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Brief Report

Recent Developments in Some Long-Term Drought Drivers

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Abstract: The droughts that hit North and North Western Europe in 2018 and 2019 served as a wake-up call that temperate regions are also affected by these kinds of slow progressing or creeping disasters. Long-term drivers, such as land-use changes, may have exacerbated the impacts of these meteorological droughts. These changes, which are spread over a long time span, may even be difficult to perceive for an individual, but make a big difference in how these rare weather events impact a region. In this paper, we introduce three long-term drivers: forest fires in Europe, global urbanisation, and global deforestation. We attempt to provide a first assessment of their trends, mainly using statistics derived from satellite imagery published in recent literature. Due to the complexity of drought impacts, and the scarcity of quantitative impact data, the relationship between drought impact and these three processes for land use change is difficult to quantify; however, hence we present a survey of the recent trends in these land use change processes and the possible mechanics by which they affect drought impacts. Based on this survey we can conclude that the extent and the number of wildfires have increased markedly in Europe since 2010. Deforestation is still occurring in the tropics, with a loss of 12% in the last 30 years but has halted in the northern regions. Urbanisation has more than doubled in the same time span in the tropics and subtropics, mostly at the expense of forests, while in Europe urbanisation took place mainly in the northern part of the continent. We can conclude that none of these implicit drought drivers followed a favourable trend in the last 30 years. With consistent and worldwide monitoring, for example, by using satellite imagery, we can regularly inform the scientific community on the trends in these drought impact affecting processes, thus helping decision makers to understand how far we have progressed in making the world resilient to drought impacts.

Keywords: drought; monitoring; deforestation; urbanisation; wildfires; satellite image processing; Global Human Settlement Layer

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1. Land Use Changes in the Last 30 Years

Drought is often perceived as mainly a meteorological driven disaster. However, land use can have a significant influence on the impact of a drought. Land use changes over time, due to phenomena, such as intensification of agricultural practices, irrigation, drainage, urbanisation, de- or reforestation, land abandonment, and disasters, such as wildfires. We present here an overview of the most important land use changes in the last decades that are potentially relevant for current drought severity and impacts. While the need for quantifying drought impacts is felt more and more due to alarming scenarios in climate change models, an overview of trends in land use change during the last 30 years, a period suitable for detecting what is changing where, is given in this paper and based on repeatable methods mainly using satellite imagery. We shortly address the land-use practices that potentially exacerbate drought impacts. Sudmeier-Rieux [1] when comparing the effect of the application of nature-based solutions on hazard reduction signaled that dryland degradation due to drought, being a slow process, receives less attention regarding disaster risk reduction compared to floods, wildfires or avalanches. Consequently, less insight is available in how land-use practices interact with dryness. Organic matter content in the topsoil, capable of retaining moisture, is the main measured parameter and is considered crucial.

Sustainable land use is a prime goal for reaching the Sustainable Development Goals (SDGs) as agreed by all member states of the United Nations in 2015. These goals should be reached in 2030. Goal 15, Life on Land, has as mission: "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss and therefore directly related to the challenge to make land use less prone to drought impacts".

Since land use change requires decades to unfold, the trends in land use changes are the main indicator for the progress towards sustainable land use. Controversies hampering a sustainable land use in relation to drought are, for example, irrigation, helping to curb drought impact and allowing agriculture in dry areas, during dry seasons, but also causing groundwater depletion, salinization of soils, and maintenance and construction of reservoirs. Another debate regards the role of certain forests, driving evapotranspiration and thus water requirement, while cooling at the same time and decreasing need for water. Such complex balances are heavily dependent on local conditions and land features.

In the following sections some of the main trends in land use changes related to wildfires, de/forestation, and urbanisation are presented. Some important topics that are not covered are soil degradation and compaction and the role of irrigation, for which not enough data could be gathered through satellite imagery.

2. Wildfires

The relationship between wildfires and drought is complex. Burned ground and mineralization provokes more surface runoff and less groundwater absorption, ultimately leading to a drier land. In contrast, burned surfaces might have a higher reflection of sunlight (albedo) [2] and boost cooler temperatures. Of crucial importance for reduction of the impact of drought events is whether a wildfire is followed by vegetation recovery or the land is changed permanently. The bar chart in Figure 1 shows the burned territory for the last 10 years, based on data of the European Forest Fire Information System (EFFIS). The repartitioning per country over the same period is shown in Figure 2.

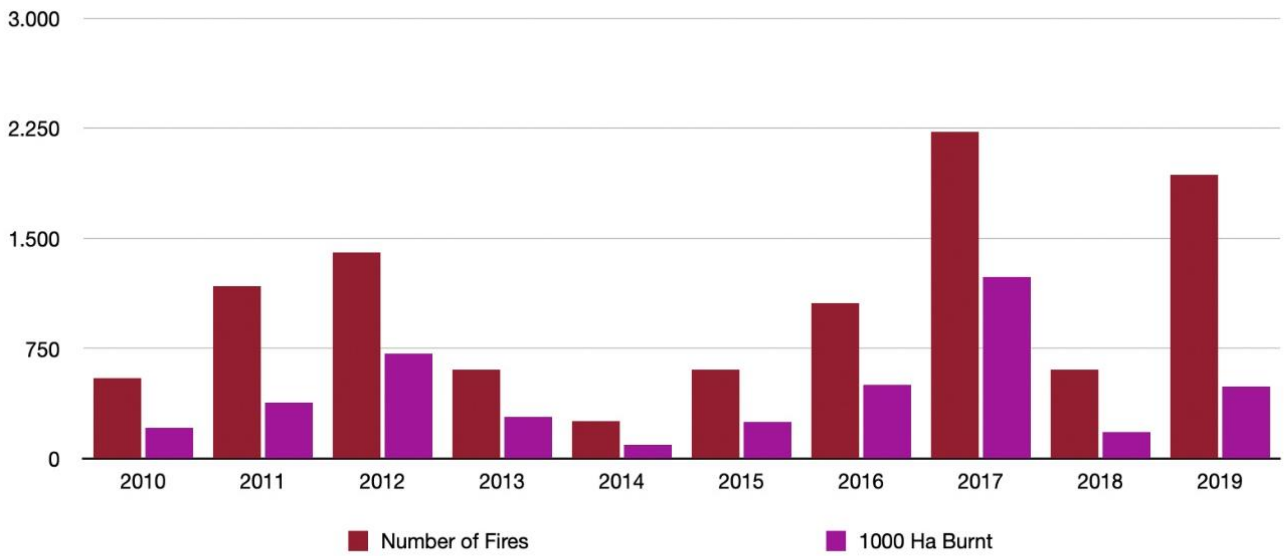

Figure 1. Forest fires above 50 hectares recorded in Europe from 2010 to 2019. Source: EFFIS, 2020.

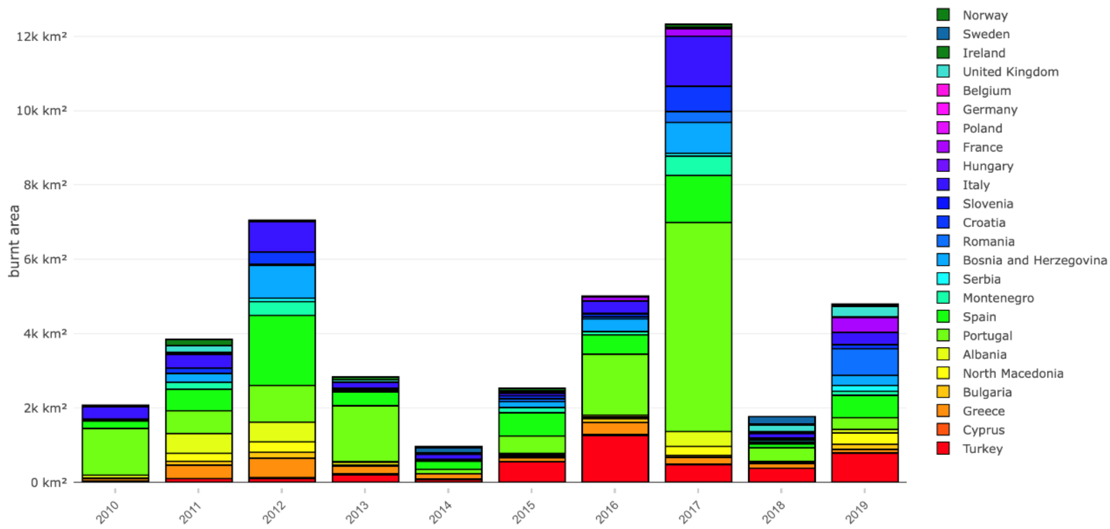

Figure 2. Burnt area by European country from 2010 to 2019, EFFIS. Source: EFFIS, 2020.

On average, Europe suffers from over 1000 fires burning an area larger than 50 hectares per year, with a yearly average total of 300,000 hectares burnt. Furthermore, 2017 was an exceptional year, especially in the south west of Europe, with 2225 fires and a total of 1,236,138 hectares burnt. After a normal 2018, 2019 also proved particularly severe, with 1932 fires and 489,213 hectares burnt. In 2019, the fires were more evenly distributed among countries, unlike 2017 when half of the total area burnt occurred in Portugal. Comparing the first half of the decade, from 2010 to 2014 (1,684,238 hectares), with the second half from 2015 to 2019, an increase of 58% of area burnt (2,669,816).

Wildfires often coincide with a dry spell, especially the so-called mega-fires, when fires burn more than 40,000 hectares, and is difficult to control due to the exceptional dryness of the litter. The extensive fires in tropical and sub-tropical forests are often lighted intentionally and may run out of control during the dry season or following an underperforming rainy season. The wildfires in the Western United States are explained primarily by the increased contact between humans and forests and the prolonged dry conditions under high temperatures [3]. The fires in Siberia and other arctic fires are mostly related to increased temperatures and availability of dry litter. Worldwide statistics on these fires are made using satellite imagery with results often leading to political debates. The European statistics presented here are made using both satellite imagery as well as national inventories, and therefore accepted by all stakeholders.

3. Deforestation

Deforestation in the tropics might partly coincide with wildfires, since fire is a common method to clear land of forest for new crops and pastures. Repeated fires may also deplete the seed bank, thus hindering the forest recovery after such events.

At higher latitudes, deforestation appears to be halted, but these forests proved prone to fires due to the specific tree types and monocultures that prevail in most of the northern territories. The current quest for biofuel, initially intended to be made from litter and leftovers from the wood industry, but now leading to full clearing of forest stands, adds to the complexity of monitoring deforestation. From the European standpoint, only 4% of the forest can be considered as forest untouched by human interests [4]; these remnants are found in Scandinavia, Slovakia, and Romania. Moreover, only 2% of the total forest stands in Europe are protected from human intervention, and a significant percentage of the forested area in Europe and the world has likely been affected by human intervention to the point that its vulnerability to drought impacts is higher than a natural forest. The restoration of a healthy forest, having enough diversity of species to withstand severe droughts, strong winds, pests, or other disasters will be a major challenge for the subcontinent.

Regarding droughts, forests contribute to a lowering of the temperature of the landscape thanks to their evapotranspiration and shadow protecting the ground from direct sunlight. Depending on the size, topography, and tree types, evapotranspiration may lead to cloud formation, which in turn reduces the heat flux and increases the probability of rainfall [5].

The world has a total of about 4000 million hectares (Mha) of forest, slightly less than one third of the inhabited land area. In 2019, a loss in the order of 4 million hectares in the tropical zone was reported [6]. In total, the world has lost 178 Mha since 1990, in the order of 5 percent of the total forest, an area the size of Libya [6]. The global net change was minus 7.8 Mha per year between 1990 and 2000, while it is now at a rate of minus 4.7 Mha per year. The current lower rate of the decline is due to forest expansion, taking place in Northern Russia, China, Ethiopia, and India [7]. In this recent study using satellite imagery to classify land use the increase and decrease in forest cover as presented in Figure 3 is reported. The virgin forests in the Amazon, Congo, and South East Asia decreased in area, while forests in the northern latitudes increased at the expense of tundra and barren land. The deforestation in the tropics might exacerbate drought impacts in adjacent regions, due to a change in type of cloud formation and increase of temperature, thus more evapotranspiration of soil-moisture and changed rain patterns while forests in the northern latitudes increased at the expense of tundra and barren land. Studies detecting cloud patterns using satellite imagery over recently deforested areas of the Amazon confirm that deforested areas develop more shallow clouds compared to the forested areas, the shallow clouds are not leading to rainfall. The forested areas can be considered as 'green oceans' creating evapotranspiration processes similar to those above warm oceans and leading to high convective cloud formation [8]. Numerical modelling of cloud formation and land use change suggests that deforestation leads to an increase in the average cloud's base height. Subsequently deforestation of a lowland might result in the disappearance of mist in the forested mountain adjacent to the lowland, subsequently leading to damage of the ecosystem in place at high elevations [9].

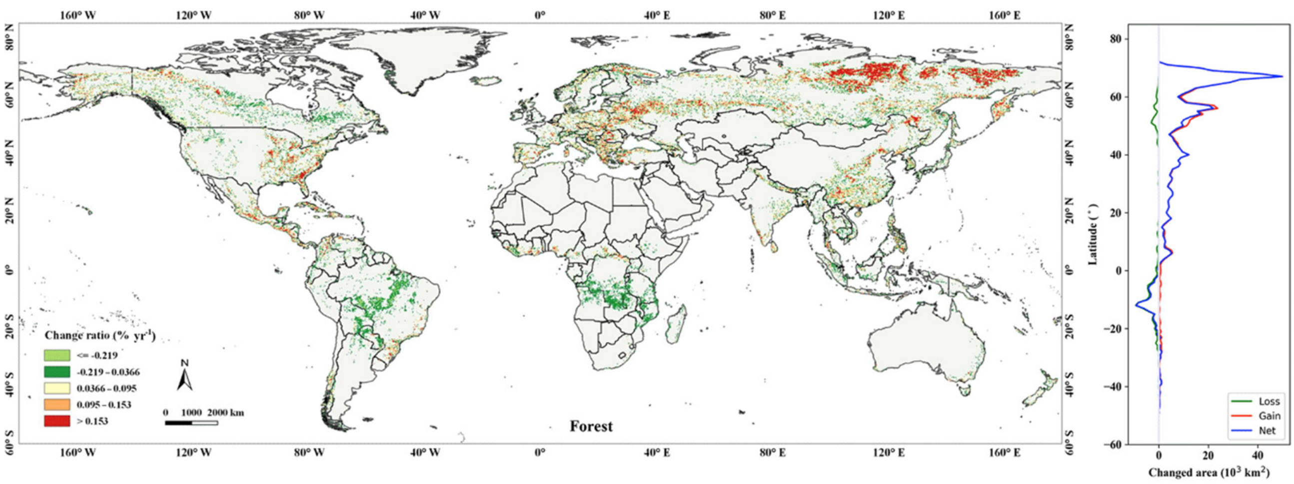

Figure 3. Percentage of annual change in forest cover at global level, the red spots in Siberia and Eastern Europe display an increase in forest cover. The green spots in central Africa, Amazonia, and Canada continued to decrease. Source Liu 2020.

There are various tree planting projects planned and taking place across the world. In 2019, Ethiopia claimed to have planted more than 350 million trees in one day. The African nations in the Sahel area are in the process of planting 'The Great Green Wall', an 8000 km barrier of trees spanning the length of the African continent from Senegal to Ethiopia. They are currently at 15% completion [10]. China is also building its own 'Great Green Wall' called the North Shelter Forest Program, albeit on desert land on which it still is not clear whether forest can grow or not. The European Union makes similar pleas; currently up to

36 percent of its territory is forested. The European forests account for less than 4% of the world forests. From 1990 to 2015, the total growing stock volume increased from 19,000 to 26,300 million m^3 in the European Union [11].

4. Urbanisation

Although urban areas make up a small fraction of the land surface (0.8%), more than half of the global population lives in urban areas [12]. Urbanisation's relevance in relation to drought events is varied. Urban areas tend to heat up more than surrounding areas because of the dark surfaces and cement that absorb the heat of the sun during daytime [13,14]. Temperatures can be up to 5 degrees Celsius higher in urban areas in both winter and summer. Buildings and paving of the surface prevent rain reaching groundwater underneath, while groundwater levels can be lowered locally on purpose, to build below the surface. Both phenomena may cause subsidence and may damage buildings and trees above. Further, drought events are often accompanied by an increase in air pollution [15].

Detailed monitoring of urbanisation at global scale is enabled by Earth observation combined with artificial intelligence in the framework of the Global Human Settlement Layer (GHSL). The GHSL produces data on the status and dynamics of human settlements by integrating remote sensing with demographic information [16]. It applies a people-based global definition, the degree of urbanisation method described by EUROSTAT [17], to the GHSL built-up and population data to delineate three spatial entities for all countries of the world: "Urban Centre", "Urban Cluster", and "Rural Clusters". An Urban Centre consists of contiguous grid cells (4-connectivity cluster) with a density of at least 1500 inhabitants per km^2 of permanent land or with a share of built-up surface greater than 0.5 of permanent land and has at least 50,000 inhabitants in the cluster with smoothed boundaries and <15 km^2 holes filled. This consistent definition allowed delineating more than 10,000 urban centers at global scale.

These spatial entities were combined with the European Space Agency (ESA) Climate Change Initiative (CCI)—Land Cover (LC) annual time series of consistent global LC maps at 300 m spatial resolution from 1992 to 2015. This dataset provides global maps dividing the land surface into 22 classes, which have been defined using the United Nations Food and Agriculture Organisation's (UN FAO) Land Cover Classification System (LCCS). In order to gain insight, we grouped land-use types of FAO into six super classes based on their relevance in drought impact and drought relief.

Urbanisation is monitored thanks to the availability of high-resolution satellite data and artificial intelligence algorithms capable of detecting build up areas [16]. In the following graphs, we give an overview of which land use type is transformed into urban and semi urban areas partitioned over the fifth IPCC report climate regions of the world in the last 23 years. We took the area occupied by the urban area in 2015 and intersected these areas with the land use [18] that was present in these areas in 1992, 2000, and 2015, thus gaining insight at the expense of which land use the city was built in recent decennia. The map in Figure 4 displays in which macro regions the urbanisation took place. In the analyses we detect which land use was transformed into urbanised landscapes with the specific characteristics we mentioned above.

Data are processed at a resolution of 300 m and give therefore a detailed overview of what has happened. In order to gain insight, land-use types of ESA are grouped into 6 super classes, in Appendix B the various land use classes and their clustering is described in detail. The classes were grouped based on their relevance in Drought impact and Drought relief listed in Table 1. The relief column lists some specific positive aspects of a land use type during a drought period, helping the population or the ecosystem to sustain the period of hardship. The impact column reveals also impacts that might be unexpected, additional impacts and not related to the expected dying off of the vegetation.

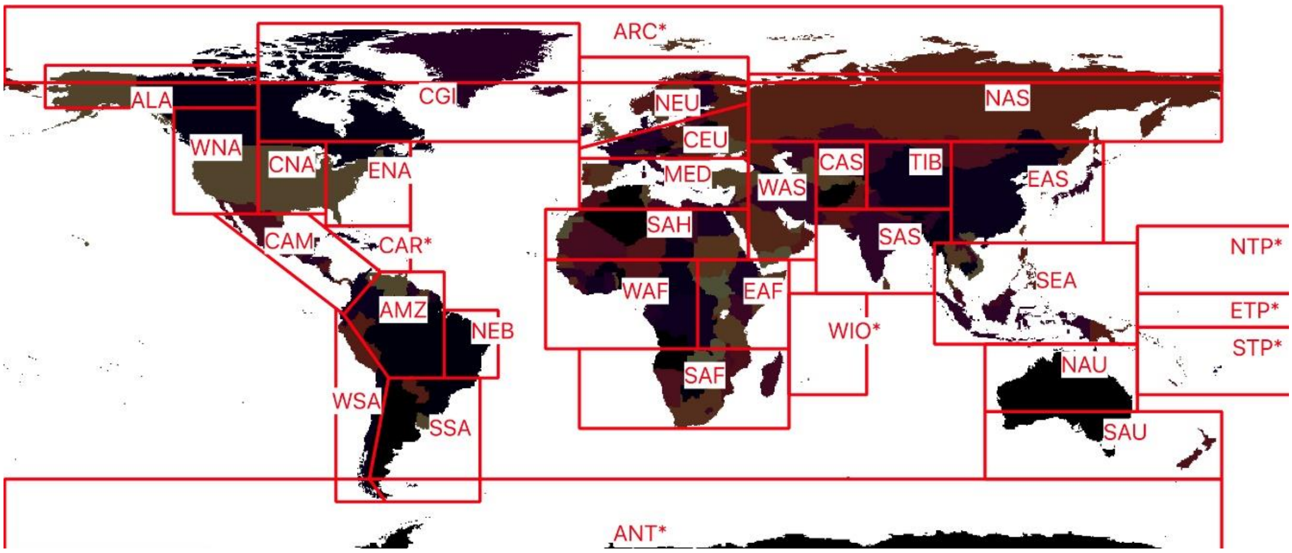

Figure 4. Map of climate macro regions of the world.

Table 1. Land use types, possible drought impacts, and droughts relief.

Land Use Type	Drought Impact	Droughts Relief
Alluvial and coastal plains	Subsidence, cracking	High groundwater level, cooling through wind
Cropland and Potential cropland	Failing harvest, groundwater depletion through irrigation	Access to crops close to the city, cooling of area
Forest	Ignition of wildfire subsequent air pollution, dying of wild species, trees might die.	Strong cooling, water reserve in groundwater, relaxation, some food (nuts, small animals, fish in creeks)
Grass	Ignition of wildfire subsequent air pollution. Grass recovers, but not all species.	Cooling through wind, access to meat, milk close to the city
Natural open spaces	Ignition of wildfire, dying of wild species.	Cooling through wind, relaxation, some food (berries, small wildlife)
Urban	Extreme temperatures, additional air pollution, groundwater depletion, surface water and reservoir depletion.	Shelter for humans and the animals and plants accompanying them.

The analysis summarised in this section, provides an overview of changes in LC within the urban centres over three main periods—1992, 2000, and 2015—that are consistent with the GHSL multi-temporal data for 1990, 2000, and 2015 [16]. Urban centres were aggregated according the climate macro regions identified in the IPCC 5th report [19]. These macro regions were defined by the IPCC in order to assess impacts of climate change in regions characterised by similar meteorological processes. The aim is to provide insights into the main changes and losses of specific classes of LC that occurred in the urban centers, thus allowing understanding of the urban encroachment process over the period 1992–2015 and its impacts on droughts.

In the map of Figure 4, the repartitioning of the mentioned IPCC 5th report macro-regions is displayed. Please find in Appendix A the full name of the abbreviated macro-regions in the map.

The three bar plots in Figure 5 show the changes in the proportions of the different land cover classes and the evolution of urban land per macro-region in 1992, 2000, and 2015. It allows identifying in which macro-region urbanisation has developed the most and at expense of which main land cover type.

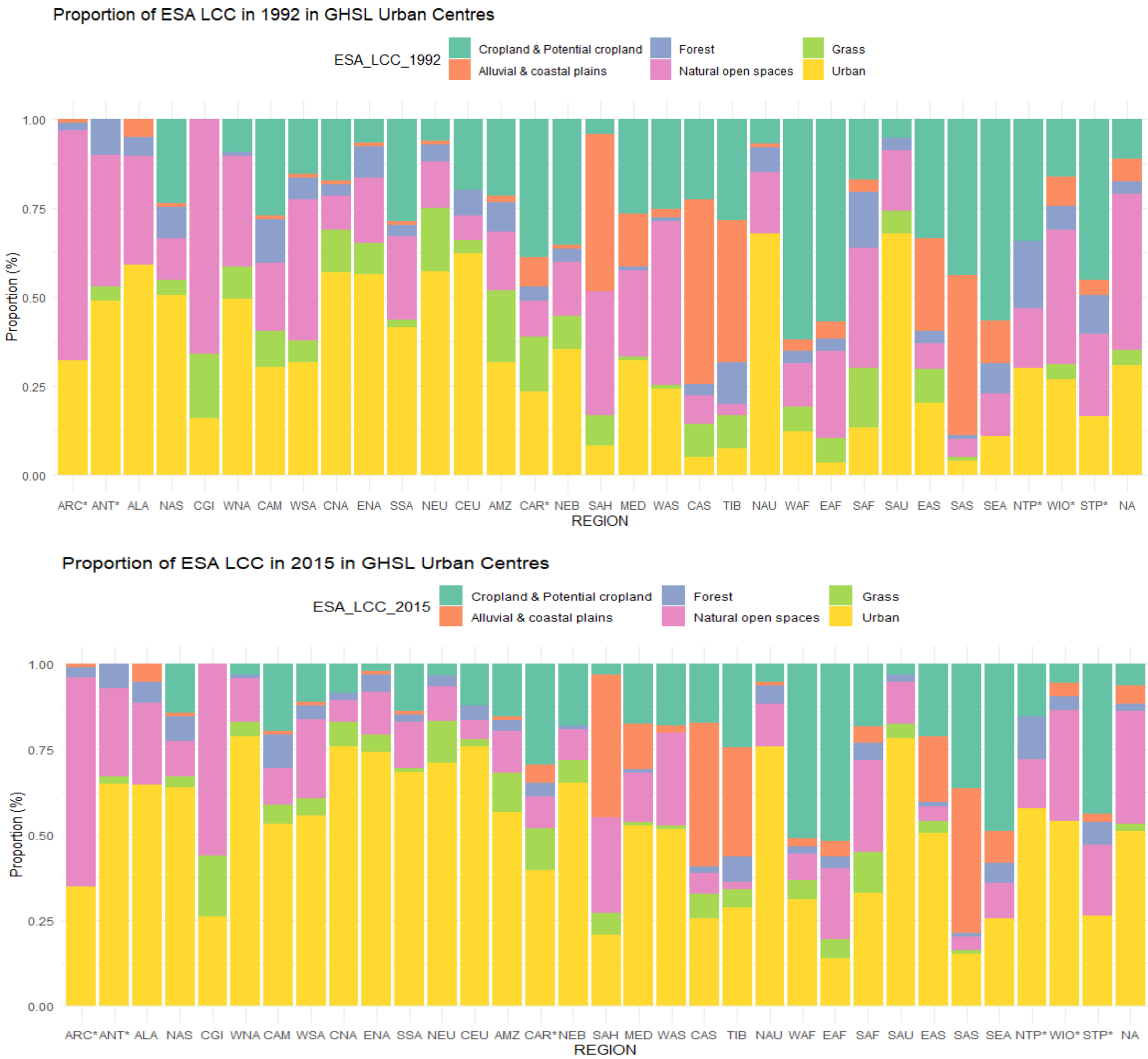

Figure 5. Landcover changes in urban centers.

In Western North America (WNA) we can see a sharp increase of the urban surface mainly at the expense of natural open spaces. Since the climate in this region is marked by hot and dry summers the risks in this region for heatwaves and wildfires are increased by an increasing urbanisation—the so-called wildland-urban interface [19,20]. Western South America (WSA) follows a similar trend, in which urbanisation is at the cost of natural spaces. In Central North America (CNA) and Eastern North America (ENA) we see a similar pattern but at the expense of cropland. In North East Brazil (NEB), a known drought prone area, urbanisation was at the expense of cropland as well, urbanisation more than doubled, and the forests disappeared completely in the urban area. In ENA cropland disappeared practically within the reach of the urban area, leaving natural open spaces as the only non-urban class available. In East Asia (EAS) the urbanisation more than also doubled at the expense of all other components. In South Asia (SAS), apparently, a very different urban landscape pattern exists leading to a more mixed land use in the urban area; urbanisation took place but not leading to high-density urban area with high risks of cementation. The urbanisation in South East Asia and in Africa both East, West and South follow a similar pattern. Urbanisation takes place, it has doubled, but the urban area remains interspersed with other land uses, with croplands as the main alternative land use. In Central Europe (CEU) and the Mediterranean area (MED) we see a very limited urbanisation, mainly at the expense of cropland. In Europe, most urbanisation took place in the north (NEU) at the expense of grasslands.

The graph in Figure 6 displays the top 20 cities in Northern Europe that witnessed the greatest increase in the proportion of urban land within the urban centers in the last three decades (yellow represents the percentage detected in 1992, red the percentage detected in 2015). It concerns cities in economically performant areas around Amsterdam, London, Birmingham, Stockholm, Oslo, and Bergen. Interesting is that German cities did not enter the list, suggesting that in Germany the urbanisation takes place by reviving existing urban areas. Further, we can see that urbanisation takes place in small towns, such as Södertälje, Alkmaar, Purmerend, Hoorn, Peterborough, Royal Turnbridge Wells, or Reddish, more than 50 km from the main urban center.

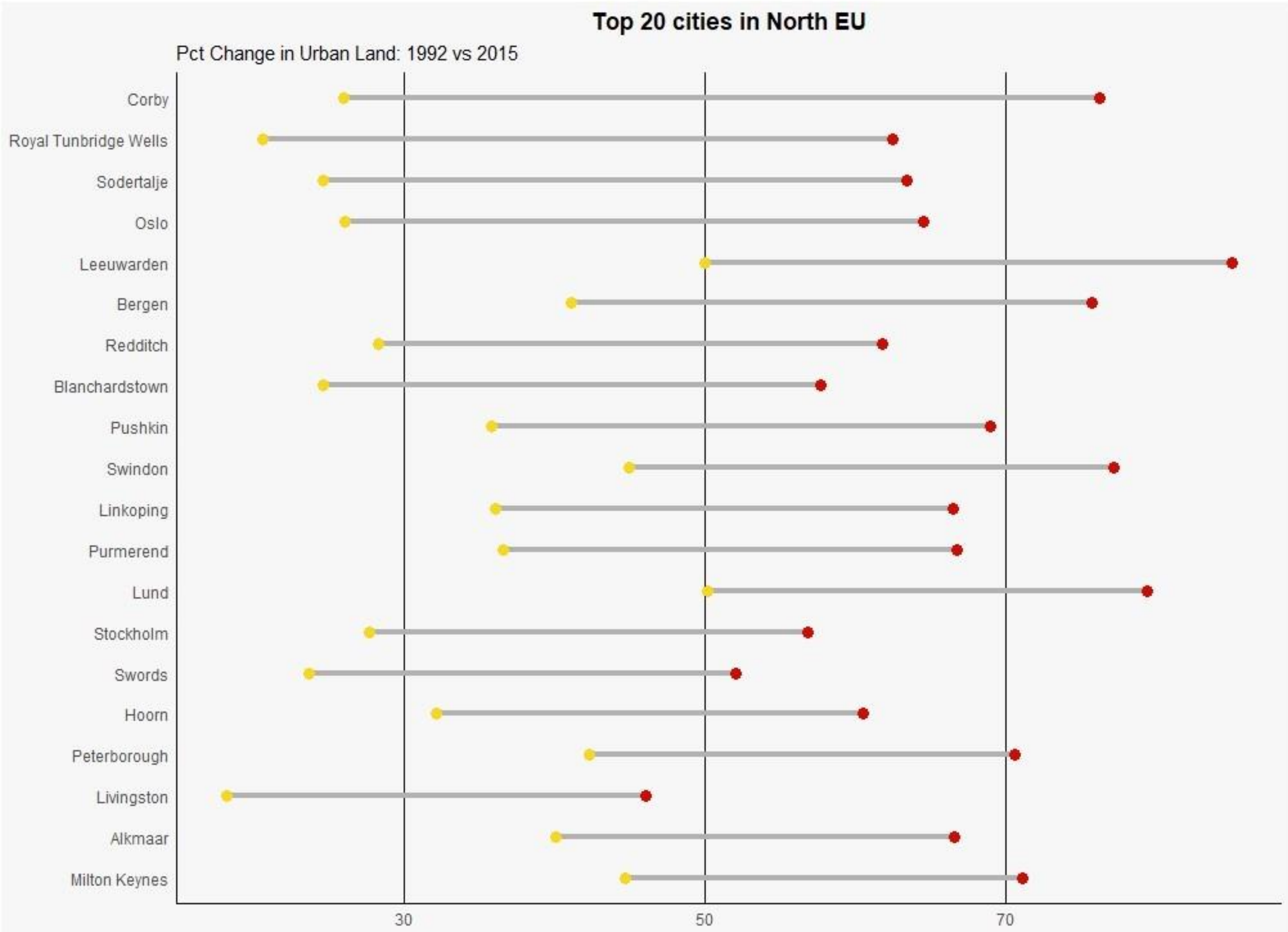

Figure 6. Land use changes in North European cities.

Linking to the subsection on deforestation we analysed which urban centers were built in the last 30 years at the expense of forest. Cities with more than 100,000 inhabitants, built at the expense of forest, we find in Southern Africa, South Asia, and South East Asia. The forest loss is displayed, in Figure 7, as a percentage of the total urban area that was detected in 2015. Note that the forest in these urban centers is lost, not only to urbanisation, but also to croplands or other human intensive uses.

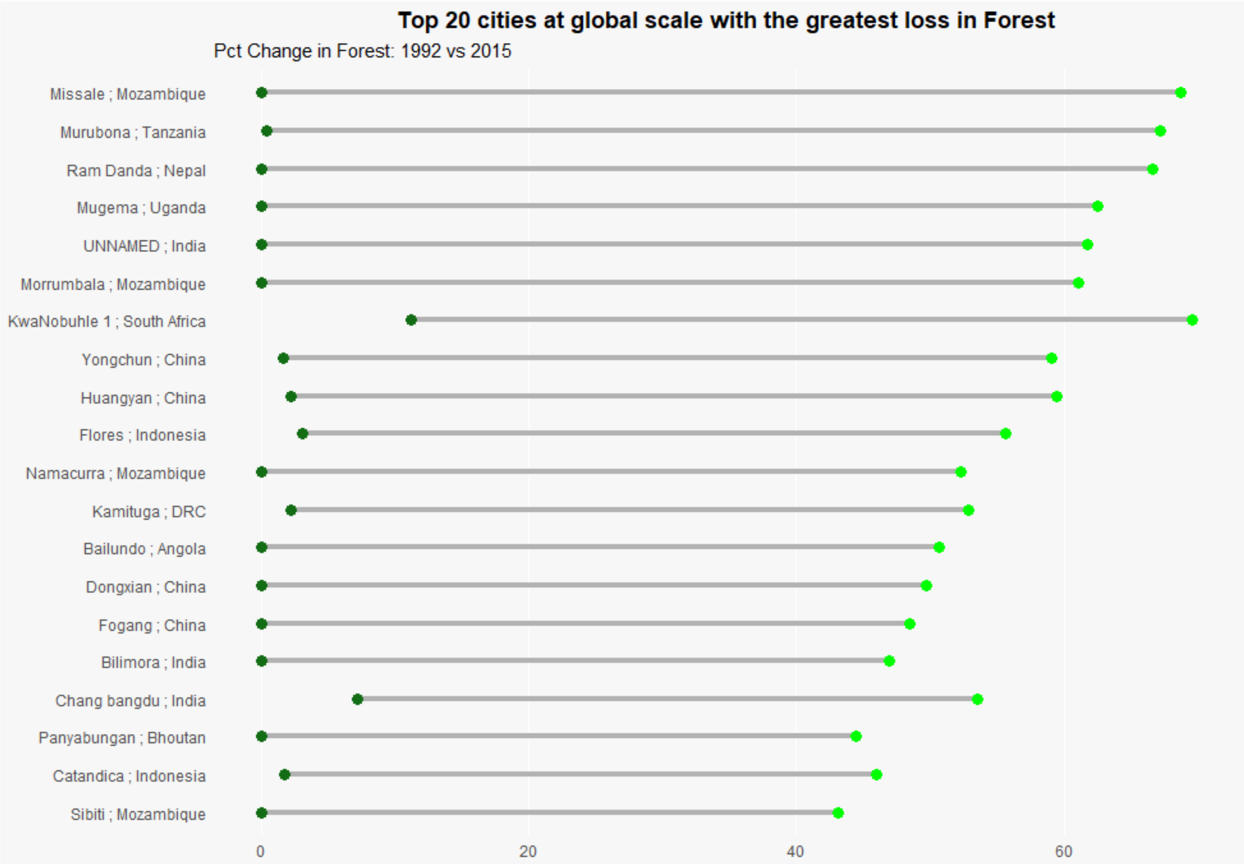

Figure 7. Forest loss due to urbanisation.

5. Conclusions on Land Use Trends and Drought

We reported that there is a trend of increasing wildfires in the last five years in Europe. The total land affected by wildfires in Europe was 12,000 km^2 in 2017, more than three times the area affected in an average year. Over 5% of the forest in the tropical zones was deforested during the last 10 years, replaced by croplands and pastures. On the contrary, an increase of natural forest at the expense of tundra and grassland was recorded in the Northern Hemisphere. The area impacted by dense urbanisation doubled, compared to 1980, especially outside Europe. Regarding soil degradation, drought leads to less vegetation cover of the soil and boosts soil erosion when rainfall returns. On agricultural land, a loss of 21 ton/ha soil per year on average is estimated, which is up to 16 times the natural weathering process of rocks to form soil [21]. The actual loss depends on tillage, terrain topology, and soil type and varies largely between regions and countries. Furthermore, drought can lead to further mineralization of the soil, a process resulting in a lower capacity of the soil to absorb rainwater. Trends is these important processes are not systematically reported using satellite imagery techniques. Apart from the reforestation in the boreal hemisphere, most of the reported trends can be considered negative for reducing drought impact. Without reversing these trends, the SDG 15 will not be achieved by 2030.

We can conclude from satellite image detection that we face a sharp increase in urbanisation, (doubling in 30 years) wildfires (doubling in last 5 years), and deforestation practices. The relevance of inverting these trends to lessen drought impact lies in two factors. First, the progressive climate heating leads to more intense droughts. Secondly, land use practices that exacerbate drought generate an ever more drought prone landscape. If the practices surpass a certain threshold, the ecosystem services that sustain the landscape can collapse. Such events are well known in recent history, with the dust bowl 90 years ago in the US as the most alarming example.

Making the landscape less prone to drought will be a task of major importance in the next decade, since the failure to curb climate change and especially its evapotranspiration component at global level may further increase the impacts of droughts. In the table below we list the most detrimental land use practices in relation to drought. Table 2, hereunder, is not exhaustive and extracted from an overview of disaster risk impacts on ecosystems [22]. Table 2 is merely published to open the debate, set up monitoring, and research priorities. With new insights and practices reported by the drought community, this table can evolve in the future. New research will need to focus on the unknown dimensions of drought, the availability of groundwater, and the variability of soils. In the table, we do not list the benefit of the named land use practice. The benefit exists and is relevant; otherwise, the practice would not exist. The mediation methods we list compete with the implicit benefit.

Table 2. Land use practices, possible drought impacts, and mediation methods.

Land Use Practice	Drought Impact	Mediation Method
Deforestation	Less shadow, less cloud formation, less rainwater percolation to groundwater reservoirs, higher average temperatures	Reforestation, rewilding, silvopasture, agroforestry, restoration of small landscape elements. Disincentivize relationship deforestation and wildfires, practices of forest clearing though fire in the dry season or during a drought.
Reservoir construction	Sediment trapped leading to beach erosion downstream, evaporation of reservoir surface water, less fertilisation of flood plains, fish migration blockage, ecosystem disturbance, loss of fertile land.	Smaller reservoirs, fish access points, sediment outlets, cleaning of reservoirs, storage of rainwater in groundwater bodies instead of reservoirs.
Road construction, urbanization	Groundwater lowering leading to soil subsidence and less groundwater, Increased temperature (black colour of tarmac) heat island effect, Temporary flooding after heavy rainfall (also related to the subsidence of the soil), no storage of the rainwater in the soil, Additional tree cutting/limited tree planting to save on maintenance costs	Creation of additional holes/lakes in the landscape to collect excess rainwater and resupply to groundwater body. Separation of sewage systems to collect rainwater and resupply groundwater bodies. Systematic tree planting along roads, on south face of buildings to provide shadow. Forbidding of pumping after completion of construction. Concentrate on high-rise buildings. Limitation of road construction, favour alternatives for mobility. Grass roofs or white roofs. Construct on soils suitable for construction (protect fertile soils from construction). Allow for wind alleys throughout the urban area. Tax tree covered soils less than covered soils in the urban area.
Irrigation	Loss of water through evapotranspiration, full failure (no harvest at all) during severe drought, groundwater depletion, dependency of glaciers (not sustainable with current lack of climate policy implementation)	Change to crop types needing less water, move to silvopasture and agroforestry, pricing water for agricultural use, desalination of seawater using solar/wind energy
River/streams canalization	Low flow during summer/dry season, ecosystem degradation, loss of peat lands, reduced capacity to store water in the land	Allowing rivers/streams to meander again, compensate landowners losing land, restore peat lands and fauna belonging to peat lands (to curb, e.g., mosquitoes)
Industrial agricultural practices	Reduction of soil organic matter content leading to less soil moisture, compaction of soils due to heavy equipment, lowering of groundwater table to allow for heavy equipment, additional evapotranspiration, and soil erosion due to large size of fields, wind erosion	Stimulate agricultural practices that favour soil quality or tax pesticides. Forbid use of heavy equipment on susceptible soil types, forbid field sizes above a certain threshold, compensate loss of land due to restoration of bushes, hedges, and parcel edge vegetation
Wildfires	Increased temperature and wind, heating up the landscape, soil erosion due to lack of vegetation cover during heavy rains, reduced capacity of the soil to buffer rainwater, loss of human and wildlife, ecosystem services loss	Reforestation, rewilding, forestation with tree types less susceptible to fire (broadleaves), less focus on (wood) production, more on quality. Landscape variation, large mammal reintroduction (to keep the landscape open) Check on relation deforestation and wildfires, disincentive deforestation (animal fodder production in former Amazon forest plots)

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Appendix A. IPCC Macro Regions

In Table A1 are reported the names of IPCC 5th report macro regions, ocean regions are not listed or analysed. The macro regions are based on climatological criteria.

Table A1. Names and abbreviations of IPCC macro regions.

Abbreviation	Name
ARC	Arctic Ocean, islands, and coasts
CGI	Canadian Artic Islands, Greenland, Iceland
ALA	Alaska and North West Canada
WNA	Western North America
CAN	Central North America
ENA	Eastern North America
NEU	Northern Europe
CEU	Central Europe
MED	Mediterranean
WAS	Western Asia
CAS	Central Asia
NAS	Northern Asia
TIB	Tibetan Plateau
EAS	Eastern Asia
SAH	Sahara
WAF	West Africa
EAF	East Africa
SAF	Southern Africa
CAM	Central America and Mexico
CAR	Caribbean, small islands
AMZ	Amazon
WSA	West Coast South America
SSA	Southern South America
NEB	North Eastern Brazil
SAS	South Asia
SEA	South East Asia
NAU	Northern Australia
SAU	Southern Australia and New Zealand

Appendix B. Clustering of FAO-EAS Land Use Classes

Table A2 in this appendix leads the analysis of a geometrical intersection of GHLS data for the last 30 years with ESA land use data in order to gain insight into what land use is transformed into urban and semi urban landscapes. Thus, the other GHSL classes can be omitted, presuming that the small fabric of villages urbanisation in the rural area does not impact the microclimate.

Apart from a clustering of the classes of the ESA land use product, a clustering on countries or regions is also required in order to condense the information and gain insight into global trends.

The ESA land use product are broken down into the classes listed in the first column, we regrouped these classes into five super classes helping to understand whether urbanisation took place at the expense of croplands, forests, nature, grasslands, or alluvial and coastal plains. Each superclass comes with its own characteristics for drought related impacts or exacerbation. Cropland reduction will create need for croplands further away, forest reduction will increase the heat island effect, alluvial and coastal plains reduce access to fertile land and have a natural inundation risk, subsidence events might also accompany such urbanisation. The loss of nature and grass classes reduce the natural and open space around the city, and might lead to groundwater level lowering, whilst probably being the cheapest option for acquiring land.

Table A2. Classification of ESA land use classes.

ESA Class	Grouped Class
10 Cropland, rainfed	10 Cropland and potential croplands
20 Cropland irrigated or post flooding	20 Alluvial and coastal plains
30 Mosaic croplands > 50%, natural vegetation	10 Cropland and potential croplands
40 Mosaic natural vegetation > 50%, cropland	10 Cropland and potential croplands
50 Tree cover, broadleaved, evergreen	50 Forest
60 Tree cover, deciduous	50 Forest
70 Tree cover, needle leaved, evergreen	50 Forest
80 Tree cover, needle leaved, deciduous	50 Forest
90 Tree cover, mixed leaf type	50 Forest
100 Mosaic tree and shrub > 50%	100 Natural open spaces
110 Herbaceous > 50%	110 Grass
120 Shrubland	100 Natural open spaces
130 Grassland	110 Grass
140 Lichens and mosses	100 Natural open spaces
150 Sparse vegetation	100 Natural open spaces
160 Tree cover, flooded, fresh water	20 Alluvial and coastal plains
170 Tree cover, flooded, saline water	20 Alluvial and coastal plains
180 Shrubs, flooded	20 Alluvial and coastal plains
190 Urban areas	190 Urban
200 Bare areas	100 Natural open spaces
210 Water bodies	100 Natural open spaces
220 Permanent snow and ice	100 Natural open spaces

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