientific research and remote-sensing analysis conducted by PAX, a clear picture emerges of both the causes and consequences of conflict-linked deforestation in Syria. To understand the scale and impacts, the following analysis will make a distinction between three different types of forest cover, namely natural forest and reserves, commercial orchards, and tree loss in and around urban areas. This will be followed by an analysis looking at the causes of forest loss.

Tree-cover Loss in Natural Forests and Reserves

Numerous assessments report significant forest loss in Syria's natural forests and reserves. Open-source data sets such as Global Forest Watch are a useful starting point to identify key areas of forest loss, providing a user-friendly platform and country- or governorate-specific information based on general forest-loss data from Hansen.[64] For example, these data show that in Latakia alone, there was a 31 per cent loss in tree cover in the period 2001-2021. In Hama the loss was even 34 per cent. An initial remote-sensing analysis using Sentinel-2 data was released by PAX in 2020, demonstrating the widespread forest loss in the western part of Syria, with a 20.4 per cent loss of tree cover in the period 2012-2019.[65] Another assessment by Mohamed using Landsat data at a 30m resolution reported the loss of more than 24 per cent of forest cover (29,155 hectares) in the western governorates of Latakia, Tartous, Idlib, Hama and Homs, which contain 76 per cent of Syria's natural forests and 11 per cent of its forest reserves.[66] This study, which included the major forest losses as a result of Syria's extreme wildfire year in 2020, attributed less than 3 per

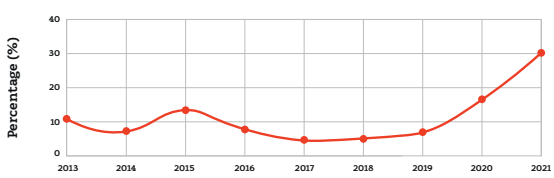
cent of forest loss to urbanisation, 28 per cent to agricultural land conversion and 69 per cent to conversion to bare areas, likely a result of wildfires and rampant clearing linked with the need for fuel wood. For a detailed analysis of tree-cover loss in Syria, PAX developed a model using Sentinel-2 20-metre resolution imagery and machine learning. This model has been applied to the largest areas where tree-cover loss was found, and some smaller areas with notable changes in forested areas and parks. For the latter, a smaller number of case studies will be presented to showcase these impacts.



Western Syria

The largest deforestation in Syria was seen in the coastal and adjacent governorates. This region has faced fierce fighting between regime forces and rebel groups since 2011. In particular, the mountainous forest areas provided cover for rebel groups, and were pounded by artillery and airstrikes in the first five years of the war. Other areas in Latakia[67] and Tartus also witnessed periods of severe forest fires from 2018 onwards, often linked with an absence of proper forest management and affecting hundreds of thousands of people.[68] Furthermore, the forest on the east side of the mountain range adjoining the Al-Ghab plain was logged intensively for firewood.

% Deforestation between 2013 and 2011 in the Western AOI



Over the period 2011-2021, the governorates of Latakia, Hama, Homs and Idlib witnessed tree-cover loss of over 36 per cent, based on remote-sensing analysis by PAX. From an initial cover of 1,230km^2 in 2010, 12 per cent was lost by 2016 and another 24 per cent was lost by the end of 2021. This represents a total loss of 45,320 hectares of tree cover in this time frame.

A significant part of the tree cover is directly linked with deforestation as trees were cut down, resulting in the satellites detecting tree-cover loss. The affected areas are also host to numerous nature reserves, including the Ferunluq, Fir and Cedar, and Abu Qubais Reserves. Some areas in Latakia faced serious wildfires in 2020. The speed of forest recovery here will depend on natural regeneration processes. However, there are indications that on some occasions, burned-down forest has been cut down and the land claimed for agriculture or housing. Hence persistent monitoring is needed to get an appropriate estimate of forest loss. From the data, a rather stable pattern is seen of around 8 per cent deforestation per year on average, but the loss doubled in 2020 and more than tripled in 2021.

Northern Aleppo

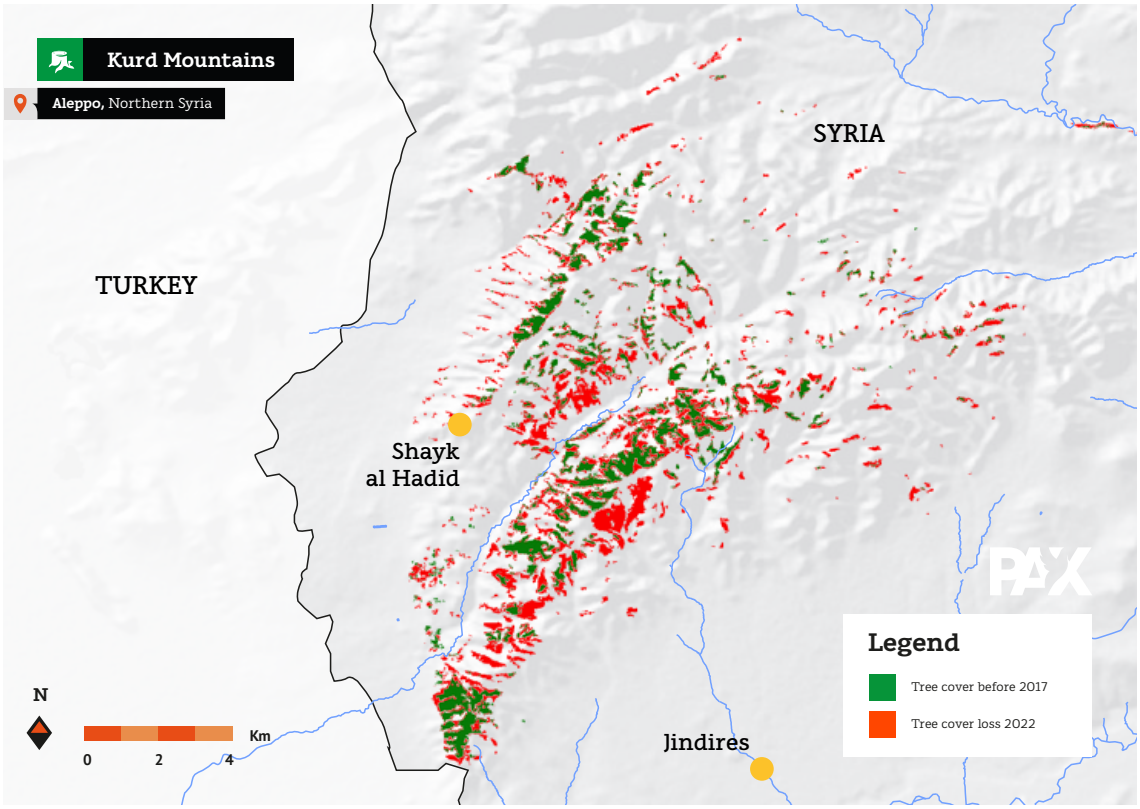
Northern Aleppo is most known for its vast hilly orchards, growing fruits such as pistachios and the famous Aleppo olives, used for producing soap. Amidst these orchards, there are large patches of natural forest with pine and oak trees growing on the Aleppo Plateau's mountains. However, the war has taken its toll in this part of the country, with some of the forests completely disappearing. Soon after the uprising against the regime, parts of northern Aleppo were controlled by the Free Syrian Army (FSA), a coalition of armed opposition groups that started with defected regime soldiers, while the YPG were able to control large parts of Afrin, driving out both regime forces and the FSA from some areas. Backed by the Turkish army, the FSA took over large parts of Afrin from the YPG in 2018. Since the area has been under FSA control, there has been an uptick of social media reporting, including verified photos and videos from this area, indicating that various militias that are part of the Turkish-backed FSA are involved in the logging, sales and export of lumber from this region.

Our remote-sensing analysis for the mountain study area found that, of forest cover of 4,750 hectares in December 2015, 58 per cent had been affected due to cutting and land clearing by October 2021. The findings clearly show that deforestation started in 2020, after the area was taken over by the FSA during the Turkish-led Operation Olive Branch in 2018. The research identified two key areas of interest with significant deforestation over the last seven years, namely Jabal al Kurd, a mountain range on the border with Turkey, and Barsaya, a mountain range north-west of Afrin city.

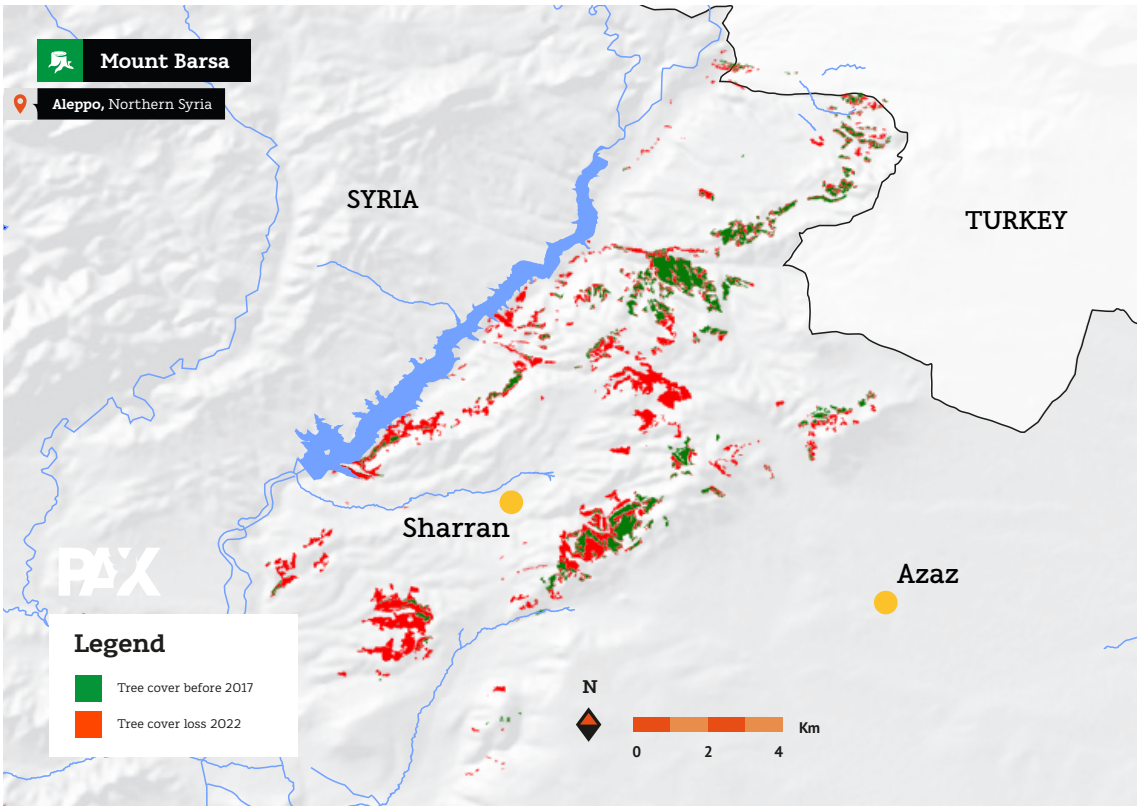
Kurd Mountains

The Kurd Mountains are one of the most heavily affected areas. These mountains are mostly known for their olive orchards, while the natural forest mainly consists of pine and cypress trees. A small degree of forest loss was seen throughout the study period, but up to 2020 the number of trees being felled was negligible. A huge spike in deforestation can be seen starting in the two years after the area was taken over by the Turkish-backed FSA. Local media reports mostly linked this to the need for fuel for fire and heating. The massive tree cutting led to completely barren lands and forest thinning.[69] Abundant social media footage reported claims of civilians and/or armed groups in this region cutting down trees.[70]

Remote sensing indicates a 56 per cent loss in tree cover over the course of almost six years, largely through deforestation in this area, from an initial forest cover of 4,750 hectares in December 2015



Large parts of the forest on the southern slopes of the mountains were chopped down completely or suffered significant forest loss. Parts of this area were also affected by wildfires in the period 2018-2022, which further contributed to tree-cover loss on Mount Kurd and surrounding areas, and potential reuse of the land for agriculture. In some locations, natural forest was cleared to build new settlements for IDPs.[71]



Mount Barsa

Located between Lake Maydanki and the city of Azaz, the mountain range of Barsaya, part of the area referred to as Sharran sub-district, or ناحية شران, has various large stretches of natural forest, starting on the shores of Lake Maydanki, and wider, larger forest areas around Kafr Janneh all the way to the peak of Mount Barsa itself.

Following the Turkish-led Operation Olive Branch in 2018, mounting evidence from social media footage and reporting indicated widespread felling of natural forest and orchards. Though claims were made of millions of trees being cut down,[72] mostly from orchards, this could not be verified with remote sensing. However, the remote-sensing analysis in this report finds that in this particular area of interest, 1,082 hectares, covering over 59 per cent of the total area of forest, was cut down between 2018 and 2021. In some areas such as the forests south of the town of al-Amrija and west of Qurt Qulaq, the complete forest disappeared, while more than half of the trees were cut down in the forests around the towns of Kafr Janneh and Qatmah. Further public reporting also confirms that the forest on the southern slopes of Lake Maydanki was chopped down completely in August 2022.[73]

Kafr Halab

Throughout Syria there are many smaller forested areas near towns and cities that witnessed severe tree loss during the conflict due to the growing need for firewood. One of many examples that can be found is the forest at Kafr Halab, a small town south-west of Aleppo. A 227-hectare forest patch was observed in 2015, but by 2021 it had lost around 40 per cent of its cover. Local mosques and authorities called upon military factions to refrain from cutting trees, yet rising fuel prices led to further tree cutting, either by armed groups or local citizens.[74]

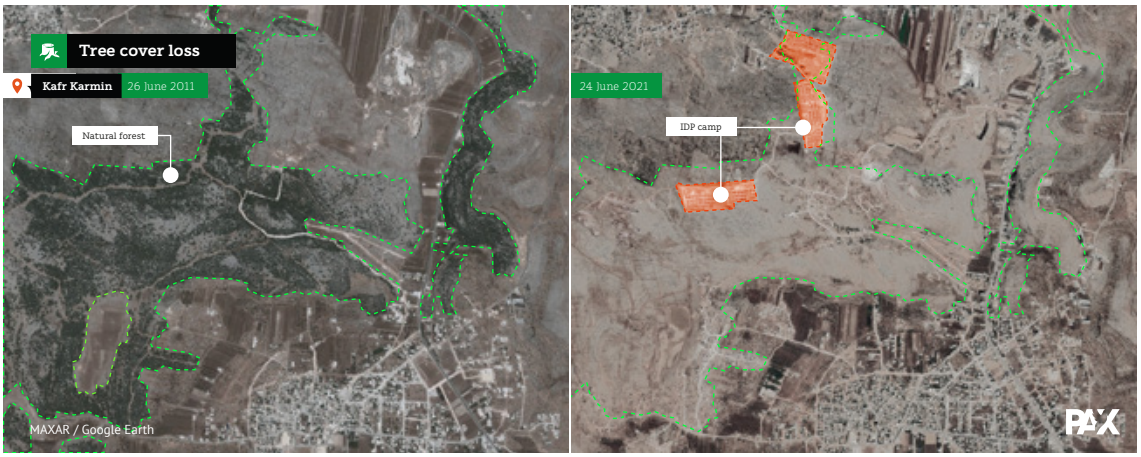
Jabar Reforestation Project

Close to the famous old fortress of Qalaat Jabar on the north-eastern slopes of Lake Assad, a reforestation project started before the mid-1990s. Landsat 5 showed that in May 1988 the area still had the agricultural activity it had had throughout the 1980s, where it 'greened' depending on humidity and land use. From April 1993 it started to show a division due to different vegetation densities. By the next spring in 1994, it already showed more 'greening' and a denser patch. In April 1996 the patch already appeared different from the neighbouring agriculture and grasses in the north. In 1998 and 2002 it was already a clear, consolidated patch. Taking a closer look with Google Earth it is possible to estimate the area of the patches: the rightmost rectangular shape is almost 100 hectares. The other area extending along the hill slopes was around 78 hectares in 2002/2004.

When the area was occupied by the Free Syrian Army and later by ISIS, demand for fuel led to the almost complete disappearance of tree cover in this area, as we previously documented in our 2021 report on north-east Syria.

Idlib's IDP camps

Displaced civilians fleeing the violence in cities and towns across Syria are often stranded at the border with Turkey, in Idlib, Aleppo and Latakia. These governorates witnessed a huge increase in formal and informal settlements: estimates in 2017 by the United Nations Satellite Centre (UNOSAT) using satellite imagery gave 267 locations and over 63,000 shelter structures, covering 1,500 hectares of land.[75] A later study from 2022 by the Assistance Coordination Unit looking at IDP camps in Idlib and Aleppo found 598 camps within 26 clusters, hosting nearly 830,000 IDPs.[76] Often displaced persons find shelter under the trees of orchards, while in other areas orchards and natural forest were cut down to make place for larger official IDP camps or informal settlements. The increase in climate-induced extreme weather events such as heavy winter rains poses additional risks to these locations as deforestation leads to soil degradation, making the area prone to flooding impacts.[77] One clear example of natural forest loss linked to the construction of an IDP camp is the village of Kafr Karmin, with what seems to be a natural forest of maquis oak.



Environmental and Socio-economic Consequences of Deforestation

Soils

The impact of deforestation on Syria's environment, people and economy starts with Syria's soils. Soil is a critical natural resource, acting as a below-ground ecosystem that sequesters carbon, absorbs water, cycles nutrients, and through these processes supports natural vegetation and agriculture. Long, dry periods followed by intense rainfall make Syria's soils naturally erosion-prone,[78] [79] [80] spurring numerous soil erosion hazard studies in coastal Syria.[81] Deforestation, whether through wildfire or timber harvesting, further increases erosion by removing soil-stabilising vegetation cover. Although instances of extreme soil erosion in the wake of wildfire are temporary until vegetation is re-established (e.g. lasting three to ten years), the effects can be severe, with increases in soil erosion of 200-800 per cent observed in coastal Syria after wildfires.[82] [83] Steep and/or south-facing slopes are particularly prone to high soil erosion, depending upon the severity of the fire.[84] In Mediterranean climates, very slow rates of soil formation and recovery after a disturbance further lengthen and exacerbate the impacts of soil loss.[85]

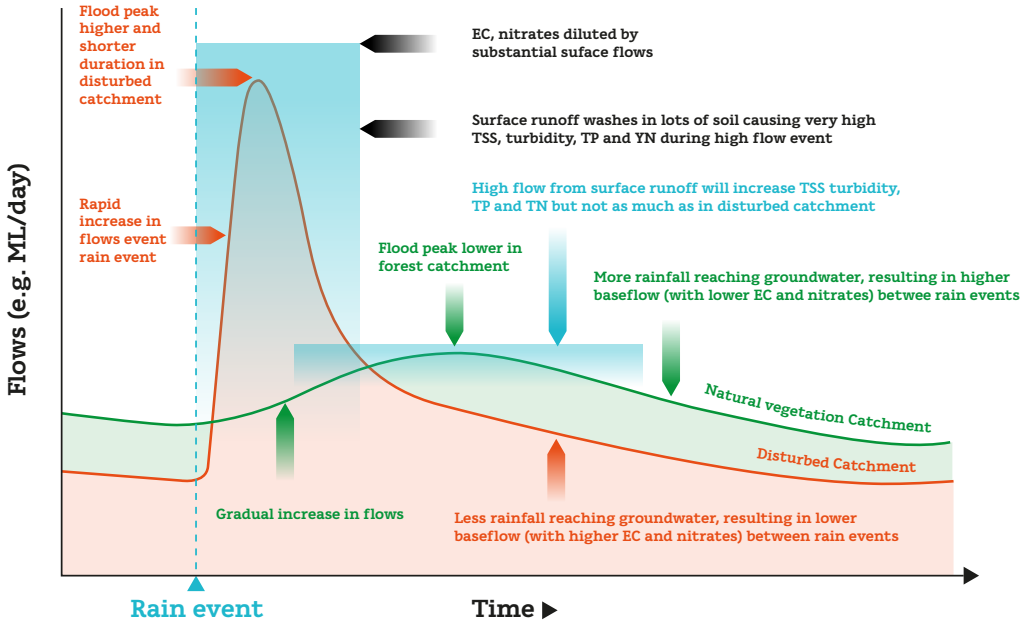
The loss of organic matter inputs due to harvesting or combustion in a fire can be particularly problematic for the re-establishment of the forest, as organic matter is a critical component in soil water-holding capacity and fertility. Thin, dry and sun-exposed soils also present challenges to forest regeneration, as does Syria's increasing propensity for severe and uncharacteristic drought due to climate change.[86]

Water Quality and Local Hydrology

Deforestation and the resulting soil erosion also negatively impact local hydrology and water quality. Heavy rainfall causes sedimentation of streams and other waterways, increasing turbidity and carrying along pollutants that have adsorbed onto soil particles. When present in excess, these factors can harm aquatic life and reduce valuable fish populations.[87] [88] Although direct causes have not been studied, Idlib has witnessed damages and losses to the tune of USD 58 million in its fisheries, with Hama following with USD 15.4 million in fishery losses.[89] Where deforested areas have been converted to agriculture or urbanised, the increase in pollutants can be particularly severe, including nitrates, phosphates, faecal coliforms and other agricultural or urban run-off.[90] In conflict-affected areas, run-off and sedimentation may carry weapon- and ordnance-related contamination into waterways.[91]

Poor water quality was already a problem in Syria prior to the conflict, and has been worsened further by the damage or dysfunction of water and sewage treatment plants and increased pollution by industry since the war.[92] Although the contribution of deforestation to poor water quality has not yet been quantified in Syria, some studies estimate that every 1 per cent increase in deforestation equates to a 0.93 per cent decrease in clean drinking water.[93] The loss of 24 per cent of western Syria's forests[94] might therefore be estimated to reduce the availability of drinking water by about 23 per cent in the Coastal and Orontes River basins. Thus deforestation further contributes to the existing water scarcity crisis in post-conflict Syria[95] and perhaps even to outbreaks of waterborne diseases in IDP camps[96] through the loss of filtering capacity. Economically, greater turbidity considerably increases the costs of water treatment and the sophistication of the treatment technologies needed.[97] In fact, the watershed services lost to deforestation in western Syria alone may have an estimated annual value of more than USD 4 million.[98]

The local hydrological impacts of widespread deforestation can be equally severe. Soil loss, and particularly the loss of organic matter, decreases groundwater recharge and increases the surface flow of rainfall.[99] The result is a greater propensity for severe flooding during the rainy season and increased soil and stream-bed drying during the dry season, further hampering the recovery of forest species.



Depiction of a typical hydrograph (surface water flow chart) for a forested catchment (green line) and a disturbed catchment (brown line), showing the rapidity and severity of surface water flow (or flooding) in deforested areas.[100]

Some settlements may be at increased risk of flood damage due to recent deforestation. Displacement settlements may be particularly vulnerable to the impacts of flooding due to their reliance upon temporary dwellings and structures not able to cope with this type of disturbance. One example is the severe flooding of 2021, which injured three displaced people, took the life of one, and impacted more than 142,000 others in IDP camps along the Syrian-Turkish border.[101]

Conflict-induced Deforestation and Impact on Biodiversity

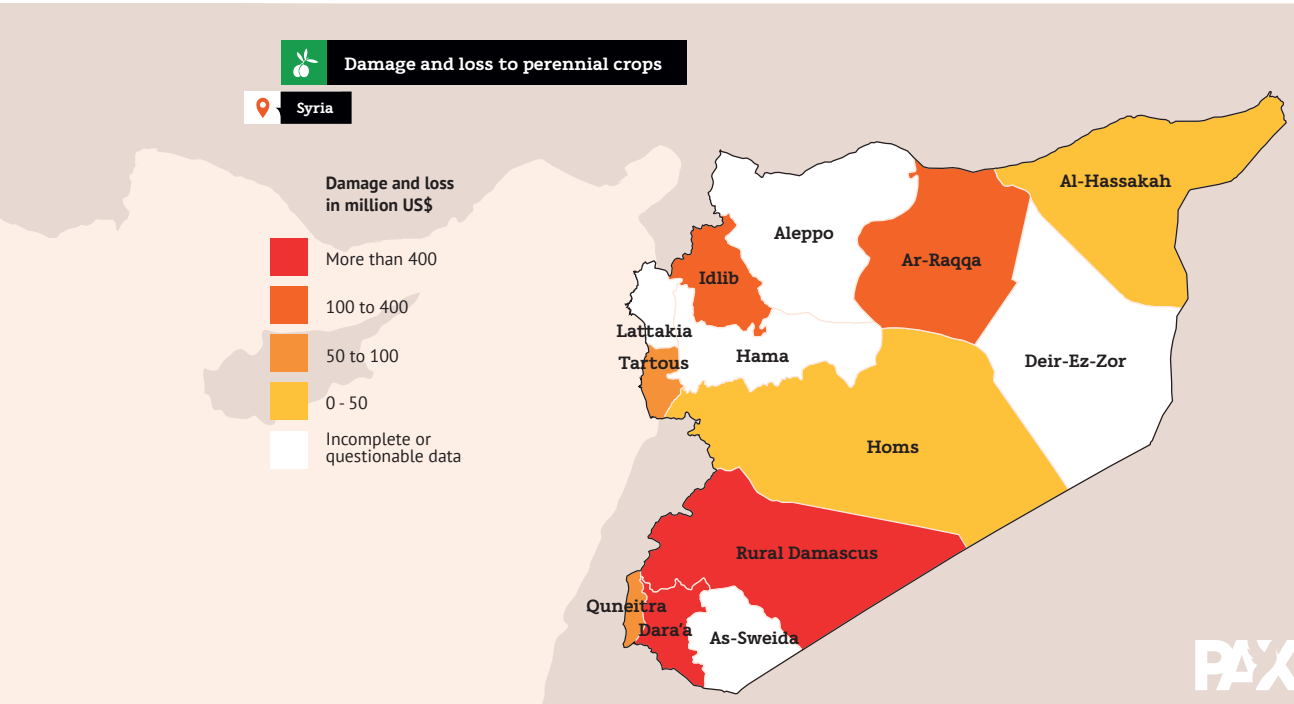
Apart from the direct impacts resulting from tree-cover loss, the large-scale deforestation of Syria's forests will also have wider implications for nature and biodiversity, including wildlife that already faces a worrisome decline. A biodiversity status report issued by Syria in 2016 [102] expressed concern about significant clearing and destruction in 11 of Syria's forested reserves, including Al-Bil'as, Abu Rajmain, Al-Ferunluq, Dimna al-Sweida, al-Laja, Jabal Abdulaziz, the Fir and Cedar Reserve and others. This included losses not only of trees both common and rare, but also of herbs and aromatic plants that had been planted for the benefit of local communities. In 2019, research showed an estimated loss of a quarter of the trees in the Farlaq reserve of northern Latakia, including conifers, hawthorn and terebinth trees.[103] The reserve had been an active conflict zone in fighting between opposition and government forces, which allegedly used a scorched-earth policy to drive out combatants. In 2020, hopeful news emerged of locals protecting the Jubata al-Khashab

Reserve from over-harvesting and degradation during the war.[104] But others were not so fortunate. In areas of eastern Syria formerly controlled by Jabhat al-Nusra and subsequently by ISIS, the Jabal Abdulaziz and Al-Kareen reserves, which are isolated forests in a largely arid landscape that hosted rare mammals such as the black-tailed gazelle, foxes, striped hyena, several species of wild cat, and others,[105] were subject to incidents of illegal logging and hunting by armed groups.[106]

Tree-cover Loss in Commercial Orchards

A bird's eye view of the hills and mountain slopes of western and northern Syria show distinctive symmetrical patterns of millions of trees in thousands of orchards. These areas produce a wide range of olives, fruits and nuts, which support the nation's economy and help provide food security. In 2013, Syria's trees produced 1,250,725 tons of citrus fruits, 842,098 tons of olives, 256,614 tons of apples, 83,229 tons of almonds, 65,272 tons of apricots, 62,373 tons of cherries, 54,516 tons of pistachios, 46,443 tons of figs and 4,039 tons of palm fruits.[107] Citrus fruits, including oranges, mandarins, lemons and grapefruits, are particularly important. Syria's bumper crop of 1998/1999 was worth an estimated USD 240 million (2002 prices), at which time there were approximately 9.47 million citrus trees in Syria.[108] Olives and olive oil production constitute another significant national product, with an average of three million olive trees planted per year prior to the crisis.[109] In 2011, the International Olive Council estimated Syria to be the fifth largest producer of olive oil in the world, at 165,000 tons or 5 per cent of global production.[110]

More than a decade of war in Syria has brought about the loss and destruction of vast areas of orchards. By 2014, Idlib, Homs and Hama had already lost some 3,900 hectares of orchards, primarily olive.[111] These losses in north-east Syria were largely due to accidental or intentional burning and felling for military purposes and for firewood. In the Orontes River Basin, significant looting and damage to water infrastructure and major irrigation schemes, in addition to mass internal displacement from the region, decreased agricultural productivity by 70 per cent.[112] In a countrywide assessment by the Regional Food Security Analysis Network, the practice of cutting down commercial trees in orchards by farmers to sell for firewood was reportedly widespread, as the conflict impacted access to supply chains, resulting in spoiled crops, as well as rising labour and fuel costs.[113]



Source: Syria Damage and Loss Assessment, FEO 2017

Perennial crop losses as of 2017 were highest in southern Syria, exceeding USD 400 million in Rural Damascus and Dara'a. (Perennial crops include tree crops such as almonds, pistachios, olives, pomegranates, citrus fruits, apples, pears, stone fruits and figs, as well as grapes.) Estimates of total losses from perennial crops reach some USD 1.5 billion, with many farmers citing the lack of fertilisers, the lack (or high cost) of fuel, and pest or disease outbreaks as some of the primary causes.[114]

A full remote-sensing analysis of changes in commercial orchards throughout Syria is beyond the scope of this study due to the complex nature of change detection for small trees using large data sets with very high resolution imagery. There have, however, been a number of conflict-linked cases where orchards have been affected, whether through the construction of military bases or IDP camps or as a direct result of fighting.

Aleppo

Northern Aleppo experienced growing population pressure from IDPs fleeing regime areas early in the conflict. This influx of displaced people, combined with rising fuel prices, drove large-scale tree cutting for firewood. Dozens of newly established IDP settlements, often placed amidst commercial orchards, have resulted in smaller-scale tree loss, such as that seen at the IDP settlement of Shamarin, established on the Turkish border in 2014.

In 2018, offensives by the Turkish-backed Operation Olive Branch against the Kurdish-led Syrian Democratic Forces continued to fuel displacement, with more people moving into the area after it had been taken over by the Turkish-backed Syrian National Army (SNA). Since then, multiple news reports from Kurdish media outlets made claims that SNA forces were deliberately chopping down orchards to sell the timber on the market[115], with some stating that at least 500,000 olive trees had been cut down.[116] These claims of mass deforestation of commercial orchards in Afrin could not be corroborated by PAX's remote-sensing analysis. A stream of reports by local human rights groups in Afrin indicate that armed groups have cut down dozens or even hundreds of trees in orchards to be used for firewood or as an alleged punishment of local farmers.[117] Again, PAX was not able to independently verify these reports with satellite imagery analysis.

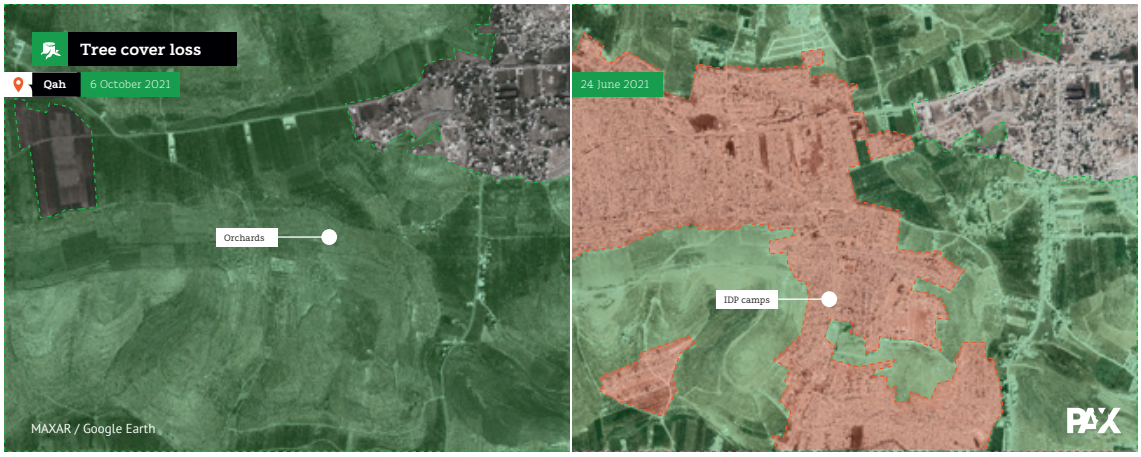
There are a few dozen cases of Turkish military outposts that have been constructed amidst orchards, resulting in hundreds of trees cut down for both the base itself and fire-line clearance around the military outposts. The satellite image below gives a 'before-after' comparison of such an outpost in Afrin near Kefer Mize.

Idlib

This governorate is currently under the control of several armed groups, such as Hay'at Tahrir al-Sham (HTS), the TFSA and several Turkish army outposts. It also hosts large IDP camps on the

border with Turkey. During the conflict, orchards were affected by the fighting and the construction of IDP camps and informal settlements. Shelling has left some areas littered with unexploded ordnance, which hinders farmers working on the land. In other areas, the explosions and fires destroyed orchards.

Agriculture remains an important economic sector, which to a large extent protects trees from being cut for firewood. There are notable cases of orchards being affected, as can be seen in the town of Qah on the border with Turkey.

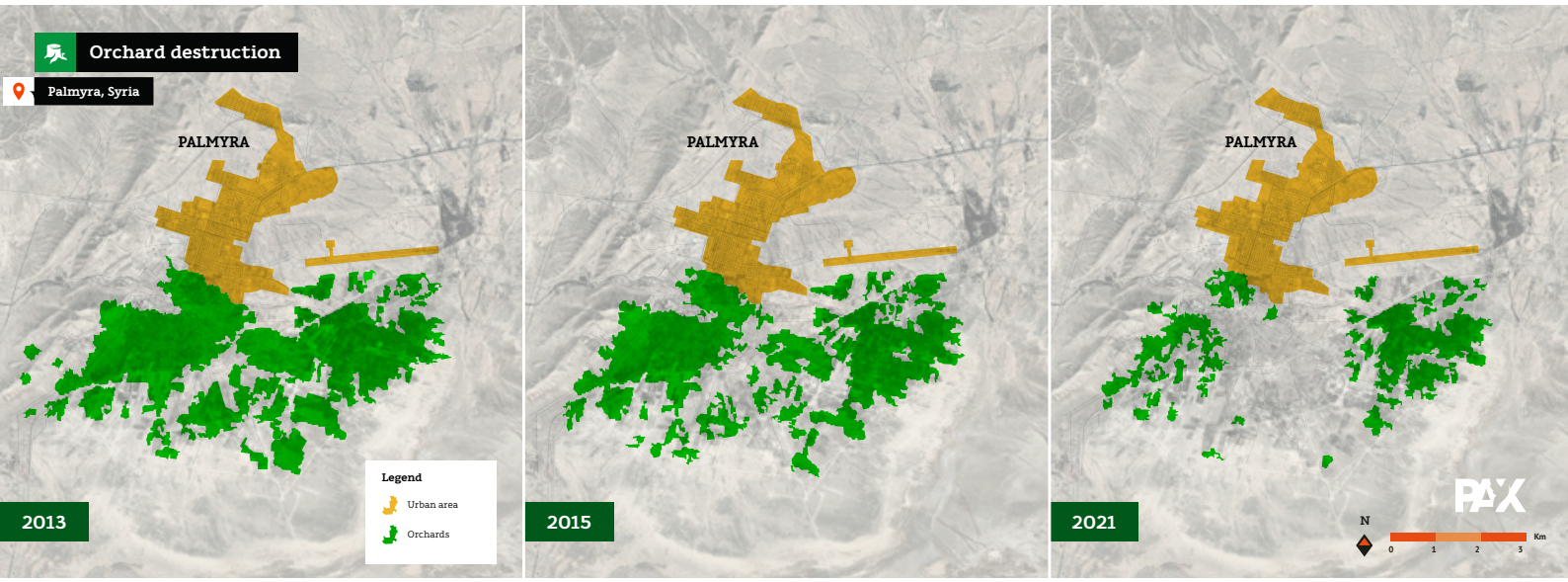


Palmyra

While known for its historical temples, Palmyra was also a green oasis in the central desert of Syria for travellers coming from Damascus and heading to the east. Fed by the local Afqa Spring, water irrigation made the desert blossom with date palms, olive and pomegranate trees in the south-east and south-west of the city, while also providing a cool place for its citizens to rest and escape from the blistering heat. In 2009, the Syrian government invested in expanding date palm plantations around Palmyra, totalling over 3,000 hectares of commercial tree plantations.[118]

But the war soon found its way to these lush green zones as in 2012 armed groups used these areas for hiding, and the regime sent in forces that shelled the areas, uprooting trees and causing forest fires. After the surrender of the rebels, locals resorted to cutting down trees due to rising fuel prices, but the worst period was to come.[119] In 2015, ISIS took over the city, followed by two large offensives led by Russia-backed Syrian troops, also hitting orchards where ISIS fighters were hiding. According to regime-linked media, damage to water and irrigation infrastructure worsened the condition of tree nurseries, resulting in the loss of 7,000 trees.[120] Recent media reports from the city indicate that regime forces continue to cut down trees to sell as firewood, worsening the already war-inflicted status of the many commercial orchards.[121]

PAX applied remote-sensing analysis using Landsat 8 of the area around Palmyra to determine the land cover change in the period 2013-2021 in the green belt around the city.

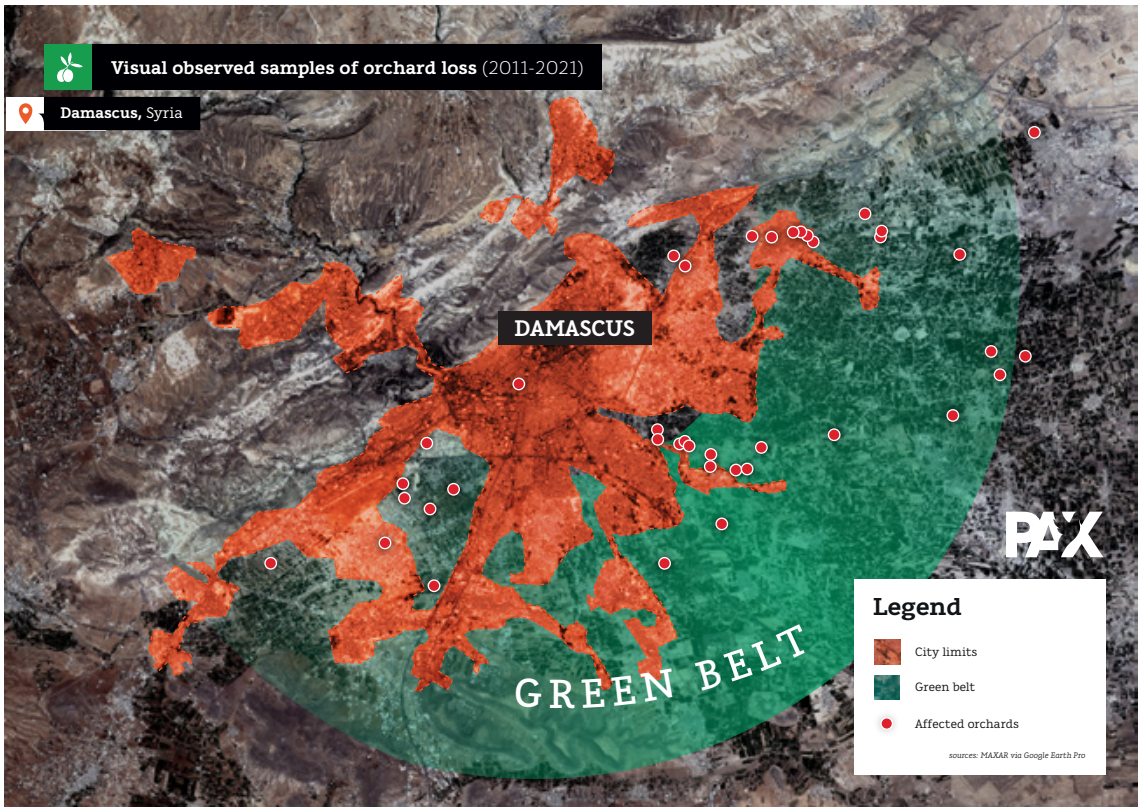


From a total cover of 1,300 hectares in March 2013, 8 per cent of the cover had been lost by January 2015 and a further 44 per cent by early 2021. In total, the loss of this land cover is estimated at 52 per cent. Based on Google Earth high-resolution imagery, the land cover can be classified as mostly orchards, using visual interpretation of the characteristic rows of planted trees. The results of the remote-sensing analysis match the visual interpretation of the high-resolution comparison of 3.2.4

Damascus

From the start of the peaceful uprising, Damascus has been at the centre of the revolution. When the demonstrations were met with deadly repression and spiralled into a civil war, fierce fighting took place in the capital, but also in the many neighbourhoods around the city, from Duma in the north-east to Darayya in the south-west, areas that later witnessed the use of chemical weapons by the regime. The green ring around the city known as the Ghouta, meaning 'garden' in Levantine Arabic, is a fertile zone hosting agriculture and fruit trees. Benefiting from fertile soil and irrigation from the Barada River, Ghouta has long been an important area of local agriculture and in fact was specifically targeted in the 1968 Damascus City Master Plan as an area to protect from urbanisation due to its high agricultural value.[122] [123]

The rapid growth of the city a century ago put more pressure on this green belt.[124] The intense fighting that erupted after 2011 soon scarred the landscape, while the subsequent siege tactics further drove up deforestation of the many orchards in the belt around the city, as residents were in need of fuel wood.[125] East Ghouta, a large neighbourhood that provided a rich agricultural resource for Damascus,[126] faced severe conflict-driven degradation as farmers fled, while attacks destroyed orchards or left the land contaminated with unexploded ordnance.[127] Now, the area has lost an estimated 80 per cent of its trees as a result of fires from bombing campaigns and a lack of water.[128] With a peace agreement in 2018 that resulted in rebel groups and their families being evacuated to northern, opposition-held Syria,[129] farmers are starting to return with hopes of reviving this critical food source and the lungs of Damascus.[130]



A recent remote-sensing study looking into land cover change around Damascus from 2010 to 2018 found a 2.5-4 per cent decrease of green spaces within the centre of Damascus, which witnessed limited fighting, while the green belt experienced an 18 per cent decrease in the same period.[131] With the use of Google Earth Pro high-resolution imagery, the destruction of orchards is clearly visible in the belt around the city. The map of Damascus shows areas where orchards were severely affected or completely disappeared. The findings would need further study with high-resolution imagery for a complete analysis of the loss of orchards around the city.

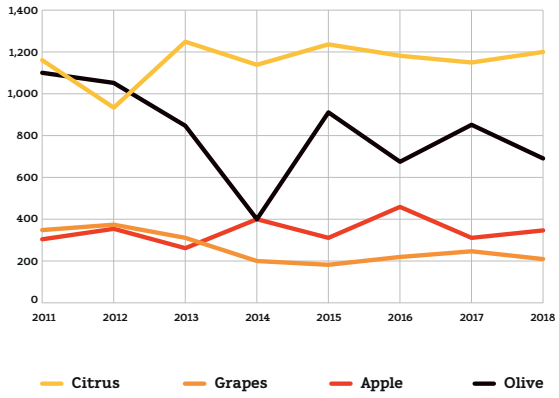
Socio-economic impacts of deforestation

The large-scale loss of orchards throughout Syria is certain to aggravate current food insecurity.[132] Whereas apple and citrus production—largely found in the relatively conflict-free governorates of Latakia and Tartous—has remained fairly stable, olive production—found largely in conflict-impacted areas—saw the greatest decreases during the war.[133] In fact, drops in olive production led to an estimated loss of more than USD 795 million in Syria during the first four years of the conflict

alone.[134] By 2017, total perennial-crop losses were estimated to have reached USD 1.5 billion, with the greatest losses recorded in the southern Syrian governorates of Dara'a and Rural Damascus, where losses exceeded USD 400 million in each.[135]

Syrian fruit tree production from 2011 to 2018 in thousands of tonnes.

Adapted from Syrian Center for Policy Research



Livelihoods of orchard farmers have also been impacted, and as production resumes, the costs of replanting orchards and fixing irrigation systems can be high. Meanwhile, the time interval from tree planting to fruit production averages five years, and may be longer yet for fruit trees to reach maximum productivity.[136] Urban residents may also suffer as a result of widespread loss in the Damascene green belt of orchards that likely contributed to air filtration from urban pollutants,[137] cooler city temperatures,[138] soil stabilisation and storm-water management prior to the war, in addition to being a source of local fresh produce. Lastly, climate change may further complicate orchard productivity, as warmer winter temperatures, unpredictable precipitation and severe drought can affect flowering, fruiting, soil water availability and pest outbreaks.[139] The combined impacts of canopy-cover loss, conflict pollutants and climate change on soil degradation may be of particular concern. Erosion (to which Syria's soils are prone[140]), arid climates and salinisation all contribute to desertification processes—the long-term or permanent loss of soil productivity.[141] Denuding these sensitive soils of plant cover further increases the risk of desertification by degrading nutrients and reducing water absorption and the water capacity of soils available to plants. Thus, re-establishing orchards and irrigation networks in the wake of the conflict will be important in restoring agricultural productivity, food security, livelihoods and ecosystem services, and buffering some of the negative impacts of climate change.

Forest Loss in Densely Populated Areas

Intense fighting in and around Syria's towns and cities has brought death and destruction upon communities. The many sieges and disruption of public services in Aleppo, Hama and Damascus resulted in residents cutting urban trees from roadsides and public parks for fuel. Severe damage to Syrian cities has been well documented by the World Bank[142] and REACH[143] with remote sensing, showing heavy urban destruction caused by shelling, airstrikes and intense fighting in cities.

Aleppo

Intense fighting, sieges and shelling laid waste to large parts of the centre and east of this famous, ancient city, ending in December 2016 when the regime regained control. Relentless fighting resulted in over 36,000 damaged and destroyed buildings. The sieges also took a toll on green spaces throughout the city, as desperate residents harvested urban trees for fuel and turned parks into cemeteries and dumping grounds for trash.[144] It should be noted that the loss of urban trees to these purposes was not permanent, and a 2021 study by M.A. Mohamed reported the hopeful news that the vegetation index in Aleppo had already started to increase from 2014 levels by 2018[145], though this is partly explained by the growth of grass and bushes in abandoned areas rather than reforestation.

Homs

Already early on in the war in 2011, reports indicated large-scale tree felling for firewood by residents of the city, as prices for fuel were skyrocketing.[146] Other areas were heavily affected by the fighting, resulting in the few remaining trees and green spaces being destroyed or burned down.[147] Though the city itself does not have many areas with heavy tree cover, some of the parks and green spaces were severely affected, as can be seen in the high-resolution satellite imagery. Local media interviewed people cutting down pine trees in the nearby orchards surrounding the city. When asked why they were doing this, a woman answered, "We have no heating fuel. We have nothing. We are getting this from our orchards. We have no other choice".[148]

Afrin

The 2019 incursion by Turkish-backed rebels into Afrin resulted again in the displacement of Kurdish civilians, and an influx of new IDPs coming from other areas. North of Afrin, a small park overlooking the city largely disappeared, as IDPs built informal settlements and cut down the trees for firewood and housing.[149] In a 27 hectare forest patch (in 2015 and 2018), around 43 per cent was deforested between 2018 and 2021. The 45 per cent at the top of the hill has deteriorated badly (and is hardly forest anymore), as has the patch at the south, representing the remaining 12 per cent.

Dara'a

Dara'a is a small city near the Jordanian border and the cradle of the uprising against Assad's regime. Heavy fighting and destruction[150] took place in and around the city before it was retaken by the regime from rebel forces in 2018. Dara'a used to have lush riverbanks and parks, providing green spaces in the hot south. The fighting and need for firewood resulted in widespread tree cutting[151], affecting both local parks and forested riverbanks. Lack of maintenance of commercial orchards worsened the conditions for trees, which were later cut down, while neglect and lack of subsidies affected tree nurseries, hampering reforestation efforts.[152] Local sources claim that 90 per cent of canopy cover has been cut down since 2011 in Dara'a Governorate.

Urban Forest Ecosystem Benefits

Trees and shrubs in an urban environment, also known as the urban forest, have been shown to provide a plethora of benefits to cities and their residents. Trees enhance air quality by intercepting and filtering airborne pollutants that proliferate in cities such as carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), ozone (O_3), and particulate matter (PM_{10}).[153] Through the provision of shade and via evapotranspiration, the urban forest cools local temperatures and mitigates the urban heat island effect—the excessive heating which occurs in city environments.[154] In fact, the loss of urban trees and green spaces and expansion of the built-up area over the years of the war have already been associated with increasing urban temperatures of between 2˚C and 5˚C in Aleppo and Damascus.[155] Trees contribute to urban wildlife habitats, recreation, leisure and outdoor exercise opportunities for city dwellers. The urban forest's role in storm-water management is particularly valuable, as city trees mitigate harmful urban flooding by intercepting rainwater, transpiring some of the water in the form of water vapour, and increasing water infiltration into the soil.[156] Pockets of urban vegetation therefore slow and soak up storm-water, decreasing the flooding associated with cities' widespread impervious surfaces. Pollutants and heavy metals that are carried from streets and urban surfaces by storm-water are also filtered out by tree roots and other urban vegetation prior to the water returning to streams and rivers.[157]

Trees also improve community economies. The presence of street trees has been shown to attract more customers and increase the willingness to pay in business districts,[158] has been associated with decreased crime rates[159] and increases home values.[160]

The urban forest also plays a critical role in supporting human health and wellbeing. A scoping review by Wolf et al.[161] reveals a wide variety of health benefits from city trees, such as improved cardiovascular, immune and respiratory functions, reduced human exposure to ultraviolet radiation and heat stress, improved cognition, focus, psychophysiological wellbeing, mental health and mood, reduction of stress and anxiety, increased social cohesion and active living, and a healthier weight status. The benefits of the urban forest on cardiovascular health have been widely supported.[162] Remarkably, one study found that the rapid loss of urban trees in the United States resulted in an additional 6,113 deaths from lower respiratory tract illnesses and 15,080 cardiovascular deaths.[163] The presence of urban trees has also been associated with such diverse benefits as improved birth outcomes and academic test scores.[164] [165] [166] The urban forest therefore plays a critical role in the larger urban ecosystem, in city economic health and societal wellbeing, as well as in human health and wellness.

Forest Loss Causes and Solutions

The massive forest loss in western Syria and tree cutting in other forested areas of the country have a range of conflict-linked causes. Local reporting and open-source investigations in the affected areas provide a glimpse into the causes of deforestation. At the same time, there is a growing awareness among civil society and the authorities that urgent solutions to tackle deforestation are needed, and initiatives for reforestation projects are blossoming throughout the country.

What is Driving Deforestation?

The reasons for deforestation and tree-cover loss in the Syrian conflict are multifaceted and there are often many variables that influence the actors engaged in cutting trees. Understanding these different drivers is important not only for accountability of those involved, but also to find solutions that can help in the regeneration of the affected areas. This analysis of the Syrian conflict has identified five main drivers of deforestation and tree-cover loss of Syria's forests.

Need for firewood

Throughout the war, lack of access to fuel and rising energy prices resulted in a massive market for firewood used for heating and cooking. Due to the lack of enforcement of local environmental regulations, local civilians and organised groups[167] cut down large swathes of forest in western Syria. Throughout the conflict, fuel prices prompted logging in Latakia[168] and Tartus governorates.[169] Media reports suggest that corruption and the creation of a black market worsened the situation, as criminal gangs paid workers to cut down trees for sale, often under the watchful eye of the military.[170] Similar scenarios are also widely documented in rebel-held areas in Idlib and Aleppo[171], despite attempts by the de facto authorities to stop illegal logging.[172] Weak oversight and absence of regulation in Idlib have been driving large-scale deforestation, providing a livelihood for many displaced Syrians.[173] Reports also suggest that local militias, some of them dominated by foreigners, are the driving force behind deforestation as it provides them with funding from black-market sales.[174]

Firewood prices skyrocketed during the conflict. Depending on the location and type of wood, the numbers provide a clear example of the forces driving the growth of sales of firewood and the

market opportunities for traders and loggers willing to utilise the opportunity to make money, be they individuals, criminal groups or militias. Prior to the conflict, one ton of firewood cost roughly 6,000 Syrian pounds (SYP). This steadily increased to SYP 20,000 in 2014 and SYP 100,000 in 2018. Prices are currently (in 2022) reported to be between SYP 900,000 and SYP 1 million. Although the near total devaluation of the Syrian pound should also be taken into account, this still shows a massive increase in firewood prices.

Displaced Syrians piling up wood logs destined to be sold to compatriots who fled conflict zones, to be used as a less expensive alternative to fuel for heating during the winter season, on the outskirts of the northwestern city of Idlib, on December 11, 2020.

Charcoal production

Another contributing factor to Syria's deforestation is the production of charcoal, which has emerged as a primary source of fuel and winter heating. Fuel shortages, a rapid rise in fuel prices, intermittent electricity provision, and charcoal's relative affordability and effectiveness as a heat source make it the only feasible choice for many poverty-stricken families.[175] [176] [177] Unemployment and food insecurity are widespread throughout government- and opposition-held Syria, further exacerbated by a rapid rise in the price of essential commodities and the plummeting value of the Syrian pound (which has lost approximately 98 per cent of its value since 2012[178]). Particularly in the winter, charcoal, which is about one quarter the cost of the traditional fuel (known as mazout), is often the only financially viable source of heat for hundreds of thousands of Syrians in informal settlements throughout the country.[179] In a country where 90 per cent are currently living below the poverty line,[180] charcoal production has become a strong economic engine, providing additional livelihoods for many and worth an estimated USD 1 million monthly in Latakia's coal market alone.[181]

Syrians sort Oak wood for manufacturing charcoal in Kafr Kila, Idlib Governorate, Syria, 28 April 2018

In opposition-held areas, some of this charcoal comes from Turkey via humanitarian aid organisations for distribution among IDP camps along the northern border, who then resell as much as they are able.[182] However, the majority of Syria's charcoal comes from Syria's forests, which have become home to thousands of licensed and unlicensed charcoal production sites. Since the start of the war, Latakia has issued at least 873 charcoal production licences and Tartous 650 licences, which should, by law, be subject to forest protection regulations such as a minimum distance of 25 metres from forested areas, a 400-kilogram daily production limit and frequent monitoring.[183] Under current conditions of minimal forest governance, it is found that even licensed sites rarely abide by these laws.

Furthermore, numerous charcoal production sites operate without a licence, often under the protection of warlords or *muallimeen* whose powerful influence puts them above the law.[184] [185] Although charcoal production relies upon the continuity of the forest, licensed and unlicensed sites contribute to deforestation both by chopping down orchard and forest trees (the most valuable of which is oak) and through fires that escape from production sites, which are often scattered deep within the forest.

Forest fires

Though the scientific literature provides few records or bases for wildfire area comparisons in Syria, the conflict appears to have caused a considerable increase in the annual average area burned in forests. That area increased by a factor of more than 5.7 in Latakia in the period 2011-2015 compared with pre-conflict (2002-2010) levels. Numbers dropped between 2016 and 2019 (due, perhaps, to the ceasefires that began in 2016) and jumped again for forested areas in 2020 to an unprecedented 73,760 hectares (4,830 in Tartous, 27,480 in Latakia and 41,450 in Hama). This is a more than 30-fold increase over pre-war levels for Latakia alone.[186]

The aftermath of the 2020 fires on the Eastern slopes of the Syrian Coastal Mountain Range in Slunfeh, Latakia's Cedar and Fir reserve: a haunting landscape of burnt cedar trees, 2022

The total area burned and fire severity depend not only upon ignitions, but also upon local topography, weather and wind conditions, and the type and continuity of fuels.[187] To some extent, therefore, the greater wildfire area in 2019 (particularly in crop fields) can be explained by greater soil moisture from the relatively high rainfall of the preceding season, which provided denser and more connected fuels. However, Zubkova et al. (2021) found that soil moisture explained less than 14 per cent of the extreme fire season of 2020, which saw greater activity in forested areas. Some blame the fires on bomb ignitions and intentional forest burning as a military tactic.[188] Studies examining the relationship between burned forest area and the shifting frontline[189] or the density of violent conflict[190] provide further support that the armed conflict was responsible for some, although not all, wildfire ignitions. Other sources of ignition may include escaped fires from agricultural burning,[191] illegal charcoal production sites[192] or arson.[193] Whether or not the fires were intentional, some locals appear to have taken advantage of burned forest areas to conduct post-fire agriculture and salvage logging (legal under Syrian law),[194] [195] essentially privatising public land. In response, the government announced the set-up of additional tree nurseries to be used for replanting the affected land.[196]

While governorate fire brigades are still active in regime-held areas such as Latakia, the civil defence or 'White Helmets' have taken up fire response services in opposition-held areas, with additional training and support services from international NGOs.[197] However, their attempts to control the 2020 wildfires were hindered by difficult terrain and limited road access as well as extreme fire weather.[198] The affected forests lost a large part of their tree cover, with scorched land apparent in satellite imagery; yet in many areas, the trees are still standing and forest regrowth is also visible.

Lack of governance

The conflict significantly degraded the capacity of the Syrian government to monitor and enforce forest regulations, and the large influx of displaced persons, combined with the issues described above, worsened the logging. Pre-conflict, the UN Food and Agriculture Organization (FAO) had already raised concerns about the absence of forest data, and weak planning, monitoring and response capacity.[199] The absence of strong oversight and enforcement during the conflict allowed some opportunists to reallocate forest land to agricultural use. In other areas, insufficient forest management reduced the ability of relevant entities to control wildfires, as they lacked equipment or relevant expertise. An absence of planting operations, either directly due to the conflict that affected the planned reforestation areas, or because of spiking fertiliser prices, hindered the much-needed planting of seedlings to ensure forest growth and maintenance.[200]

Military operations

Intense fighting between regime forces and armed groups in forested areas is a major cause of deforestation, particularly in Idlib, Latakia, Hama and Homs. Throughout the conflict, rebel groups used forest cover when setting up military camps, which led Syrian regime forces, supported by the Russian air force, to undertake massive strikes by both aircraft and ground systems against these positions. Strikes with thermobaric weapons, designed to cause huge blasts from fuel explosions, were frequently used by Russia in Hama and Latakia against targets in forested areas. One documented case was the use of a TOS-1 thermobaric launcher in Hama in October 2015, geolocated by OSINT experts[201], where post-strike satellite imagery showed widespread burned forests. This particular area later witnessed severe logging of forests. Open-source video footage also shows ongoing artillery strikes in the areas around Jisr ash-Shugur in Idlib and airstrikes in Latakia.[202] Apart from direct destruction by military action, incidents of troops burning and cutting down trees to clear firing lines have also been observed[203], as has the clearing of forests to set up military outposts, most notably in northern Syria.[204] Due to the destruction of tree nurseries, forest management and tree-planting operations were also affected.[205]

Reforestation and Restoration Efforts

Although largely unsuccessful, efforts have been seen by both the Syrian government and local residents to undertake afforestation campaigns. In 2015, state media announced 500 pine tree seedlings had been planted in Maaloula, with an eventual goal of 23 million seedlings being planted. However, this turned out to be a scam, with no real achievements ever being made in the project.[206] New programmes in conflict-affected areas focusing on environmental education and greening activities are gaining popularity,[207] while urban planners are coming up with ideas to address green space recovery while rebuilding the cities.[208]

A Syrian man puts a plant in the farmland in the town of Zabadani, countryside of Damascus, Syria. The rehabilitation of the farmlands in Zabadani has started with the help of the United Nations Food and Agriculture Organization (FAO) after the area suffered damages due to the battles between the Syrian army and the rebels. October. 19, 2017

Early on the war, local councils and residents in opposition-held areas[209] also attempted to work on reforestation,[210] but exact numbers of seedlings planted or the degree of success of these programmes in the long term are unknown. Most of the areas with programmes of this type were retaken by government forces in later years.[211] Many small and larger reforestation efforts have been undertaken in opposition-held areas in northern Syria. The United States Agency for International Development (USAID) financed a programme that helped commercial nurseries in SDF-controlled Raqqa to grow over 65,000 olive-tree seedlings per nursery, allowing local farmers to replant decimated olive orchards with healthy stock at a fraction of the actual cost.[212] In 2021, Damascus Governorate Directors of Agriculture and Decision Support and Regional Planning addressed the loss of green space around Damascus, sharing plans to replant some of the 3.3 million trees alleged to have been lost, establish a 500m^2 tree and agriculture belt around Damascus in which development is forbidden, and enforce pre-existing policies that protect trees and green space.[213] Though the many local initiatives are a hopeful start, the lack of proper water infrastructure, degraded capacity, increased climate-induced droughts and increasing heatwaves will have a serious long-term impact on the reforestation efforts if these efforts are not conducted structurally and with robust implementation.

Future Climate-change Resilience

Climate-change projections for Syria indicate a general warming of 1˚C to 5˚C (depending upon the emissions scenario) for mean annual temperatures by the end of the century.[214] Increasing evaporative demand with warmer temperatures and projected decreases in precipitation,

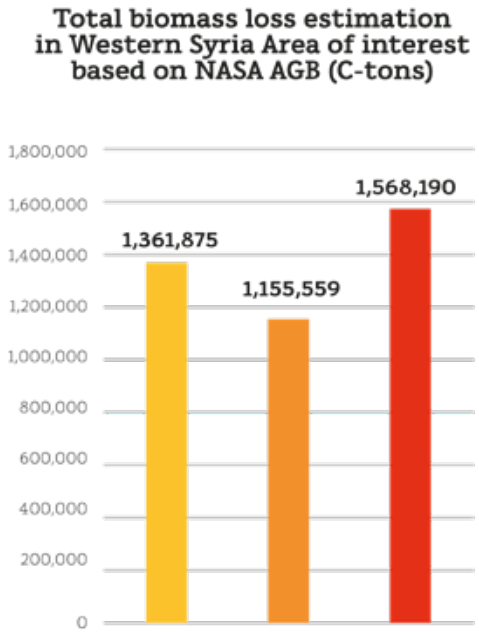
particularly in wetter areas of the country, will lead to drier soils. An increased frequency and severity of drought has also already been observed in coastal and montane Syria, particularly during the spring, which constitutes a critical growth period for Syria's forests.[215] This warming and drying climate puts numerous forms of stress on tree species. For example, warmer winter and spring temperatures can impact sensitive phenological phases, such as dormancy, bud break and blossom.[216] Water stress reduces trees' natural defences against pests and diseases, making forests more susceptible to wide-scale pest or disease outbreaks. Although trees can generally withstand brief exposure to heat and drought,[217] persistent drought conditions can lead to tree death through carbon starvation (due to closed stomata) or hydraulic failure.[218] Fires that are sufficiently large in area may also limit seed sources for natural regeneration, particularly when salvage logging removes all the burned trees (and their seeds) from a given area. All of these factors may impede forest regeneration in deforested areas. This is particularly true on south-facing slopes, where high soil erosion, exposure to solar radiation and the loss of organic matter and stabilising vegetation significantly diminish the soil's capacity to hold moisture and support the growth of vegetation.

Additionally, seedlings, whether naturally occurring or planted, rely heavily upon cool-season (and particularly spring) precipitation in order for the roots to become well-established prior to summer droughts. As spring droughts increase in frequency and severity, this further hampers natural forest regeneration and the success of reforestation campaigns.

However, warm-season droughts and wildfires are a natural part of Syria's coastal climate, and local tree species have many adaptive traits that allow them to thrive in this environment. Some species, such as Calabrian pine, have serotinous, or fire-adapted, cones with a waxy outer coating that melts and releases seeds during wildfires.[219] Others, such as the terebinth or turpentine tree (Pistacia palaestina), quickly re-sprout from their roots after a fire.[220] Aleppo pine and some other native species are able to go dormant during summer droughts and resume growth under cooler, wetter conditions.[221] Deforestation in Syria therefore should not be assumed to be permanent, but rather should be subject to monitoring and restoration efforts where necessary.

Syria's deforestation not only exacerbates a negative feedback loop between climate change and forest health, it also threatens the resilience of wider biodiversity to climate change. Forest degradation, fragmentation of forest habitats, smaller patch sizes, and the loss of connectivity between forest remnants all decrease the future resilience of both flora and fauna.[222] As the climate warms, many species may no longer be well-adapted to their current locations, and may need either natural or assisted migration to more suitable areas, or the introduction of more drought-tolerant seed sources of the same species, or they may risk local extinction. Studies local to Syria are needed. However, tree species distribution studies considering the effects of future climate change in nearby Lebanon indicate that some species, such as the Cilician fir and Turkey oak, are particularly vulnerable to significant decline or local extinction whereas the Calabrian pine appears to be able to survive in lower numbers.[223]

In 2009, total above-ground biomass carbon stocks in Syria's forests were estimated at 7 million tons.[224] Biomass, or all living or formerly living tissue, is generally divided into above-ground and below-ground biomass. Above are the plants, trees, leaves and forest floor litter from dead vegetation. Below-ground biomass includes roots, decayed litter and carbon that is part of the soil. Remote sensing and GIS can be used to estimate losses from these carbon stores. This quantification was done by classifying the areas into 10-ton classes. Estimations for an average, low and high calculation of carbon loss based on existing data sets, which for this research produced a range of results. Finally, these areas per class were summed to obtain the total volume of lost biomass in tons.



Using NASA's 'Global Aboveground and Belowground Biomass Carbon Density Maps', the carbon loss for the coastal hills and western study area is estimated at around 1.4 million tons between 2013 and 2021 (although the permanence of these losses will depend upon the success of forest regeneration in the coming decades). This amounts to a loss of some 20 per cent of Syria's total forest carbon stores, which would be 3.5 per cent of Syria's annual carbon emissions.[225]

The Syria Civil Defense/ White Helmets are battling a forest fire in Latakia, September 10, 2020.

© Azalden Idlib/Syria Civil Defense

Key Findings and Recommendations

With the war in Syria having raged for nearly 12 years, the path of destruction only gets longer and more intense. Beyond the grave humanitarian suffering brought by violence, the environmental costs of war are growing by the day, and will increase the burden of Syrian communities struggling to survive with the little means left. With the impacts of the climate crisis being felt more every year, conflict-linked environmental degradation is only worsening living conditions and socio-economic prospects. With that in mind, this report sought to look at how the war impacted Syria's biodiversity-rich forested areas in the west and north of the country and the many commercial orchards that provide food and incomes to millions of people. Beyond being a valuable natural resource for Syria's economy and providing livelihoods, the forests and orchards are also host to unique ecosystems and species endemic to the region. Back in 1977, forest management was given priority and the government set ambitious goals to increase reforestation projects to boost forest cover up to 15 per cent of the country.[226] The importance of addressing deforestation and forest management for healthy ecosystems, livelihoods and communities, as outlined in Chapter 4, underscores the relevance of including this topic in broader conflict analysis: from the accountability of states and armed groups involved in the overexploitation of natural resources to greening the humanitarian response and reforestation programming in post-conflict rehabilitation work to strengthening climate resilience, across the conflict cycle. There are numerous opportunities that can help prevent and minimise the destruction of natural resources and biodiversity, ranging from local initiatives to international organisations providing support in nationwide programmes.

Conflict-linked Deforestation

The findings of this research are shocking: of the nearly 3 per cent of land in the country still covered by natural forest, mostly located on the green mountain ranges of Latakia, Hama and Idlib, 36 per cent was affected. Most of these areas were deforested, with all the trees cut down or damaged from fighting, while other areas witnessed serious tree-cover loss from intense wildfires taking place in the last four years. In northern Aleppo, on the mountain ranges of the Aleppo Plateau, where dense forests are mixed with millions of orchard trees on the hillsides growing pistachios, olives and walnuts, armed groups cut down over 59 per cent of the trees in the remaining natural forests. Intense fighting in and around Palmyra as well as urgent demand for firewood led to at least 51 per cent of the orchards being cut down or damaged. Limited analysis of commercial orchards using high-resolution historical imagery with a focus on northern Syria indicates that the growing numbers of IDPs, the establishment of military positions and activities by armed groups (e.g. fire line clearing and alleged repercussions) contributed to the loss of fruit trees. To understand the full extent of the damage to orchards, a spatial-temporal study with high-resolution and/or Laser Imaging, Detection, And Ranging (LIDAR) data would be required to quantify this loss.

Urban green spaces such as parks or green belts around major cities such as Aleppo, Idlib, Hama, Homs, Tabqa and Dara'a also witnessed large-scale tree loss, often directly related to the fighting in those areas or siege tactics that drove civilians to cut down trees for heating and cooking.

Drivers of Deforestation

Based on the analysis of media articles, social media posts, government reports and consultations with partners, and remote sensing analysis, the following main causes can be identified:

1. **Logging and thinning for firewood.** Soaring fuel prices combined with massive displacement form the main driver for large-scale deforestation throughout Syria. Civilians are cutting down trees for cooking and heating, while there are clear indications that armed groups also use illegal logging and wood sales as a source of income.

2. **Wildfires**. Conflict-induced fires linked with military activities such as airstrikes and shelling, but also arson-induced, accidental and naturally occurring fires, ravaged thousands of hectares of forest, in particular from 2018 onwards.

3. **Charcoal production**. The production of charcoal can be a lucrative business, both for domestic use and export. In some areas, particularly Latakia and parts of Idlib, charcoal production sites sprung up and can be linked with increased logging in the area.

4. **Failure of governance**. The collapse of forest management due to the conflict has hindered monitoring and enforcement of environmental regulation and limited the means to ensure proper forest management to prevent forest loss.

5. **Conflict-linked destruction**. In areas of intense fighting, direct shelling and fires caused by the fighting damaged or destroyed forest, in particular in Idlib, Latakia and Hama. Indirect impacts came from the destruction of irrigation infrastructure, which affected forest management and tree nurseries.

6. **Change in land use**: Land-use changes as a consequence of the massive movement of displaced people also had an impact on forest cover, ranging from orchards being used for IDPs camps and informal settlements in and around urban areas, to trees being felled for agricultural land use due to the influx of refugees in certain areas.

Environmental Peacebuilding and Recommendations to the International Community

As international actors in Syria transition from the humanitarian to the development stage, the loss of the country's canopy cover should continue to be a primary concern. Addressing the impacts of the war on natural resources is needed not only to address the immediate and long-term consequences for communities and climate resilience, but also as a potential source of

collaboration and environmental peacebuilding. The term 'environmental peacebuilding' here refers to the idea that collaborative management of forests (i.e. their protection and restoration from deforestation) can be used to strengthen peace processes in Syria, for example by contributing to social or economic stability or providing a neutral space for cooperation.

Environmental degradation, such as deforestation, soil loss and water contamination, can aggravate social and political tensions linked to scarcity, livelihoods and the cultural significance of the land or resource. There is a growing discourse building on cases of conflict-linked deforestation where civil society groups, academics[227] and international organisations have developed initiatives for shared natural resource management. In countries such as Liberia,[228] the Democratic Republic of Congo[229] and Colombia,[230] each with unique conflict settings and context-bound deforestation, projects have sought to explore the role of shared resource management in forested areas that could address conflict tensions and foster peace initiatives. In addition, experts are also exploring how nature-based solutions, a concept supported in the UN Environmental Assembly's Resolution 5.5[231], can be applied in a post-conflict setting, particularly in forest landscape restoration[232] and through community engagement.[233] On a broader level, the UN is including reforestation as a tool for peacebuilding through international agreements, such as the Peace Forest Initiative as part of the UN Convention to Combat Desertification (UNCCD),[234] and through the UN-REDD+, which addresses climate-linked deforestation programmes, including climate-security analysis.

Forest restoration in post-conflict Syria, including through nature-based solutions, could be an explorative project that taps into the potential of environmental peacebuilding by implementing reforestation projects through community engagement, thus seeking to ensure sustainability, buy-in, and use of local knowledge. In fact, local authorities and NGOs in Syria have been using small-scale reforestation projects as both a peacebuilding tool and to raise awareness of deforestation (outlined in Chapter 4). Considering the enormity of forest loss in regime-held western Syria, significant resources will be required to set up effective, multi-stakeholder management, which must also address changing land tenure and access rights, in particular for marginalised communities and displaced people. This will require an inclusive process with communities, land owners, local government and both national and international institutions. The inclusion of parties currently engaged in the deforestation industry may help to ensure that new management solutions are not only environmentally sustainable, but also include economic opportunities that replace previously unsustainable livelihoods. Indeed, even people involved in logging and charcoal production might be motivated by a rapidly shrinking resource base to discuss more sustainable solutions. This inclusion of economic considerations may furthermore decrease the likelihood that continued illegal activities undermine any new forest management strategy.

However, even forest management is likely to come with a serious risk of misuse of resources, as existing projects have demonstrated.[235] Hence a more bottom-up approach through communities may be a preferred course that international organisations can support, while institutional support should be given to strengthen monitoring and enforcement of regulations. In areas under the de facto control of armed groups, engagement through dialogue and support to relevant governance bodies should be explored to identify needs and capacities, while international organisations active on the ground can support community-led initiatives in forest restoration and natural resource management. In particular, land ownership, water use and landscape management can be crucial in bringing together different stakeholders. As most forest loss in Syria has occurred as a result of insufficient fuel availability and rising fuel costs, a broader strategy that includes sustainable energy sources should be part of the analysis and solutions put forward. In the initial humanitarian response phase, there is already potential for minimising deforestation linked with firewood logging by providing sustainable energy solutions. The growing body of literature and practical solutions on reducing the environmental impact in the humanitarian response[236] provides

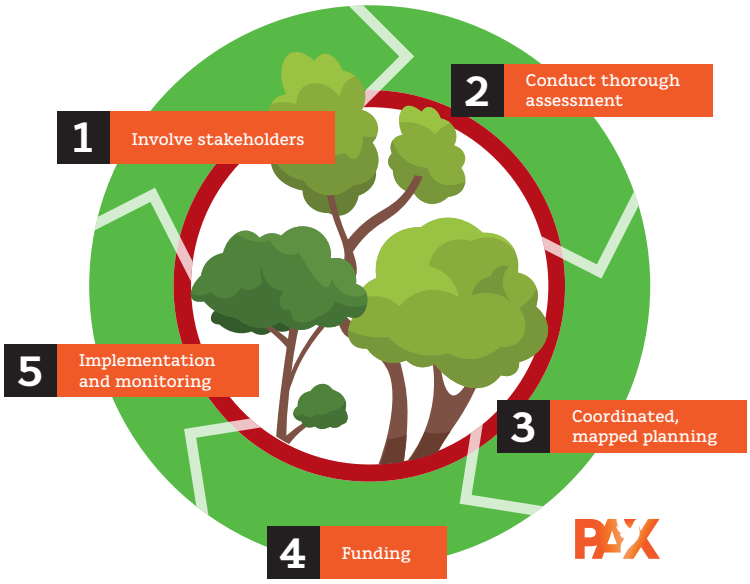
promising options for clean energy in conflict-linked responses of affected communities, such as through the use of solar power.[237]

It is crucial that the international community recognise the severity of the deforestation's impacts on health, livelihoods, biodiversity and climate resilience in an already vulnerable Syria. As the impact of the climate emergency is felt more on the ground, environmental peacebuilding efforts will be essential in bolstering both ecological and economic resilience. In addition to the recommendations listed above, actors in the international community such as the FAO, the UN Environmental Program (UNEP), UNDP, USAID and the humanitarian community should consider contributing to:

- Full remote sensing of the whole of Syria and on-the-ground forest assessments and monitoring.
- Forest restoration and sustainable management expertise and technology.
- The funding of forest restoration projects and sustainable livelihoods.
- Recommendations on appropriate policies to tackle the causes and find solutions for reforestation.
- The establishment of a watershed payment programme, providing economic support to communities that protect their watersheds from deforestation.
- During the war, Protected Areas lost their effectiveness in protecting the forest landscapes and their flora and fauna. Therefore, it is necessary to re-establish their role and effectiveness in the conservation of species after the war.[238]

On an international level, states should highlight the linkages between conflict, deforestation and the wider impact on lives and livelihoods, and link this with the environment, peace and security agenda building throughout the UN system.[239] This could for example be highlighted in the UN Environment Assembly discussions and UN Security Council discussions on the exploitation of natural resources and financing of armed groups, but also in specific relevant international agreements, including the UNCCD and through the UNREDD+ to ensure conflict-linked deforestation is included in conflict assessments and climate-resilience programming.[240]

Sustainable Forest Management Cycle



Recommendations to National Actors

Forest management in Syria currently faces the extreme challenge of attempting to balance the need for healthy forests and ecosystem services (such as soil stabilisation, water purification and climate-change resilience) and the need for livelihoods and affordable fuels in a devastated economy. Indeed, the restoration of forests, be they natural, urban or orchard, is only one aspect of a much-needed sustainable forest management plan in affected governorates throughout Syria. Developing a country-wide plan to tackle forest loss can only be successfully accomplished with a multi-step approach: greater stakeholder inclusion throughout the planning and implementation process, a thorough assessment of current resources and hazards, a concerted effort to seek internal and external funding, and ongoing monitoring and plan revision. A considerable body of literature has been published on sustainable forest management, the technical details of which are beyond the scope of this research. The following figures and text highlight some important steps which forest management entities might consider implementing in Syria, including a few guidelines and resources which may be helpful in the process.

Involve Stakeholders

Inclusive stakeholder engagement means working toward a cooperative effort between the scientific and forestry community, local groups and NGOs, and the relevant government entities such as forestry directorates and the Ministry of Agriculture and Agrarian Reform. Multi-stakeholder forest management can be assisted using Center for International Forestry Research's (CIFOR) free tools and guidelines.[241] In non-regime areas, local authorities can also collaborate with civil society groups, community representatives and international organisations to develop analysis and rehabilitation programmes.

Conduct thorough Assessments

A thorough assessment of current resources, forest health and natural forest regeneration should be conducted. This assessment should include areas at risk of high and severe erosion (which may be based on numerous GIS studies of the region such as those conducted by Abdo et al.[242] [243] [244] or Mohammed et al.[245] [246] [247]). Other health and safety hazards areas within forested regions should also be located and assessed, such as impaired and polluted waterways and conflict-based pollutants and hazards (e.g. weapons ordnance). Areas of intact and pristine forest can also be studied to form reference sites for restoration. Open Foris[248], a platform hosted by the FAO, offers free forest monitoring and citizen science data-collection tools that may be helpful while conducting assessments.

Coordinated, mapped planning

A mapped and coordinated sustainable forest management plan can be developed based on previously conducted assessments and with stakeholder input. Measures that increase ecosystem resilience to climate change should be included in this plan, such as creating and protecting refugia, increasing forest patch size and connectivity, and, where necessary, transitioning to more climate-adapted seed sources after a disturbance (such as wildfire).[249] Further guidelines and tools for increasing climate-change resilience in forests can be found in Swanston et al.'s 2016 report 'Forest Adaptation Resources' (cited below). Several open-source platforms and models allow forest managers to trial different management options and their impacts on timber production and ecosystem services, such as Landis-II[250] and products offered by the Natural Capital Project.[251]

GIS-based mapping of this plan may include elements such as: 1) areas for protection (e.g. areas of high biodiversity or cultural value); 2) areas for priority restoration (conflict pollution or erosion hazards, waterway impairments, ecological corridors and buffers to enhance biodiversity and climate-change resilience); and 3) areas for sustainably managed logging. 'Managing Forests in Displacement Settings' (by the FAO and United Nations High Commissioner for Refugees UNHCR[252]) offers guidelines for sustainable forest management around refugee and IDP settlements, such as planting species for fuel, food, fodder and construction materials to mitigate further losses to surrounding forests.

Funding

A coordinated plan can be presented for internal and external funding. A recent report to combat land degradation conducted by the Syrian Arab Republic and the UN Convention to Combat Desertification estimated the costs of forest restoration in Syria at over USD 45 million, of which it is suggested that half should come from external funders.[253] Beyond the regime-held areas, funding should also be given through international organisations active in north-east and north-west Syria. For example, USAID is already providing agricultural support in the north-east and has extensive expertise working on forests and peacebuilding in other conflict-affected areas that can be mined to address these issues in Syria.

Implementation and monitoring

The implementation of a sustainable forest management plan and ongoing monitoring of forested and restored sites should be a collaborative effort between stakeholders. The involvement of local communities and community groups can be particularly fruitful and provide further economic benefits to the project and its participants. The Lebanon Reforestation Initiative[254] has numerous English- and Arabic-language resources on conducting seedling production, forest restoration, monitoring and even wildfire management based on the organisation's experience with a similar climate and similar species in nearby Lebanon. Monitoring is typically based on measurable indicators and criteria. The FAO's eLearning Academy offers a free online course, 'Monitoring Forest and Landscape Restoration'[255], which includes sample ecological, social and economic indicators. Ongoing monitoring and assessment can then form the basis of plan revisions and re-prioritisations, thus restarting the sustainable forest management cycle.

Post-conflict orchard restoration

While the above roadmap may be the best solution for sustainable natural and urban forest management, the revival of orchard productivity in post-conflict Syria likely requires a more customised approach. Although an extensive review of post-conflict orchard rehabilitation is beyond the scope of this study, some strategies include redeveloping supply chains (preferably through local private markets), bolstering agricultural knowledge in and through extension services, and rehabilitating and updating necessary infrastructure, such as fixing roads and installing modern, high-efficiency irrigation schemes.[256] Research, development and the distribution of future climate-resilient crops and varieties can also be helpful, but only if farmers have sufficient knowledge about how to cultivate them and if there is a strong market in place to drive profits. It may also be helpful to plant large areas with polyculture orchards to improve biodiversity and soil health and diversify incomes.

Using agriculture to re-absorb ex-combatants into the socio-economic fabric can be a valuable opportunity to simultaneously support peacebuilding efforts, although sufficient support (financial, material and educational) and a 'graduation date' from this support must also be provided.[257] Establishing an effective system to resolve land tenure disputes and updating agricultural policies

are likewise important to post-conflict peacebuilding, as is the safe removal of unexploded ordnance that may impact farming families.

Organisations working to restore agriculture in Syria, such as the FAO,[258] will need to have flexible, adaptive programmes that can quickly adjust to meet local needs while also being careful to monitor and prevent leakage of funds. However, despite the numerous challenges that face Syrians as they replant their orchards, their country has a long history and a wealth of knowledge in orchard productivity that will serve them well in restoring these valuable forests.

Latakia, Syria, 2017, © Agham Daiyoub

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