Student thesis series INES nr. 587

Climate, Conflict, and Fire: Examining Correlations and Fire Indicators in Manisa and Diyarbakir, Turkey

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2023

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Bachelor's degree thesis, 15 credits in **Physical Geography and Ecosystem Analysis**

Department of Physical Geography and Ecosystem Science, Lund University

Level: Bachelor of Science (BSc)

Course duration: *March* 2023 until *June* 2023

Disclaimer

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Acknowledgements:

Great thanks to Lina Eklund and Micael Runnström, who introduced me to the topic of Climate, Conflicts and fire dynamics in the Middle East and sparked my interest in doing research in this area and dedicating my bachelor's thesis to the question of how well climate and conflict correlate with the frequency and occurrence of fires. I would also like to thank you for all the guiding questions, encouraging different perspectives and support.

Thanks also to my evaluators, Marko Scholze and Veiko Lehsten, as well as my critics Julia Bergwall for their valuable input.

Thanks to the Department of Physical Geography and Ecosystem Science for building the basis for a comprehensive understanding of environmental analysis and to my fellow students for all the exchanges and good times.

Abstract

Climate issues are currently of attention in various contexts as changing climate factors affect us in many ways. One of these effects is the influence on the probability and frequency of fires, although other factors, especially anthropogenic ones, also play a role. In the Diyarbakir region, a Kurdish-Turkish province affected by the PKK's conflict (Partiya Karkerên Kurdistan - Kurdistan Workers' Party) with Turkey, an exceptionally high number of vegetation fires and armed conflicts occurred in the year of the failure of the peace process in 2015. Diyarbakir is here compared with the non-conflict region of Manisa, which are climatically comparable and mainly characterised by agricultural land. Climatic and conflict-related influencing factors to the appearance of vegetation fires are examined and compared for these two regions in this Bachelor thesis. This study finds that Diyarbakir has more recorded vegetation fires in almost all years considered from 2001-2021, despite climate conditions similar to Manisa. Further, the spatial proximity of vegetation fires and armed conflicts was studied in Diyarbakir in 2015 using the Bivariate Local Moran's I analysis (BiLISA). It reveals a correlation between the number of armed conflicts and vegetation fires from June to September. Significant correlations are found in cities and agricultural land. By performing the Spearman's Rank Correlation test between climatic variables, the occurrence of armed conflict and the number of vegetation fires to better understand how well they correlate, a relationship is found between the climatic variable and fire in both provinces. However, only one correlation between armed conflicts and vegetation fires was found in December Diyarbakir 2015. The results of the quantitative analysis show that the relationship is very localised. Thus, considering the complexity of fire occurrence and connections to climatic, topographical and anthropogenic factors, further investigation of the occurrence of vegetation fires should also take into account political and socio-economic factors and be assessed at different local scales and various regions.

Keywords: Geopolitics, Vegetation fires, Armed conflict, Earth observation, Kurdistan, PKK, Turkey

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1. Introduction

The effects of climate change can be seen in various facets, such as the increase in extreme weather (Barmpoutis, 2020; Ganteaume et al., 2021). The countries of the Mediterranean region are exposed to numerous fires each year due to increased levels of fire weather risk (Ganteaume et al., 2021; Jolly et al., 2015). In Turkey, this is shown by an increase in temperature and regional decreases in precipitation, with an increase in extreme values of individual fire risk days also evident (Ertugrul et al., 2021). Natural fires largely follow a temporal pattern, with fire frequency highest in summer (Ganteaume et al., 2013).

Studies based on future climate simulations driven by the IPCC (Intergovernmental Panel on Climate Change) emission scenarios show how an increased temperature increases the risk of fire in Mediterranean countries (Lestienne, 2022). The likelihood of fire depends on various climatic factors (temperature, precipitation, wind, soil moisture) throughout the year and environmental factors (vegetation matter, available biomass). Factors affecting the moisture content of vegetation mass affect flammability and combustibility (Calle, 2008; Gülçin & Deniz, 2020). Topographic factors such as elevation, slope, and aspect, as well as the distance to settlements or roads, are influencing factors that can favour or weaken the intensity and spread of fires (Gülçin & Deniz, 2020). In mountainous areas, for example, the topography is decisive for the wind direction and speed and, thus, also for the relative humidity (Calle, 2008). Anthropogenic factors should also be considered in addition to climatic factors causing fire activity. Unintentional fires, e.g., due to negligence and intentional fires, such as those caused by burning fields as an agricultural measure, are common burning sources in Turkey, Syria and across the globe (Avci, 2011; Zubkova et al., 2021).

However, the geopolitical aspect and the occurrence of extraordinary fires due to armed conflict have not yet been adequately researched. The effects of armed conflicts in their causal connections to the environment, land systems, economy, and migration must be better understood (Eklund et al., 2021; Eklund, 2017). Based on the observation and different analyses of exceptionally high fire activity in conflict regions, it is shown that an increased frequency of fires is correlated to conflicts and used as a tactical military tool (Dinc, 2021; Dinc et al., 2021; van Etten et al., 2008; Zubkova et al., 2021). In the Kurdish regions of Turkey, setting fire to forests or agricultural land is a military tactical measure that has been used repeatedly in the various phases of the Turkish-Kurdish conflict, especially since 2015, the end of the peace process, although the government denies this. Nevertheless, an exceptionally high frequency of fires in Kurdish-Turkish areas is reported in print and social media, accompanied by accusations against the Turkish army (Dinc, 2021; Dinc et al., 2021).

However, many studies also already focus on the effects of fire and conflict on land systems and their importance to populations (Baumann & Kuemmerle, 2016; Eklund et al., 2021; Eklund, 2017). The increased frequency of fires in conflict areas in Turkey's neighbouring countries, Iraq and Syria, has also been explored regarding causal relationships (Zubkova et al., 2021). Correlation analyses are applied to illustrate their relationships, such as between fire, climate, land use, and land cover in the studies by Dinc, 2021, Dinc et al., 2021, Eklund et al., 2021, Eklund, 2017, and Jaafar et al. (2022).

The correlation between climate, conflict, and fire is described by Zubkova et al. (2021.), whereby the focus is on the analysis of fire activity in Syria concerning socioeconomic issues related to food security as well as the assessment of climate variables to determine the most important predictors of fire activity (Zubkova et al., 2021). The study by Zubkova et al. (2021) showed that the climatic variables of precipitation and soil moisture had the strongest correlation to burned areas (km^2) in the growing season (defined as October to April).

Another strong correlation has been between the cumulative FWI (Canadian Fire Weather Index) and burned areas during the fire season (May to October). Further, it concludes that the conflict intensity, combined with climatic conditions, boosts fire activity (Zubkova et al., 2021).

It is necessary to understand that fires occur due to various influencing factors. The geopolitical aspect of fire must be addressed in regions of armed conflict or socioeconomic stress. Therefore, it is essential to understand how these different influencing factors, natural and geopolitical, through e.g. conflicts, contribute to fires. The extent and significance of how conflicts contribute to fires must be further analysed in different conflict regions to understand the causal relationships better and thus gain a greater comprehension of conflict situations and their potential effects on fire incidents and the environment.

1.1 Study Aim and Objectives

This Bachelor's thesis aims to test how well climate and conflict correlate with the frequency and occurrence of fires. For this purpose, a comparison is made between the provinces of Manisa, unaffected by conflict, and Diyarbakir, where there is a conflict between Turkey and Kurdistan Workers' Party (Partiya Karkerên Kurdistan, PKK). The study is based on using remote sensing products, GIS applications, and statistical and geospatial analysis.

In arid and Mediterranean regions, as in Turkey, climate is a strong predictor and influence of fire activity (Bedia et al., 2018; Dube, 2009; Miller et al., 2023; Zubkova et al., 2021). Nevertheless, other variables can also influence fire. Therefore, this thesis compares and examines the relationship between climate, conflict, and fire in Manisa and Diyarbakir regions over the period 2001-2021 and in more detail in 2015, thus contributing to a better understanding of the fire's driving factors and geopolitical aspects. It is assumed that climate variables strongly influence fire in these regions and that armed conflicts act as an additional driving factor of fires and thus influence fire occurrence. The objectives of this thesis focus on (1) a spatial-temporal description of the climate variables and the number of conflicts and fires, (2) an evaluation of the spatial proximity of conflicts and fires in Diyarbakir in 2015, and (3) analyses of the correlation of climate, conflict, and fire via the Spearman's rank correlation test in Manisa and Diyarbakir, 2015.

1.2 Background on theory involved and historical-political context

1.2.1 Conceptual Framework

For several years, remote sensing techniques and geospatial analyses have been used to investigate fire risks, determine fire parameters and their cartography (Bedia et al., 2018; Camia et al., 2006; San-Miguel-Ayanz et al., 2013). This approach is also used to study the connections of fire, it’s influencing factors, and geopolitical context (Calle, 2008; Eklund et al., 2021). Many of these data are freely available and in relatively high resolution. For this presented analysis, the focus is mainly on satellite-based climate and fire data. Multitemporal Earth observation data are usually related to the spectrum of visible light, respectively their reflectance, infrared sensors, microwaves, and radar sensors. Fire observations specifically are additionally based on thermal anomalies. This spatial-temporal information is extracted and stored as image data or in a spatial database representing the real world (Barmpoutis, 2020; Janssen & Huurneman, 2001). Earth observation data are versatile. A further advantage of remote sensing analysis is the study over more extended periods to identify changes and draw conclusions about changing factors (Janssen & Huurneman, 2001). Remote sensing techniques are also particularly suitable for areas that are difficult to access, such as conflict regions (Eklund et al., 2021; Janssen & Huurneman, 2001). Spatial cluster analysis and spatial statistics determine a correlation based on their feature's value, location, and contiguity, showing spatial proximity and locational similarity. Thus, this correlation analysis is used to check for spatial clustering. These geoprocessing tools are integrated into software systems products, such as ArcGIS or GeoDa (Anselin, 1995; Anselin, 2005, 2023; Esri, 2020).

1.2.2 Historical-Political Situation of the Turkish-Kurdish Conflict

The Turkish-Kurdish relationship describes a protracted conflict that has lasted over a century. With the founding of the Republic of Turkey in 1923, tensions increased. The Kurds are not a protected minority, settled in the east and southeast of Turkey. Their identity and civil rights still is severely restricted. Kurdish culture, language, and tradition were also banned. Even the Kurdish existence in their ethnic-religious or cultural differences within Turkish society is denied (Savran, 2020). Some rebellions were brutally put down in the 1920s and 1930s (Savran, 2018). The Kurdistan Workers' Party PKK was founded in 1978 and took up armed conflict against Turkey in 1984. The PKK's goal was the recognition of Kurdish identity and a form of autonomy in the Kurdish areas (Savran, 2020; Savran, 2018). In 2009, the first peace process surprisingly began under the leadership of the ruling Justice and Development Party (Adalet ve Kalkınma Partisi, AKP), which only lasted until 2011. A second attempt at the peace process began in 2013 after PKK leader Abdullah Öcalan called for a ceasefire (Savran, 2020). However, there was disagreement between the parties on many issues regarding the intended path, e.g. the question of when the PKK should lay down its arms or even the expectations of both parties. Overall, the process lacked transparency and missed the opportunity to allow independent mediators (Akgül & Görgün Akgül, 2023). Doubts prevailed on both sides, so the peace process did not enjoy unqualified public support. On the one hand, the Turkish side doubted that negotiations with "terrorists" were possible; on the other hand, Öcalan was not considered a legitimate spokesman by all groups within the PKK. After the election success of the pro-Kurdish party (Halkların Demokratik Partisi, HDP) in the parliamentary elections in June 2015, the AKP lost its absolute majority. As a result, the Turkish government broke the peace process through Prime Minister Recep Tayyip Erdoğan (Bingöl, 2022). With the failure of the peace process, the Turkish-Kurdish conflict increased sharply again(Savran, 2020; Savran, 2018).

1.2.3 Geopolitics in the Turkish-Kurdish Conflict

Similarly, the number of fires in Kurdish areas increased after the peace process broke down in 2015 (Dinc, 2021). Setting fires in Kurdish areas was a military tactic of the Turkish army against the PKK as early as the 1990s to suppress Kurdish uprisings (Dinc, 2021; Dinc et al., 2021; van Etten et al., 2008; Zubkova et al., 2021). Forest fires were frequently observed near the evacuated Kurdish villages (van Etten et al., 2008). An analysis by Dinc in 2021 of fire incidents in the Kurdish provinces of Sirnak and Dersim in Turkey showed a positive correlation between the number of fires and the number of conflicts taken up. In the public reporting in the print media following the end of the peace process, the Turkish-Kurdish daily newspaper Özgür Gündem reported intensively on the fires in 2015, unlike the pro-government dailies, which ignored this almost completely. Özgür Gündem's reports blamed the Turkish Armed Forces (TAF) for causing the fires. Also, they explained that the army deprived civilians of the opportunity to extinguish the fires (Dinc et al., 2021). The systematic destruction of the environment by fire, with its short- and long-term impacts on land systems, land cover, and land use, is already been analysed in research (Baumann & Kuemmerle, 2016; Eklund, 2017; Sauti & Karahalil, 2022; Viedma et al., 2017) Some studies explore the use of fires and their consequences as a geopolitical measure (Dinc, 2021; Jaafar et al., 2022). This bachelor thesis focuses on testing the relationship between conflict and the occurrence of fires in Diyarbakir province.

2. Materials and Methodology

2.1 Study Area

The Turkish province of Manisa and the Kurdish-Turkish province of Diyarbakir (Figure 1) are the sites of interest for this analysis and comparison.

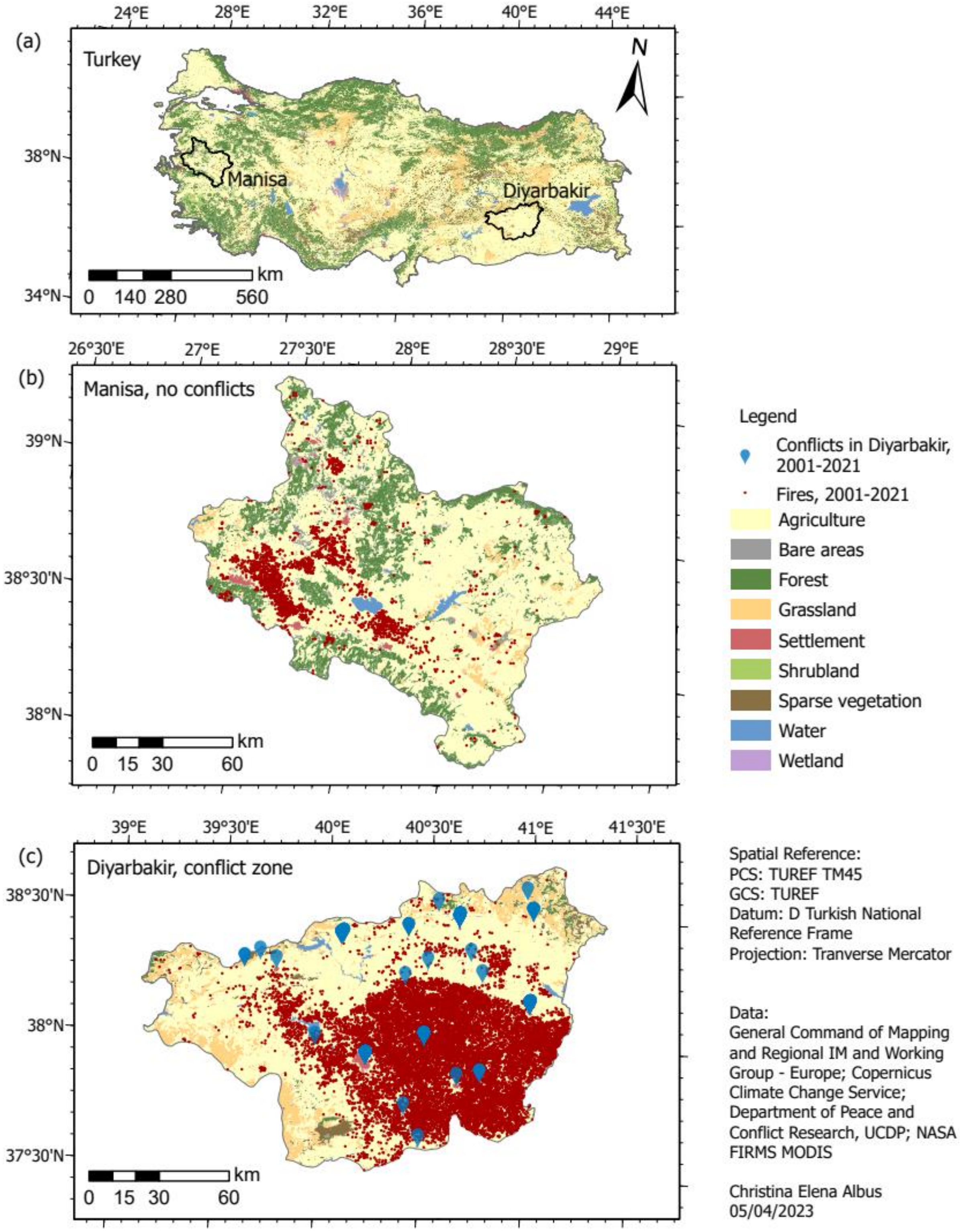

Figure 1. Study area of the Turkish province of Manisa (b) and the Kurdish-Turkish province of Diyarbakir (c) and their classified land cover, occurring conflicts and fires in 2001-2021, and their location in Turkey (a).

Manisa province (Figure 1b) is located in western Turkey (Figure 1a) and is predominantly covered by agricultural land (68%) and forests (22%), according to the 2015 Copernicus Climate Change Service land cover dataset (2019). The agricultural land can be found in the entire province, while the forest is located on the northern and southern borders and in the west of the province. The province has a size of 13339km^2 and elevations up to 2000m in the northeastern mountainous region and the southeastern border of the province, according to the datasets of General Command of Mapping and Regional IM and Working Group (2023) and NASA-JPL (2020). The Mediterranean climate dominates most parts of Manisa, while the continental climate of Central Anatolia influences the high mountains and plateaus. The province has several national parks and natural and cultural monuments, such as Spil Mountain National Park and Mesir Nature Park, Sureyya Nature Park, and Kula Fairy Chimneys Natural Monument (Gülçin & Deniz, 2020). The province of Manisa is located on the western edge of Turkey, a part of the country that is not part of the settlement area of the Kurds (predominantly south-eastern Turkey) (Kaya, 2020).

Diyarbakir (Figure 1c) is located in the southeast of the country and has an area of about 15020km^2 (General Command of Mapping and Regional IM and Working Group, 2023). The province is predominantly characterised by agricultural land (82.7%) and grassland (11.6%), based on the 2015 Copernicus Climate Change Service (2019b). A semi-arid continental Mediterranean climate predominantly characterises Diyarbakir province. The high altitudes, up to 2852m (NASA-JPL, 2020), in the north and northwest are part of the foothills of the Eastern Taurus Mountains. In these regions, the climate is more continental influenced and thus colder and wetter than in the Mediterranean southern areas of the province (Almazroui et al., 2019; Iyigun et al., 2013). In the Diyarbakir region, the proportion of the Kurdish population is 75-100% (Kaya, 2020).

The Mediterranean climate strongly characterises both regions. Although they differ slightly in temperature and precipitation, see Figure 2, the two regions are still climatically comparable. Diyarbakir has significantly less precipitation in the winter and summer months than Manisa and almost constant precipitation from January to April. The summer months of July and August are exceptionally dry in Diyarbakir, with only minimal precipitation. Air and surface temperatures in winter in Diyarbakir are close to 0°C and rise to about 30°C in the summer months. Temperatures in Manisa Province, on the other hand, have a less extensive range. In winter, the temperature is at its minimum value of 4°C and ranges to 25°C (air temperature) and 27°C (surface temperature) in July and August. The average values of the months are shown in Table A1. in the Appendix.

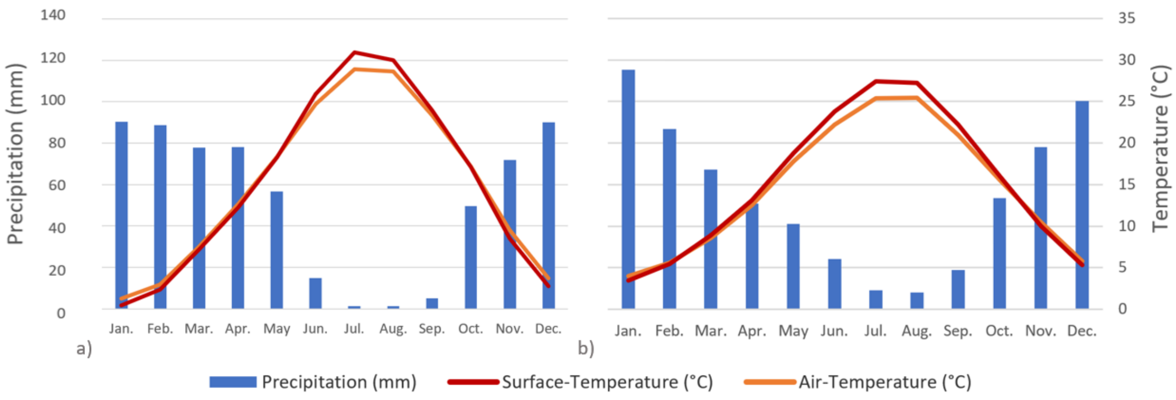

Figure 2. Climograph of the average monthly air and surface temperature (°C) and precipitation (mm) from 2001-2021 in Manisa (a) and Diyarbakir (b).

The classification of the cumulative frequency of annual mean surface – and air temperature and total precipitation over the 20 years is presented in Appendix Figure A1(a-f).

2.2 Data Description and Materials

The administrative data are taken from the Humanitarian Data Exchange (HDX) website, an open licensed platform (General Command of Mapping and Regional IM and Working Group, 2023). Land Cover CCI" version 2.0 (CCI-LC PUGv2) land cover data are from the Copernicus database for 2015 (Copernicus Climate Change Service, 2019a). The spatial resolution of the annual global CCI-LC map is 300m. The data are collected from the sensors of AVHRR, SPOT-VGT, MERIS FR and RR, and PROBA-V. The land cover classes used are based on the CCI-LC classes and have been summarised according to the IPCC (Intergovernmental Panel on Climate Change) classes considered for land changes (Copernicus Climate Change Service, 2019b).

Temperature data are used from GLDAS-2 (Beaudoing & Rodell, 2020) via the NASA EARTHDATA website. The GLDAS-2 has a spatial resolution of 0.25° x 0.25° and a temporal resolution of 1 month (Beaudoing & Rodell, 2020). For the Air- Temperature 2m above ground, the dataset layer "Tair_f_inst" and for the Surface Temperature (LST, Land Surface Temperature), the layer "Average Surface Skin temperature" of GLDAS-2 is used. The monthly value of the dataset is an averaged value of the 3-hourly resolution (Beaudoing & Rodell, 2020). The precipitation data are from CHIRPS, which has a very high spatial resolution of 0.05°. The datasets incorporate satellite and in situ station measurements (CHIRPS, 2015). Precipitation monthly data for 2015 and yearly data from 2001-2021 are used for the analysis. The Copernicus Emergency Management Service provided the Canadian Fire Weather Index (FWI) dataset. The FWI - fire risk assessment index is calculated from precipitation, air temperature, relative humidity, and 10m wind speed of the previous day (Copernicus Climate Change Service, 2019a). The monthly climate data and FWI are used for the period 2001-2021. The FWI is one of the best-known indices. Although it was developed for Canada, many studies have shown it to be a suitable index for the Mediterranean region (Moriondo et al., 2006).

The Uppsala Conflict Data Program (UCDP) creates and publishes the armed conflict events as a spatial dataset. The used dataset is the content of Global Version 22.1 (Department of Peace and Conflict Research, n.d.). The UCDP defines an armed conflict event as an instance of organised violence that results in at least one fatality. Conflict events have a temporal dimension and include information on the parties involved and the type of violence (state-based, non-state, one-sided) (Department of Peace and Conflict Research, n.d.). In Diyarbakir, all but one of the armed conflicts identified in the period under consideration are state-based between Turkey and Kurdistan. There is one one-sided event between the PKK and the population. UCDP collects data from publicly reported accounts from news sources, social media, governmental, nongovernmental (NGO), or international organisations, such as the UN (Davies et al., 2022; Sundberg & Melander, 2013).

The frequency of active fires is taken from NASA's FIRMS (Fire Information for Resource Management System) data set (Giglio et al., 2020). The data comes from the Terra and Aqua satellites using the MODIS (Moderate Resolution Imaging Spectroradiometer) system. MODIS detects fire sizes of $1000m^2$ and larger. Smaller fires can only be detected under optimal conditions, i.e., with low smoke formation or no complication of the detection due to cloud cover. The size of $1000m^2$ is a relatively high value, which makes it likely that the number of fires is underestimated. The data set chosen was the global product MCD14ML (Collection 6 and 6.1) with a spatial resolution of 1km. It is a monthly dataset created from daily data (Giglio et al., 2020). Only active fires with the attribute of type "presumed vegetation fire" are used.

2.3 Methodology

For the analysis and processing of the geographical data, the software products Microsoft Excel (Microsoft, 2023), ArcGIS Pro 2.7 (Esri, 2020) and GeoDa (Anselin, 2023) were used.

2.3.1 Geographical and Statistical Analysis

To study the appearance of armed conflicts and vegetation fires in the provinces of Manisa and Diyarbakir, the annual values of the variables from 2001 to 2021 are compared.

Z-score analysis for precipitation, air, and surface temperature data evaluates how the average annual value, respectively, the annual total, behaves concerning the average conditions over the standard deviation (Eklund et al., 2021; Zubkova et al., 2021). The analyses of the variables are based on the period from 2001 to 2021 and conducted for both provinces. The time is over 20 years to represent a broader variance and change in the data. The Z-score is calculated using the following equation:

$$z = (\chi - \mu)/\sigma \quad (1)$$

where:
z = anomaly of the variable
χ = variable of the year in question
μ = mean value of the variable for 2001-2021
σ = standard deviation of the variable for 2001-2021
(Eklund et al., 2021; Rogerson, 2020; Zubkova et al., 2021).

The Z-score analysis is conducted from 2001 to 2021 to rule out anomalies in 2015 and subsequent conflict years and to discuss the extraordinary occurrence of conflict-related fire events (Eklund et al., 2021; Rogerson, 2020). When the Z-value is above +1.00, it indicates a positive deviation that surpasses the standard deviation. A Z-value below -1.00 represents a negative deviation below the standard deviation (Rogerson, 2020).

2.3.2 Statistical Cluster Analysis of the conflict region Diyarbakir, 2015

A spatial correlation between armed conflicts and vegetation fires can be demonstrated using the Bivariate Local Moran's I analysis (Dinc et al., 2021), also known as Bivariate Local Indicators of Spatial Association (BiLISA) (Anselin, 1995). Here, the correlation between armed conflicts and vegetation fires in a given area (10 km*10 km) and their neighbouring areas in Diyarbakir Province is analysed. A neighbourhood is defined as eight surrounding defined $100km^2$ areas around a single one of these areas where conflicts or fires occur (Anselin, 2005; Dinc et al., 2021). This analysis was performed separately for each month of 2015, recording the number of conflicts and fires per defined area. Over the bivariate local relationships of the two variables, spatial clusters are identified as High-High, Low-Low, High-Low, and Low-High relationships. High-High areas describe a high occurrence of both variables within a space and their neighbours. The discordant cluster description of Low-High defines a space and neighbours of low-occurring conflicts and a high number of fires. The meaning of High-Low and Low-Low clusters correspond vice versa (Dinc et al., 2021).

In addition to the cluster map, the Bivariate Local Moran's I analysis produces a corresponding Significance map and a Moran Scatter plot. The plot in the Significance map indicates how likely the null hypothesis is (there is no relationship between conflict and fire). The null hypothesis holds if the p-value is high and there is no relationship between armed conflict and vegetation fire. If this probability (likelihood of error) is less than 5% ($p < 0.05$), then it is unlikely that the null hypothesis (no relationship) is true. Consequently, the alternative hypothesis (there is a relationship between conflict and fire) is accepted, and the null hypothesis is rejected (Anselin, 2005).

The Moran Scatter plot is another statistical description of the spatial data analysis, where the global Moran's I describe the mean value of the individual local Moran values (Anselin, 2005). The number of conflicts is the independent (spatially unlagged) variable and is contrasted with the number of fires (lagged no_fire) as the dependent variable (spatially lagged)(Anselin, 2005). A positive value of local Moran's I can be associated with either a High-High or a Low-Low cluster. Negative local Moran's I denote the discordant clusters that exhibit High-High or Low-Low correlations, respectively (Anselin, 2005).

2.3.3 Spearman's Rank Correlation of Climate, Conflict, and Fire

A Spearman's rank correlation analysis between the number of fires and climatic factors of precipitation, surface temperature, air temperature, FWI, and the number of conflicts measured from January to December 2015 was carried out in the two study areas, Manisa and Diyarbakir. The correlation coefficient (r) can be used to make statistical statements about the relationship between the variables. The value of the correlation coefficient represents the strength of the relationship. Furthermore, a significance test is carried out for the correlation coefficient r in order to be able to assess whether the correlation is significant for the test carried out by determining the p-value (Rogerson, 2020).

The Spearman's rank correlation analysis is a nonparametric statistical test that does not require a normal distribution of the variables. A set of ranks is determined for each variable, which is then used as converted data in the correlation analysis. The variables are scaled metrically and can be sorted into a logical order to form ranks. In this analysis, the provinces were divided into 10km*10km regions. For each region, which lies entirely within the provinces, the average temperature (air and surface), FWI, and total precipitation per month were determined. These values are the basis for the rankings per month. In Manisa, there are 142 regions (nM = 142) and in Diyarbakir 153 (nD= 153). The Spearman's rank correlation coefficient is calculated with the general formula, which allows multiple expressions of ranks (Rogerson, 2020):

$$r_s = \frac{\sum_{i=1}^{n} (rxi - \overline{rx})(ryi - \overline{ry})}{\sqrt{\sum_{i=1}^{n} (rxi - \overline{rx})^2} * \sqrt{\sum_{i=1}^{n} (ryi - \overline{ry})^2}}$$

rx_i rank of variable xi
$\overline{rx}$ mean of the rank of variable x
ry_i rank of the variable yi
$\overline{ry}$ mean of the rank of variable y

Generally, when evaluating the correlation coefficient, an r-value of r>0.7 or r<-0.7 is assumed to indicate a strong relationship between the variables. However, it should be noted that the sample size influences the minimum r-value at which the correlation of the variables can be significant (Rogerson, 2020). This is the critical r-value (r_{crit}), which is calculated as follows:

$$r_{crit} = \frac{2}{\sqrt[2]{n}}$$

r_{crit} critical r-value

According to the formal for r_{crit}, the following critical r-values result:

Manisa

$r_{Mcrit} = \pm 0.1678$

Diyarbakir

$r_{Dcrit} = \pm 0.1617$

To carry out a significance test for the correlation coefficient, the t-statistic and the degree of freedom (df) are first determined according to the following formula (Rogerson, 2020):

$$t = \frac{r * \sqrt{n-2}}{\sqrt{1-r^2}}$$

r correlation coefficient
n sample size
t t-statistic value

The calculation of t and df is followed by a two-tailed test with an assumed significance level of α = 0.05, which tests for the null hypothesis, which states no correlation between the variables. If the p-value is less than α, the null hypothesis is rejected; the correlation is significant, and the variables have a relationship. The p-value is determined via t-tables using the calculated t-statistic and the degree of freedom of the sample (Rogerson, 2020).

3. Results

3.1 Statistical Spatial-temporal Description of Conflict and Fire

The occurrence of armed conflicts and fires in Diyarbakir and Manisa from 2001 to 2021 is shown in Figure 3. The fluctuations in the number of conflicts in Diyarbakir can be explained by prominent events in the Turkish-Kurdish conflict and peace process. The number of conflicts, which was low until 2003, increased significantly in 2004, associated with the preparations for founding the Union of Kurdistan Societies (KCK). Erdoğan's speech in which he announced a democratic solution for the first time is highlighted in the literature as an announcement for a peace process and taken as an indication that the decline in conflicts in 2005 could be related to this (Akgül & Görgün Akgül, 2022). However, due to a lack of implementation of a solution, the conflicts increased again and levelled off again in preparation for the first phase of the peace process in 2009, which remains visible in the years that followed until 2011 (Akgül & Görgün Akgül, 2022; Bingöl, 2022). With the end of the first peace process, the conflicts increased again (Akgül & Görgün Akgül, 2022; Bingöl, 2022; Savran, 2020; Savran, 2018). Few conflicts are recorded from the start of the second phase of the peace process from 2013 to 2015. The year 2015, in which the second attempt at the peace process failed, stands out. Forty-eight violent conflicts were recorded in Diyarbakir by the Uppsala Conflict Data Program (UCDP) that year. The conflicts level off at a low level in the period 2017-2021 but never come to a complete standstill (Akgül & Görgün Akgül, 2022; Bingöl, 2022).

The active fires in Diyarbakir show a more varied pattern over the years, with a minimum of 124 recorded fires in 2008 and the highest record in 2009 with 2693 active fires, followed by 2015 with 2035 active fires recorded. Furthermore, 2010, 2011, 2013, and 2016 show a significantly high number of fires. No armed conflicts are recorded in Manisa. The active fires in Manisa had high records in 2005, 2007 and 2008. Relatively few fires occurred in 2001 and 2002. In Manisa, with one exception in 2008 (254 active fires), the number of fires is consistently below 250 records. In Diyarbakir, however, 90% of the years considered are described by more than 250 recorded fires. The difference in fire occurrence between the two provinces is considerable, with the number of active vegetation fires in Diyarbakir almost consistently higher than in Manisa (Figure 3). Only in 2008 did the number of fires in Manisa exceed those in Diyarbakir. It is noticeable that in 2009 with a difference of over 2000, and in 2015 with a difference of 1910, active recorded fire points are exceptionally high compared to the other years (Figure 3).

In the Appendix, the individual values are listed again in tabular form, Table A2.

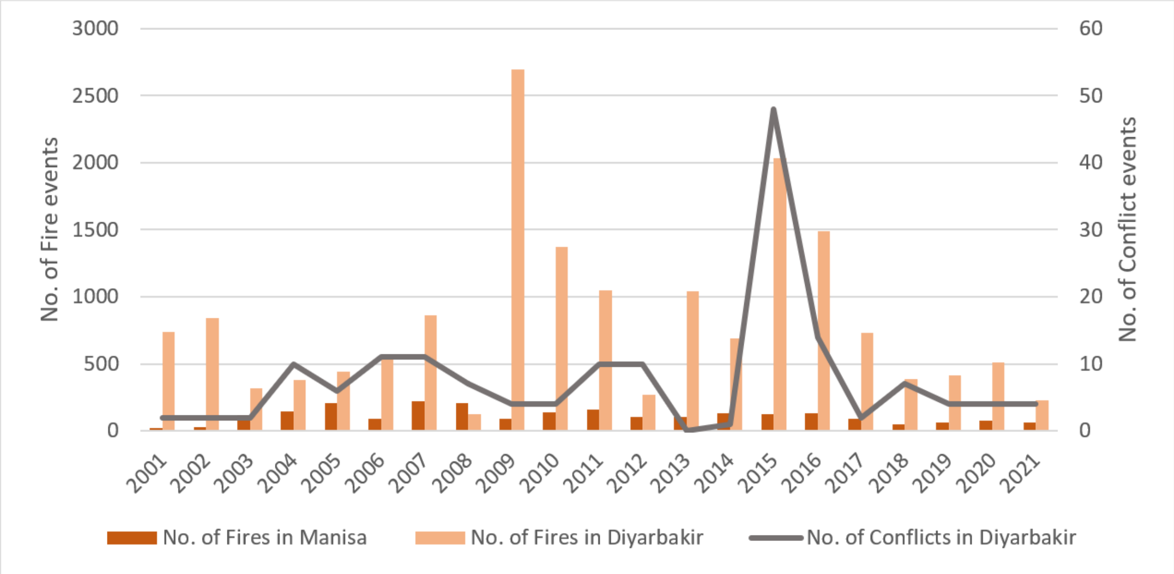

Figure 3. Recorded numbers of conflicts and fires in Diyarbakir and Manisa from 2001 to 2021. The number of active fires (only presumed vegetation fires) is based on MODIS data, and the number of violent conflicts is provided by the Uppsala Conflict Data Program (UCDP) dataset.

2015 shows an exceptionally high occurrence of armed conflict and vegetation fires after the end of the peace process as well as an unusually high difference in the number of recorded fires between Diyarbakir and Manisa, therefore, this year is the focus of attention.

The spatial distribution of armed conflicts and vegetation fires in both provinces in 2015 is shown in Figure 4.

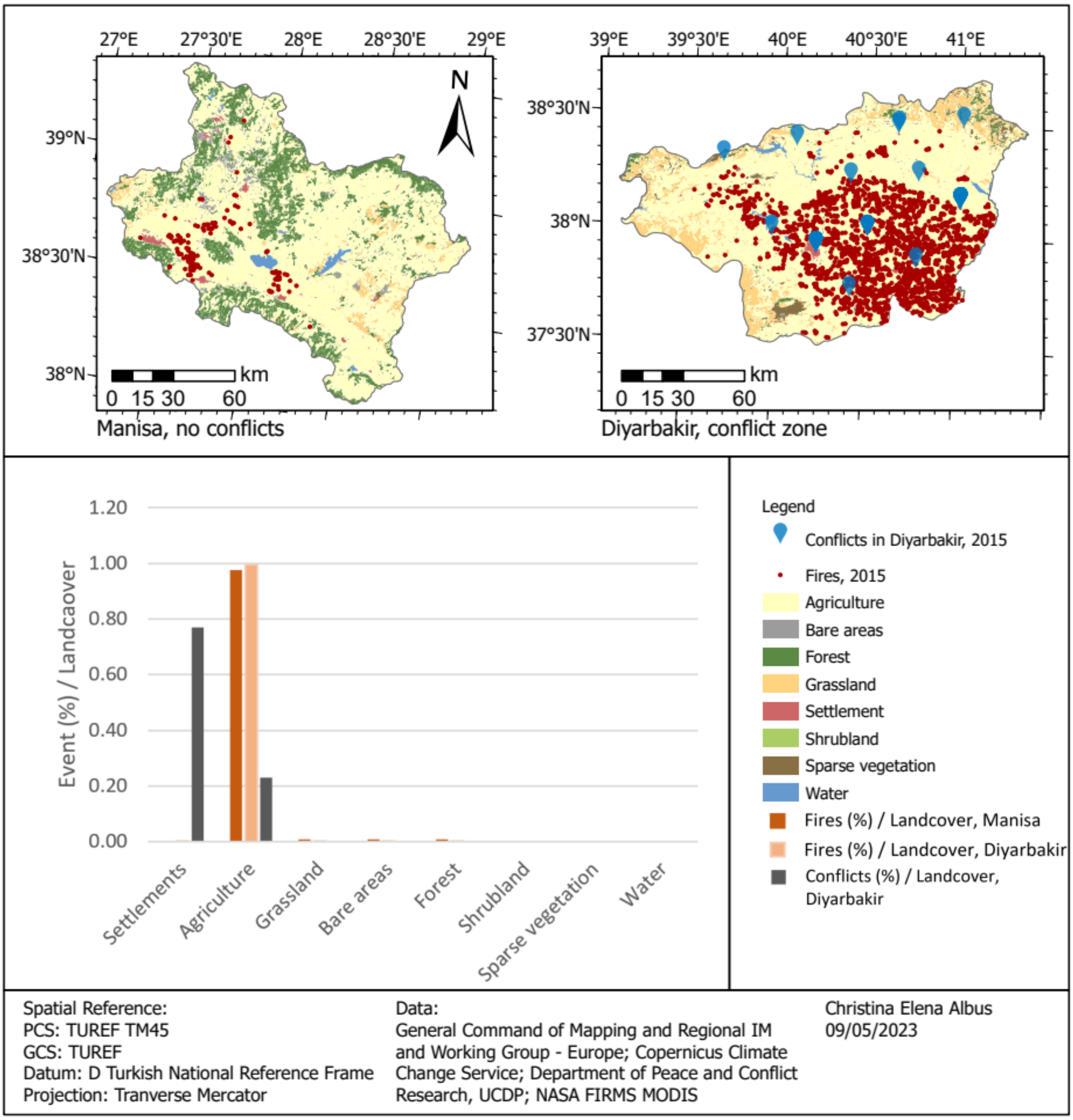

Figure 4. Distribution of recorded fire occurrences and conflict events of 2015 on land cover classes from IPCC land categories and CCI-LC classification.

The agricultural land is the most fire affected land cover in both provinces, with nearly 90% in Manisa and nearly 100% in Diyarbakir. The remaining 10% of fire occurrence in Manisa is in settlements and a very small portion in bare areas and forests. Slightly more than three-quarters of the recorded conflicts in Diyarbakir occurred in settlement and agricultural areas. The exact values are listed in Table A3. in the Appendix.

3.2 Climate Statistics of Precipitation and Temperature

The climatic factors of precipitation and temperature are statistically represented by the Z-score in Figure 5. The annually summed precipitation shows irregularities over the years in both regions. The regions are also similar in their variance of total precipitation. The lowest precipitation of both regions was recorded in 2008 and 2021. Diyarbakir had precipitation of about 411mm in 2021 and 440mm in 2008. The total precipitation in 2021 Manisa was almost 470mm, and in 2008 438mm. The years with the highest precipitation differ in the provinces. The highest measured precipitation was in Diyarbakir in 2018, with 873mm. On the other hand, the highest precipitation in Manisa was 656mm in 2009, following the remarkably dry year of 2008. Slightly more than 80% of the annual precipitation in Manisa is within the standard deviation of the average precipitation. In the Diyarbakir region, on the other hand, two more years deviate above the norm. Like precipitation, surface and air temperatures show similar patterns in the years under consideration. Air temperature in the two provinces ranges from 13°C to about 16°C, with an increasing trend over the years in both provinces. About one-third of the surface temperatures showed notable fluctuations above or below the standard deviation between 2001 and 2021. The surface temperature in Manisa and Diyarbakir fluctuates between almost 14°C and about 17°C. The surface temperature in Manisa is described from 23°C to about 16.5°C. In contrast to the precipitation values of the region, the surface and air temperatures each record almost 40% deviations outside the standard deviation of the average. In general, the temperature and precipitation of the two regions show a similar pattern over the 20 years. A closer look at 2015 also shows a similar pattern in precipitation and temperature in the two regions and is within normal conditions.

The data for the individual years can be found in the Appendix in Table A2.

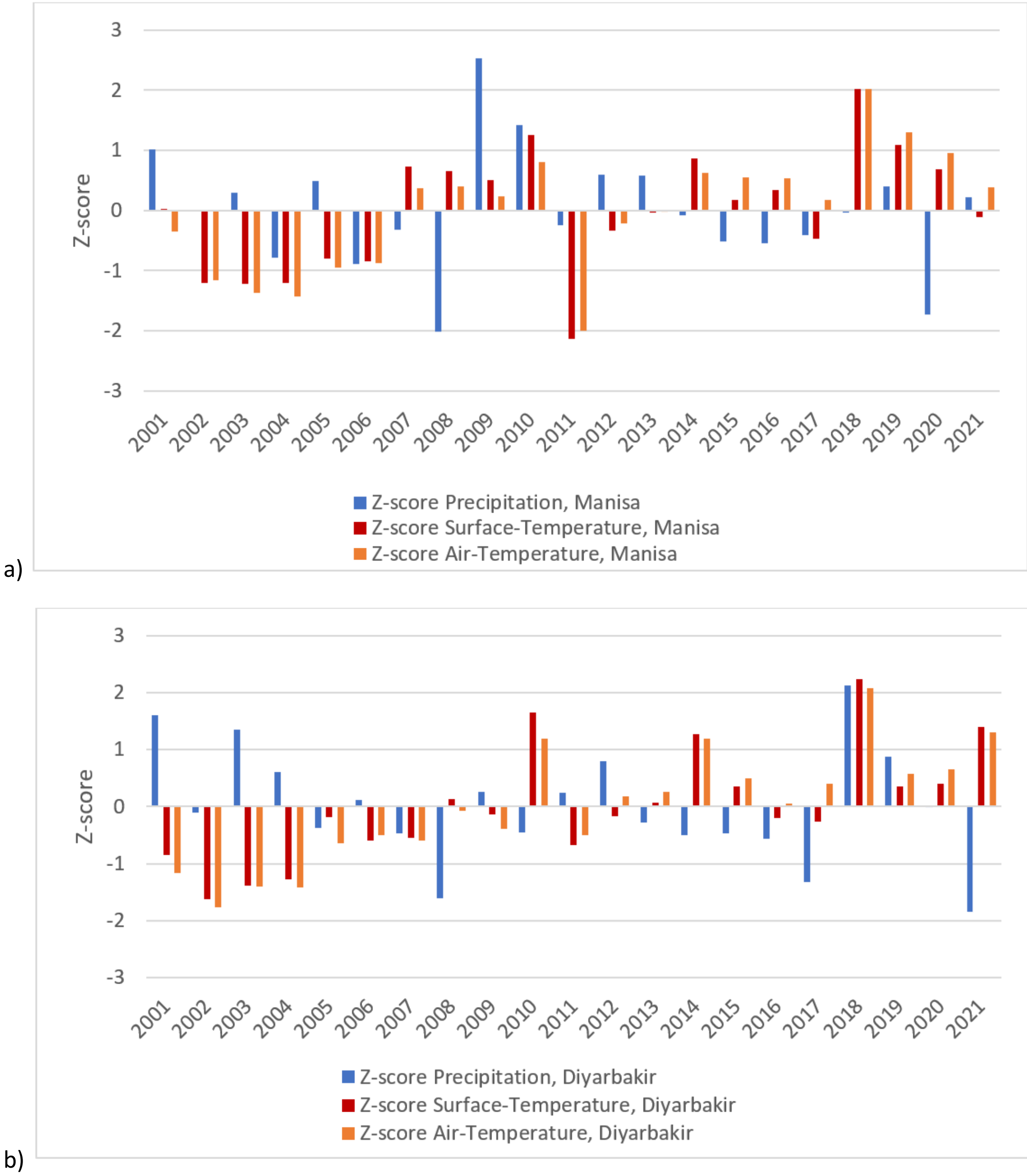

Figure 5. Standardised anomalies of climate variables. The Z-score of precipitation and surface and air temperature is conducted from 2001 to 2021 in Manisa (a) and Diyarbakir (b) provinces. The annually summed precipitation data are taken from the Climate Hazards Group InfraRed Precipitation with Station dataset. The average air and surface temperature is based on GLDAS Noah Land Surface Model.

3.3 Spatial Proximity of Conflict and Fire in Diyarbakir, 2015

The spatial cluster of armed conflict and vegetation fire, determined by their bivariate local relationship, shows June to September 2015 areas with high appearance of conflicts and fires in spatial proximity and their spatial connection to their corresponding land cover (see Figure 6 (High-High)). Surrounding them are predominantly Low-High areas characterised by low conflicts in spatial proximity to a high number of fires. The temporal trend of the bivariate local relationship of conflict and fire over 2015 shows a changeable development.

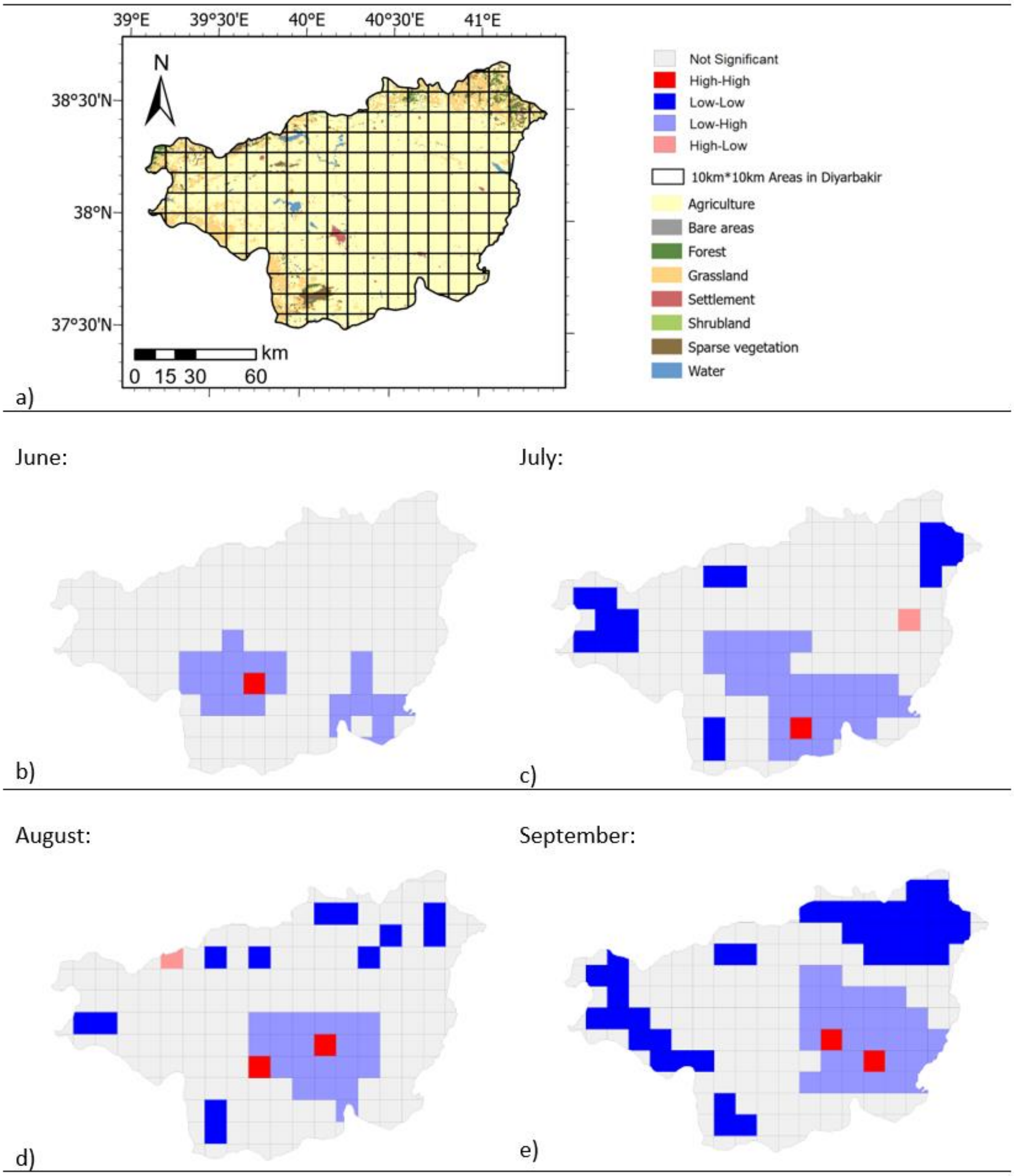

Figure 6. Spatial cluster of fire and conflict by their bivariate local relation in June (b), July (c), August (d), and September (e) of 2015 in Diyarbakir and corresponding land cover of the spatial clusters (a).

Only a few fires are recorded in the first half of the year. In contrast, the number of conflicts is significantly higher. The UCDP recorded a conflict from 10 March to 10 May, in addition to a few others at the time, in the city Silvan, so while the number of conflicts is high, the spatial appearance is low. Consequently, there is no bivariate local High-High relationship between conflicts and fires within the clusters and their neighbours. Furthermore, the global Moran's I indicate that a High-High relationship does not occur this month, as it is negative (Figs. A2 a-m).

From June to September, the global Moran's I is slightly positive, indicating High-High or Low-Low bivariate local relationship. June has the highest global Moran's I of 0.074 (Figures 6b and A2o). This month shows a sharp increase in active fires, counting 56 (Table A4) and two conflicts. A significant spatial relationship (High-High) is found in June, whereby the conflict is in the city of Diyarbakir and the fires in the surrounding agricultural land. The relation continues to expand in areas of low conflict and high fire appearance (Low-High) (Figure 6c). Like June, July has another sharp increase in fires (390 active fire points) and two conflicts (Table A4). A High-High bivariate local relationship can be observed, with the conflict in Çınar (city) and fires in the adjacent agricultural areas. The other conflict is located in Silvan and is described by a spatial cluster with a High-Low relationship. August shows two High-High clusters with a maximum of 13 conflicts and 270 fires (Figure 6d and Table A4). The High-High clusters describe the spatial relationships of conflicts and fires in the city of Diyarbakir and on agricultural land. This High-High relationship is surrounded by a relatively compact area of Low-High relationships. Furthermore, a bivariate local relationship between a high number of conflicts and a low number of fires (High-Low) is found on agricultural land northwest of the province. As in previous months, September shows a broad grouping of Low-High relationships around the High-High cluster, representing a locational similarity between the high number of conflicts and fires on agricultural land (Figure 6e). September records the most fires of the year (638) and seven conflicts (Table A4). The multiple Low-Low relationships from July to September are not close to conflicts or High-High clusters but show fire activity. All relationships from June to September are significant (Figs. A2o,r,u,x)

Although the second highest number of fires was recorded in October (625 fires) (Table A4), there is no spatial correlation between the high occurrence of conflicts and fires (High-High) (Figs. A2z-ab). There is also no High-High bivariate local relation found in November and December. The Fire activity has dropped significantly in the last two months of the year to 38 fires in November and 11 in December (Table A4). The negative global Moran's I also mark the lack of bivariate relation of the high occurrence of conflicts and fires from October to December (Figs. A2 ac-ai).

In February, no autocorrelation analysis can be performed and is excluded from consideration because there is only one conflict but no fire. Under these conditions (one variable has zero value), the correlation coefficient calculation always results in the value "zero". There is no correlation between the variables.

3.4 Spearman's Rank Correlation of Climate, Conflict, and Fire

The Spearman's rank correlation analysis results are summarised in Table 1.

Table 1. Spearman's rank correlation coefficients and corresponding p-values of the variables total precipitation, surface temperature, air temperature, FWI, and the number of conflicts with the number of active fires in Manisa (a) and Diyarbakir (b) provinces. The orange marked boxes indicate the correlation coefficients that exceed the r_{crit}. The blue markings indicate which of these r-values meets the significance level.

a)

	No. of Fire & Precipitation (mm)/ Month		No. of Fire & Surface temp. (°C)/ Month		No. of Fire & Air temp. (°C)/ Month		No. of Fire & FWI/ Month		No. of Fire & No. of Conflicts/ Month	
Spearman's rank correlation coefficient **r** & **p-value**	r	p-value	r	p-value	r	p-value	r	p-value	r	p-value
Jan.	-0.108	0.201	0.088	0.295	0.056	0.504	0.056	0.504	-	-
Feb.	-0.114	0.177	0.080	0.343	0.048	0.568	0.067	0.430	-	-
Mar.	-0.130	0.122	-0.023	0.789	-0.063	0.459	-0.108	0.201	-	-
Apr.	-	-	-	-	-	-	-	-	-	-
May	-	-	-	-	-	-	-	-	-	-
Jun.	-0.051	0.546	0.082	0.334	0.136	0.108	0.098	0.247	-	-
Jul.	-0.085	0.313	0.008	0.923	0.130	0.122	0.108	0.201	-	-
Aug.	-0.137	0.105	0.090	0.285	-0.072	0.393	-0.026	0.762	-	-
Sep.	-0.210	0.012	0.332	5.4E-05	0.328	6.7E-05	0.114	0.176	-	-
Oct.	0.001	0.992	0.406	5.3E-07	0.423	1.5E-07	0.147	0.081	-	-
Nov.	-0.049	0.566	0.073	0.388	-0.031	0.714	0.078	0.354	-	-
Dec.	-0.052	0.536	0.072	0.395	-0.001	0.990	0.108	0.201	-	-

b)

	No. of Fire & Precipitation (mm)/ Month		No. of Fire & Surface temp. (°C)/ Month		No. of Fire & Air temp. (°C)/ Month		No. of Fire & FWI/ Month		No. of Fire & No. of Conflicts/ Month	
Spearman's rank correlation coefficient **r** & **p-value**	r	p-value	r	p-value	r	p-value	r	p-value	r	p-value
Jan.	-0.125	0.124	0.102	0.210	0.072	0.379	0.073	0.367	-0.007	0.936
Feb.	-	-	-	-	-	-	-	-	-	-
Mar.	-0.166	0.041	0.171	0.034	0.104	0.201	0.177	0.028	-0.013	0.871
Apr.	-0.125	0.124	-0.095	0.245	-0.105	0.198	0.039	0.636	-0.007	0.936
May	-0.109	0.178	0.040	0.626	0.020	0.811	0.152	0.060	-0.016	0.842
Jun.	-0.086	0.291	0.324	4.3E-05	0.326	3.9E-05	0.065	0.426	0.124	0.128
Jul.	-0.287	3.2E-04	0.614	3.3E-17	0.587	1.5E-15	0.036	0.656	0.157	0.053
Aug.	-0.322	5.0E-05	0.482	2.9E-10	0.527	2.7E-12	-0.034	0.679	0.040	0.625
Sep.	-0.216	0.007	0.653	6.4E-20	0.737	1.7E-27	0.418	7.3E-08	0.134	0.098
Oct.	-0.227	0.005	0.667	4.4E-21	0.735	2.8E-27	0.418	7.4E-08	0.030	0.717
Nov.	0.273	0.001	0.365	3.5E-06	0.377	1.5E-06	0.065	0.422	-0.045	0.585
Dec.	-0.126	0.120	0.166	0.040	0.154	0.057	0.204	0.011	0.189	0.019

In Manisa, a correlation between precipitation, air and surface temperature, and fire occurrence can be observed in September. Likewise, a correlation between temperature variables and fire occurrence was found in October. All r-values reaching the critical r-value r_{crit} have a p-value smaller than 0.05, and thus the relationship has reached the significance level.

In Diyarbakir, the relationships found are more extensive: For the variable precipitation, the critical r-value is reached in March, and from July to November, for surface temperature in March, and from June to December, for air temperature from June to November, for FWI in March, September, October, and December and for conflicts in December. The significance test of these correlations shows that all r-values exceeding r_{crit} have a p-value smaller than 0.05, as in Manisa. Significant correlations are found between all climate variables and fire, with Surface Temperature standing out with eight correlations found. The relationship between Conflict and Fire is significant for December, with a p-value of p= 0.019.

Since there are no conflicts in Manisa, there are, accordingly, no r- and p-values. In the absence of fire, as in Manisa in April and May and Diyarbakir in February, results that no r and p values can be calculated either.

4. Discussion

4.1 Spatial-temporal Pattern of Climate, Conflict and Fire

Over the 20 years of the observation period, the variables of climate, conflict, and fire show some fluctuations. The climates of Manisa and Diyarbakir are climatically comparable (Figs. 2a and 2b), and the Z-score analysis shows a similar temperature variability pattern between the two regions. Differences can be seen in the precipitation anomaly pattern for individual years (Figs. 5a and 5b). Via the Z-score analysis, deviations exceeding the standard deviations can be displayed, thus indicating anomalies. The climate data do not show anomalies. However, the recorded numbers of conflicts and fires differ greatly between the two provinces, with Manisa showing no conflicts (see Figure 3).

Climate is a crucial factor influencing fires (Calle, 2008; Gülçin & Deniz, 2020). Within the 20 years of consideration, 2008 stands out climatically, especially for its dryness, as the Z-score of precipitation falls below the mean value in Manisa and Diyarbakir by about two times the standard deviation, see Figures 5a and 5b. Precipitation values are very low in both regions (Manisa 438 mm/p.a.; Diyarbakir 440 mm/p.a., Table A2). Dry summers are often accompanied by an increase in fires, which is why drought is one of the factors used to determine fire weather indices (Ganteaume et al., 2021). San-Miguel-Ayanz et al. (2013) also point out that Portugal experienced a record high of fires as a result of two extremely dry periods in 2004 and 2005. The situation was similar in Greece in 2007, where quite a few large fires followed severe drought (San-Miguel-Ayanz et al., 2013). The low rainfall in Manisa and Diyarbakir in 2008 shows that drought alone is not a fire predictor, as there was no increase in fires, as shown in Figure 3. However, severe drought from the previous year could underlie the extremely high number of fires in 2009 (Figs. 3, 5a and 5b & Table A2). Heavy precipitation promotes vegetation growth and thus increases biomass production. Biomass accumulation makes more combustible material available for fire activity (Calle, 2008; Zubkova et al., 2021). For example, in the winter of 2019 in Syria, the sudden increase in fires could be explained by that (Zubkova et al., 2021). In 2009, precipitation values were peculiar: Manisa had very high precipitation values (the highest in the considered period), while Diyarbakir had no particular deviations. Due to the lack of climatic anomalies in Diyarbakir, the exceptionally high recording of fires this year compared to Manisa cannot only be due to climatic reasons. However, it must be caused by other influencing factors, like anthropogenic factors (agricultural practice, arson, conflicts, and lack of firefighting).

The year 2015, the focus of this study, also shows an exceptionally high number of fires, as in 2009 (Figure 3). Nevertheless, no climatic anomalies could have notably increased the occurrence of fires. For both years, the Z-scores of the temperature values (surface and air temp.) and for 2015 also, the precipitation amount are within the standard deviation see Figures 5a and 5b. The overall significantly higher number of fires in Diyarbakir than in Manisa over the years is not accompanied by a similar concise behaviour of the climate or climatically induced differences between the regions. Therefore, other factors besides climate have a decisive influence.

In the spatial aspect of 2015, it should be noted that in both Manisa and Diyarbakir, most fires are located on agricultural land. Conflicts are predominantly found in settlement areas and second most frequently in agricultural areas. Thus, an influence of agricultural practices on the occurrence of fires can be assumed. However, it should also be noted that approximately

23% of the conflicts are recorded on agricultural land. Due to the simultaneous occurrence of conflicts and fires, the local population and the PKK accuses Turkey of using fires as a military tactic in forests and agricultural fields. This can be understood in terms of intimidating the population and depriving them of their economic base by destroying crops and influencing food security, thus referring to a geopolitical aspect (Dinc et al., 2021; Zubkova et al., 2021). van Etten et al. (2008) also describe firing in agricultural fields as a tactic used by the Turkish military over the past three decades in the Turkish-Kurdish conflict.

4.2 Relationship between Climate, Conflict and Fire

4.2.1 Indication of Bivariate Local Relation and Spatial Clusters

The spatial proximity analysis shows the bivariate local relationship between conflict and fire in Diyarbakir, 2015. A significant spatial relationship of high occurrence and frequency of both variables within a space and their neighbours is found from June to September 2015, see Figures 6b-e. The bivariate local relationship thus indicates a correlation between the variables and, thus, locational similarity. However, it is essential to consider the location of the spatial High-High clusters. Half of these clusters were in a settlement area, and the other half were on agricultural land.

After the peace process ended, several cities, including Diyarbakir, declared themselves self-governing zones, which was the cause of months of military conflict within the cities. According to reports, the destruction of entire neighbourhoods led to several fires and the permanent displacement of residents from their homes (Saadi, 2021).

Conflicts on agricultural lands are associated with the conquest of agriculture and control of crops or the destruction of agricultural lands and crops to harm the opposing side. Conflict on agricultural lands is especially prevalent during growing seasons, and attacks on crops are always attacks on the food security of the population (Linke & Ruether, 2021). Mohamed et al. (2020) studied conflict-induced changes in land systems and pointed out that most frontlines of armed fighting are in agricultural areas, and deliberate destruction of agricultural land is related.

When considering armed conflict and vegetation fires for their spatial proximity and locational similarity, it appears that fires are particularly common on the surrounding agricultural land (depicted as a Low-High cluster, Figure 6) of settlements, where both a high number of conflicts and fires are recorded (High-High cluster, Figure 6). This could be related to conflicts moving from populated areas to agricultural areas and causing fires. However, there is uncertainty about the full coverage of armed conflict and its spread. Since only conflicts with fatalities are recorded through the UCDP dataset, the magnitude of unrecorded armed conflicts without fatalities is unknown. This raises the possibility that unrecorded conflicts caused some of the fires.

The significant spatial relationship between conflict and fire on agricultural land, reflected in the BiLISA analysis as High-High clusters, can be taken as an indication that the allegations of the use of fire as a military tactic are correct (Dinc, 2021; Dinc et al., 2021; van Etten et al., 2008; Zubkova et al., 2021). The same pattern of Low-High clusters surrounding High-High clusters is found here. Thus, it is clear that fire is particularly concentrated around conflicts. Since farmland is spatially close to settlements for cultivation reasons, a conflict fought on farmland directly affects the rural population of the settlement area in terms of vulnerability as well as food security (Linke & Ruether, 2021).

Based on the results of the significant spatial relationship and the locational similarity of conflict and fire, it can be concluded that conflict can be identified as a possible cause of fires. The spatial relationship shows a correlation but does not reflect causality. Furthermore, High-High clusters in the summer months, signifying a locational similarity of the number of conflicts and fires (Figure 6). In these months, the temporal relations of the breakdown of the peace process in June, the agricultural practices of burning the fields after the harvest, and the generally higher climate-related fire risk in the summer months overlap. Thus, even from this perspective, only an indication and assumption about the spatial relationship between armed conflict and vegetation fire is possible, but no concrete connection can be proven.
It should be noted that a high occurrence of conflict and fire in spatial proximity (High-High clusters) is formed in June, July, and September, although there is only one conflict within this space. A high occurrence of conflicts is not necessarily required to establish a High-High bivariate relationship. This seeming contradiction could be because the number and frequency of conflicts are considered relative. The low number of conflicts compared to the number of fires suggests that several fires are spatially associated with one conflict, which also explains the wide spread of the relationship between low conflict and high fire appearance (Low-High clusters) in neighbourhoods around the high occurrence of conflict and fire (High-High clusters). It can be assumed that if conflicts without fatalities are included, on the one hand, the absolute number of conflicts will increase and, on the other hand, a variation in the spatial proximity of conflict and fire may occur, thus strengthening the assumption of the spatial relationship between conflict and fire.

In the study of Dinc et al. (2021), a quantitative analysis of the relationship between fires and conflict in the Kurdish-Turkish province of Dersim is conducted to assess geopolitical questions about the cause of fires through statistical spatial analysis. In this bivariate local analysis, areas with high conflict and fire are also found, indicating a relationship. In assessing these results, a relationship between fire and conflict is confirmed. For the Dersim region, given the local conditions and circumstances, there is a correlation between the variables, which was tested and confirmed using Spearman's rank correlation test.

The statistical cluster analysis shows significant spatial correlations between conflicts and fires in urban areas and agricultural lands in Diyarbakir province in 2015. This supports the assumption that conflict can act as a fire indicator. However, it should be noted that, as also noted by Dinc et al. (2021), fire is not indexed by one variable alone and equally, conflicts are not the sole drivers of exceptional fire numbers. Conflict must be analysed and understood in the context of other driving factors, such as climate (Zubkova et al., 2021).

4.2.2 Correlation between Climate, Conflict, and Fire (within and outside the Turkish-Kurdish Conflict Area)

In addition to climatic factors, the development of fires is influenced by anthropogenic factors of various kinds. Since it has been established that there are a lot of active fires on agricultural land in the study area, the influence of agricultural practices, such as the burning of fields, must be taken into closer consideration.

The agricultural economy of Diyarbakir province consists of three main types of cultivation, in particular: barley, lentils, and vineyards. Diyarbakir is the centre of grain production in the

South Anatolia region. It accounts for 2% of barley production in Turkey (7-8 million tonnes of barley) (Pala, 2020). In Turkey, as in many countries, burning arable land and pastures is a common practice as a regularly recurring agricultural measure. The intentions may be to fertilise the soil before sowing, remove crop residues, or prepare fields for harvesting (Avci, 2011; Le Page et al., 2010). Agricultural fires can also be controlled by deliberately igniting fires to prevent expected large fires via small fires (Rabin et al., 2018). Barley is planted annually in winter (Pala, 2020).

The flat plains of Manisa province, like Diyarbakir, are heavily influenced by agriculture (Aksay et al., 2022; Güney, 2020). Especially in the Gediz Basin, there are large areas of cultivated land (Gulgun et al., 2009). The district of Akhisar is a focal point of olive production in Turkey. Concerning Manisa, 55% of the olive harvest comes from Akhisar. Tobacco, wheat and cotton are also grown (Gulgun et al., 2009). Other cotton production centres are Salihli and Saruhanli districts (Bayram & Hakerler, 2022; Evcim & Öz, 1998). In the northeastern district of Demirci, pastoralism with flocks of sheep and cattle dominates (Topuz & Deniz, 2023).

Burning fields is a common post-harvest practice traditionally used by farmers as a post-harvest tool. Agricultural burning practices are predominantly applied to wheat, barley, cotton, and lentil fields (Schon et al., 2021). Barley and wheat are grown in both regions, with the harvest season usually beginning in June (Zubkova et al., 2021). The harvest season of cotton and lentils is also in the summer months (Balli & Özaslan, 2020; Gulgun et al., 2009; Pala, 2020). Schon et al. (2021) studied the correlation between agricultural fires in cereal fields and the Normalized Difference Vegetation Index (NDVI) and demonstrated a positive correlation until September. Based on the localisation of fires on agricultural land and the particularly high frequency of fires in September and October after the harvest season, conclusions can be drawn about agricultural fire practices. In the case of Diyarbakir, this fact should be taken into account when considering conflicts and fires.

The correlation analysis with Spearman's rank coefficient is used to examine the expected relationship between the climatic factors and armed conflicts on vegetation fire, whereby each of these factors was individually tested to fire. By comparing the two provinces, it is investigated whether the same or similar correlations exist regarding the number of fires.

Biomass, availability for burning, fire spread and ignition are factors strongly influenced by climate, thereby determining fire occurrence (Bradstock, 2010). Precipitation, temperature, and evaporation impact moisture through their influence on biomass and availability to burn. Wind and temperature, in turn, affect fire spread properties, and lightning is a natural ignition source (Bradstock, 2010).

Fire weather indices are intended to account for the fact that climate factors are less likely to occur as a single factor but usually occur in combination with multiple factors (Bedia et al., 2018). A fire season starts when two weeks in a row have a FWI > 15 and ends when four weeks in a row have a FWI < 15. An average of 7 days is used in the calculation to compensate for fluctuations (Giannakopoulos et al., 2012; Moriondo et al., 2006). A study on large forest fires in the Çanakkale region, Turkey, states that the fire season in Turkey generally covers a period of 5 months (May - September) (Ertugrul et al., 2019). Other studies simplify the determination of fire seasons by Moriondo et al. (2006) and define the period as June-September (Bedia et al., 2018). The monthly average FWI used in this study exceeds 15

(FWI > 15) from May to September. Thus the fire season is from May to September, as defined by Ertugrul et al. (2019). Since the FWI values of the two regions did not differ significantly in 2015, and thus a similar fire risk can be assumed, the results suggest that the particular accumulation of fires in Diyarbakir within the fire risk months has other causes. Since in both provinces, the FWI values are especially high from July to September, and the number of fires is high from July to October (Table A4), a correlation was expected for both regions, which is not confirmed in the Spearman's rank correlation (Table 1). In the study conducted by Ertugrul et al. (2019), the importance of fire weather indices as a predictive tool for fire occurrences in a Turkish region with high index values could be confirmed. No FWI with a sufficiently high r-value for Manisa could be determined in any month. In contrast, significant relationships are evident in Diyarbakir in March, September, October, and December (see Table 1).

Zubkova et al. (2021) point out that, contrary to common belief, the FWI is significantly less informative than temperature. Regardless of how suitably the FWI can be identified as a complex structure of climatic influencing factors or individual climatic factors as drivers, there may be additional anthropogenic influence of the most diverse kind.

When comparing the two regions, the Spearman's rank correlation analysis reveals significantly fewer relationships in Manisa than in Diyarbakir that fulfil the conditions for a significance test (orange marking in Table 1). With a p-value of less than 0.05, all these r-values meet the significance condition, meaning a statistically proven relationship exists (blue marking in Table 1).

The analysis results in Manisa show only relationships between fire and the climate variables precipitation, surface and air temperature in one or two months, September and October. On the other hand, in Diyarbakir, relationships are shown in more months: March, and June to August, and November and December. The climate variables tested are similar between the regions, but the results of the correlations analysis and the number of recorded vegetation fires differed decisively between the regions. Fires are the largest identifiable difference in the data series between the two provinces. Cumulatively over the whole year, there are 2035 fire occurrences in Diyarbakir and only 125 in Manisa (Table A2). The formation of correlation coefficients with ranks based on a comparatively small number of variable values, as in Manisa, may lead to a lower r-value. Nevertheless, from the Spearman's rank analysis results, it can be concluded that the extreme number of vegetation fires is not due to the conspicuousness of an extreme climatic situation, as shown by the spatial-temporal analysis results (chapter 3.2). However, it can be assumed that climate does not act as the sole determinant of fire but is favourable to the occurrence and spread of fires in Diyarbakir, as the fire season coincides with the failure of the peace process.

In Diyarbakir, a correlation between conflicts and fire was only found to be significant in the month of December using the Spearman's rank correlation analysis. However, the significance of a correlation analysis always depends on the selected sample and, thus, the size of the study area. In calculating the Spearman's rank correlation coefficient, this study determines an r-value and a p-value per month for the entire province, i.e. a province-specific overall r- and p-value. The results of the Correlations analysis are based on the average or total values of the variables per month, which refer to the whole province. Thus, this analysis is in a different spatial perspective than the cluster analysis, which tests for spatial proximity and locale similarity, and thus points to a very local indication of the relationship. Based on the BiLISA analysis (chapter 3.3), it is tested that the relationship between conflict and fire is very localised, and therefore it is understandable that an overall correlation between conflict and fire is not necessarily found to the same extent.

This study showed through BiLISA analysis that spatial locational correlations exist between conflicts and fires during 2015. Since neither conflicts nor fires are continuous data, the correlation cannot necessarily be found in an overall correlation for the whole region as in the Spearman's rank analysis test. In a study on the Turkish-Kurdish region of Dersim, Dinc et al. (2021) demonstrate a correlation between fires in the region and conflicts in the whole of Turkey between 2003-2019 using a Spearman's rank correlation test, which is a difference in approach compared to this bachelor thesis. Further, for Syria, evidence of the relationship between conflict and burned areas between 2002 and 2020 was found by Zubkova et al. (2021). Given the results of existing studies, it can be concluded that a relationship between conflict and fire is found in different spatial and temporal contexts. Le Page et al. (2010) consider fires on agricultural land and highlight that the anthropogenic influence on agricultural fires (agricultural fires and conflicts) complements the climatic factor. In this context, the climatic influence can favour the spread of fire. This is also reflected in the results of this Bachelor's thesis. The high number of fires in September and October can be attributed to agricultural practice, as well as the result of a local relationship between conflict and fire, as shown in the cluster analysis.

Zubkova et al. (2021) emphasise that conflict cannot be the sole driver of exceptional fire numbers. Natural ignitions, such as lightning, and anthropogenic ignitions, which include conflict, can only have their effect in concert with other factors, such as biomass and fire weather (Bradstock, 2010). Other factors can be added to the list of potential contributors to fire, such as poor fuel or poorly trained agricultural labour (Schon et al., 2021). In addition, it is important to note that lack of firefighting by non-existent or inadequately trained firefighters also has broader consequences in that grain infrastructure (machinery, irrigation facilities, storage facilities) is also affected (Middleton et al., 2018). Further, other influencing factors may exist, such as cultural, and regional festivals associated with local, limited fires.

4.3 Limitations, Uncertainties and Further Studies

The results of the analyses depend on the reliability of the available and used data sets, both in the temporal context and in terms of quality. The study is limited in terms of the availability of publicly accessible data. The data set of land cover does not precisely match the recorded active fire points, as 15 listed fire locations were in the water in 2006, 2009, 2010, 2011, 2012, 2013, 2016, 2017, and 2021. These fire points are excluded from the analysis. Thus, the selected data sets do not exactly agree with each other. Despite this, land cover species affected by armed conflict can be used to make crucial statements about the relationship between fire and conflict events. Therefore, a relative inaccuracy in the evaluation of the results has to be taken into account.

UCDP provided the conflict data used. UCDP obtains armed conflict information from publicly available news sources as well as reports from governmental and non-governmental organisations. Other studies, such as Akgül and Görgün Akgül (2022), Bingöl (2022), Savran (2020) and Savran (2018) dealing with the Turkish-Kurdish conflict and the peace process also use these information sources. They draw on further literature research, such as public reports from various Turkish dailies, news from BBC News or NTV, reports from NGOs, such as the International Crisis Group, and extend these with independently conducted interviews with contemporary witnesses (politicians, civil society figures, journalists, academics) who were involved in the negotiation processes. Therefore, there is a great deal of agreement between the statements of the literature sources and those of the UCDP, as they use the same sources of information. Since, according to the UCDP definition, a conflict event requires at least one fatality, conflicts without fatalities are not present in the conflict datasets. For this reason, an underestimation of the number and occurrence of conflicts can be assumed, which has a decisive influence on the significance of the analysis concerning the connection with fires, as discussed in the studies of Eklund et al. (2021) and Dinc et al. (2021).

The MODIS MCD14ML fire dataset shows the active fires within a month and is based on daily NRT (near real-time) fire data. Thus, the use of this data as an indication that a fire has occurred at this point can be used to describe a relative relationship between the factors influencing the fire and its occurrence. The analysis is limited by the fact that the behaviour and other characteristics of the occurring fire are not included in the consideration of the relationships. For example, no information is given on the fire's size, spread, and duration. A distinction between individual fires and large-scale, spreading fires is not possible. Fire characteristics and behaviour can extend and improve the analysis regarding influencing factors to build more specific relationships. The MODIS fire data is available at a resolution of 1km, which is another limitation in the evaluation possibilities. Fires of smaller size may not be detected at this resolution, as well as fires that are not detected under suboptimal conditions, such as cloud cover and smoke formation (Schon et al., 2021). Although the VIIRS fire data with a resolution of 375m offer a better resolution, these are only available from 20.01.2012 and therefore do not cover the entire period under consideration in the study (LAADS-DAAC., n.d.).

The CHIRPS dataset provides precipitation data with a very high resolution of 0.05°. Katsanos et al. (2016) carried out a validation of these new precipitation datasets available since 2014 by comparing the measured values with the datasets of TRMM (Tropical Rainfall Measuring Mission's) 3B43 and E-OBS (ENSEMBLES gridded observational dataset) version 8.0, which has a resolution of 0.25°. The result shows that CHIRPS correlates very well with TRMM. However, it should be noted that the monthly precipitation values in 2015 (Table A4) slightly exceed the values for the year in Table A1, thus indicating an inaccuracy. Nevertheless, it can be assumed that all climate variables could be expanded in further studies by including station data from Turkey to increase the data's reliability and improve the study.

In this bachelor thesis, primarily the climate factors temperature and precipitation are used to investigate the influence of climate factors on fire. Temperature and precipitation are the most characteristic features for describing the climate of an area (Peel et al., 2007). Therefore, the climatic analysis focuses on temperature and precipitation. Temperature and precipitation are the two variables that have the most influence on drought and thus also affect fire risk (Dinc et al., 2021; San-Miguel-Ayanz et al., 2013). Fire weather indices, including temperature, precipitation, and other climatic factors, are generally used to determine the fire risk. Therefore, in this thesis, the FWI is also examined concerning the occurring fires. In further studies, other individual factors included in the FWI could be included in the analysis and thus create a more comprehensive picture of the climatic factors influencing fire.

Further analysis can be done in subsequent studies. For this bachelor thesis, only 2015 was studied in detail for the conflict region of Diyarbakir. The analysis of this region in a conflict-free year can provide more precise information on the strength of the effect of climatic factors on fire occurrence due to the exact geographical location and, thus, comparable climatic conditions in a year-to-year comparison. This also applies to further investigating agricultural fires in conflict-free years to better include this factor in the evaluation of the analyses.

In the temporal view of the analyses, monthly values were used as the smallest unit. The temporal observation can be refined by changing the scale level to 8-day or daily values (fire data are available at this level). In addition to the occurrence and frequency of fires, other characteristics can be investigated. For example, whether fires with a conflict indicator show different behaviour than agricultural burnings or climate-related fires could be investigated.

The Spearman's rank correlation analysis could be tested in further studies on a local basis. For example, regions comparable to those used in the cluster analysis could be formed and tested for local correlation to allow a more direct comparison between the individual regions of a province. For the concrete implementation of the Spearman's rank test on smaller areas, the daily values of the variables for a month could be used, and the ranks formed over the days of the month in the context of the Spearman's rank correlation analysis.

5. Conclusion

The year 2015, which is related to the end of the peace process in the Turkish-Kurdish conflict, stands out due to a particularly high occurrence of conflicts and fires in Diyarbakir. Using various statistical analysis tools, selected climate factors and conflicts were tested for their relationship to the number of fires in the provinces of Manisa and Diyarbakir.

The climate values of the regions are similar and show neither anomalies nor an increased fire risk in 2015. Armed conflicts and vegetation fires have, indicated by their locational relationship, spatial proximity and locational similarity from June to September 2015. Since most fires were on agricultural land, agricultural burnings were also considered in the analysis, in addition to the influencing factor of conflict. The Spearman's rank correlation analysis results show significant relationships between the temperature and precipitation values with the occurrence of fires in the provinces. The results in Diyarbakir were detectable for several months, for Manisa only in September and October. The correlation between conflicts and fire is less clear, with a significant value only in the month of December.

It can be concluded that the relationship between conflict and fire is very local. However, the causality cannot be explained by the relationship of proximity. Since climate does not show any exceptional behaviour that could explain the exceptional number of fires compared to Manisa, it can be assumed that climate caused the spread of fires in Diyarbakir. Due to the strong localisation of conflicts and fires on agricultural land, it is difficult to differentiate the influence of fires caused by conflicts or agricultural praxis. The development of fires is very complex and must be considered under numerous variables and circumstances, climatic and anthropogenic.

Further studies can be conducted in other conflict regions, under different climatic conditions and in different spatial and temporal contexts to better understand the relationship between climate, conflict and fire. Further attention should be paid to the geopolitical and socio-economic aspects of fire since, as stated in the study, the causal relationship of this aspect is difficult to prove due to the mixture of other factors and, therefore, can be accompanied by a trivialisation of this aspect.

6. References

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7. Appendix

Table A1. Monthly air and surface temperature (LST) (°C) and precipitation (mm) from 2001-2021 in Manisa and Diyarbakir.

	Manisa			Diyarbakir		
	Precipitation (mm)	Air temperature (°C)	Surface temperature (LST, °C)	Precipitation (mm)	Air temperature (°C)	Surface temperature (LST, °C)
Jan.	115.18	4.00	3.49	90.43	1.26	0.45
Feb.	86.81	5.55	5.45	88.59	2.92	2.32
Mar.	67.13	8.54	8.89	77.78	7.48	7.16
Apr.	50.91	12.51	13.10	78.25	12.62	12.25
May	41.05	17.78	18.78	56.78	18.31	18.24
Jun.	24.20	22.21	23.79	14.78	24.75	25.93
Jul.	9.13	25.38	27.40	1.26	28.93	30.99
Aug.	8.18	25.48	27.24	1.38	28.69	30.04
Sep.	19.00	20.98	22.23	5.01	23.34	23.97
Oct.	53.37	15.63	16.06	49.53	17.20	17.09
Nov.	78.14	10.45	10.01	72.00	9.52	8.50
Dec.	100.28	5.79	5.32	90.18	3.68	2.73

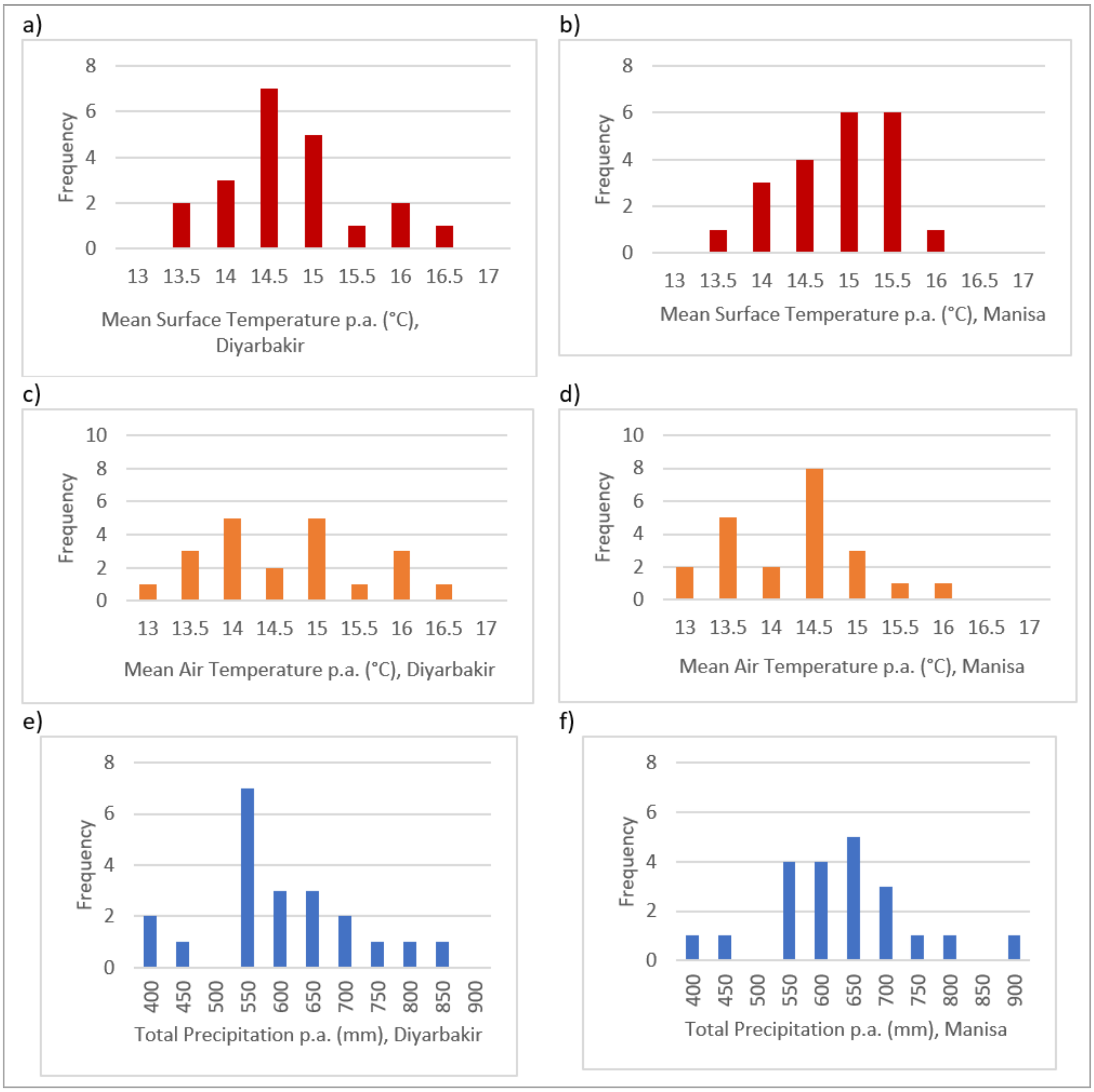


Figure A1. Cumulative frequency of annual mean surface - (a, b) and air temperature (c, d) and total precipitation (e, f) in Diyarbakir and Manisa, 2001 – 2021.

Table A2. Recorded numbers of conflict and fire events in Diyarbakir and Manisa, as well as annual average of air and surface temperature, total annual precipitation (mm) and their corresponding Z-score for Manisa (a) and Diyarbakir (b).

a)

	Total Precipitation p.a. (mm)	Z-Score annual Precipitation	Mean Surface Temperature p.a. (°C)	Z-Score annual Surface Temp.	Mean Air Temperature p.a. (°C)	Z-Score annual Air Temp.	Sum of active fire points p.a.	Sum of conflicts.
2001	763.47	1.01	15.18	0.03	14.28	-0.35	19	0
2002	656.31	0.02	14.38	-1.20	13.64	-1.16	27	0
2003	687.04	0.30	14.36	-1.22	13.47	-1.38	115	0
2004	570.44	-0.78	14.37	-1.21	13.44	-1.42	145	0
2005	707.45	0.49	14.64	-0.80	13.81	-0.95	206	0
2006	558.54	-0.89	14.61	-0.84	13.87	-0.87	89	0
2007	619.48	-0.33	15.64	0.73	14.85	0.37	219	0
2008	438.30	-2.01	15.58	0.65	14.88	0.40	207	0
2009	926.69	2.53	15.49	0.50	14.75	0.24	89	0
2010	808.11	1.43	15.97	1.25	15.19	0.80	137	0
2011	628.47	-0.24	13.77	-2.13	12.98	-2.00	156	0
2012	719.37	0.60	14.94	-0.33	14.39	-0.22	107	0
2013	716.37	0.57	15.14	-0.03	14.55	-0.01	104	0
2014	646.80	-0.07	15.72	0.87	15.06	0.63	130	0
2015	599.12	-0.52	15.27	0.17	15.00	0.55	125	0
2016	595.72	-0.55	15.38	0.34	14.98	0.53	130	0
2017	610.25	-0.41	14.86	-0.46	14.70	0.17	91	0
2018	650.62	-0.04	16.47	2.01	16.16	2.03	47	0
2019	696.96	0.39	15.87	1.08	15.59	1.30	61	0
2020	468.87	-1.73	15.61	0.69	15.32	0.96	74	0
2021	678.44	0.22	15.09	-0.10	14.86	0.38	60	0
annual mean	654.61		15.16		14.56		111.33	
annual standarddeviation	107.65		0.65		0.79		55.77	

b)

	Total Precipitation p.a. (mm)	Z-Score annual Precipitation	Mean Surface Temperature p.a. (°C)	Z-Score annual Surface Temp.	Mean Air Temperature p.a. (°C)	Z-Score annual Air Temp.	Sum of active fire points p.a.	Sum of conflicts. p.a.	Difference of Active fire points |Fire points, Diyarbakir - Fire points, Manisa|
2001	811.54	1.60	14.35	-0.85	13.67	-1.17	737	2	718
2002	613.84	-0.10	13.77	-1.63	13.07	-1.76	841	2	814
2003	783.09	1.36	13.95	-1.38	13.44	-1.39	317	2	202
2004	695.50	0.60	14.03	-1.28	13.43	-1.41	382	10	237
2005	583.45	-0.37	14.85	-0.19	14.21	-0.64	440	6	234
2006	639.05	0.11	14.55	-0.59	14.34	-0.50	561	11	472
2007	572.57	-0.46	14.59	-0.54	14.25	-0.59	865	11	646
2008	440.33	-1.60	15.10	0.14	14.78	-0.07	122	7	85
2009	656.33	0.26	14.89	-0.13	14.45	-0.39	2693	4	2604
2010	573.27	-0.45	16.23	1.65	16.05	1.19	1372	4	1235
2011	654.75	0.25	14.49	-0.67	14.34	-0.50	1047	10	891
2012	717.65	0.79	14.86	-0.17	15.04	0.19	267	10	160
2013	594.20	-0.27	15.04	0.07	15.11	0.25	1038	0	934
2014	568.00	-0.50	15.95	1.28	16.05	1.19	689	1	559
2015	572.06	-0.47	15.26	0.36	15.35	0.50	2035	48	1910
2016	560.68	-0.56	14.85	-0.19	14.91	0.06	1491	14	1361
2017	472.77	-1.32	14.80	-0.26	15.26	0.41	728	2	637
2018	872.53	2.13	16.67	2.24	16.95	2.08	385	7	338
2019	726.94	0.87	15.26	0.36	15.44	0.58	416	4	355
2020	624.94	-0.01	15.30	0.41	15.51	0.66	510	4	436
2021	411.44	-1.85	16.04	1.40	16.17	1.31	228	4	168
annual mean	625.95		14.99		14.85		817.33		
annual standarddeviation	115.83		0.75		1.01		637.24		

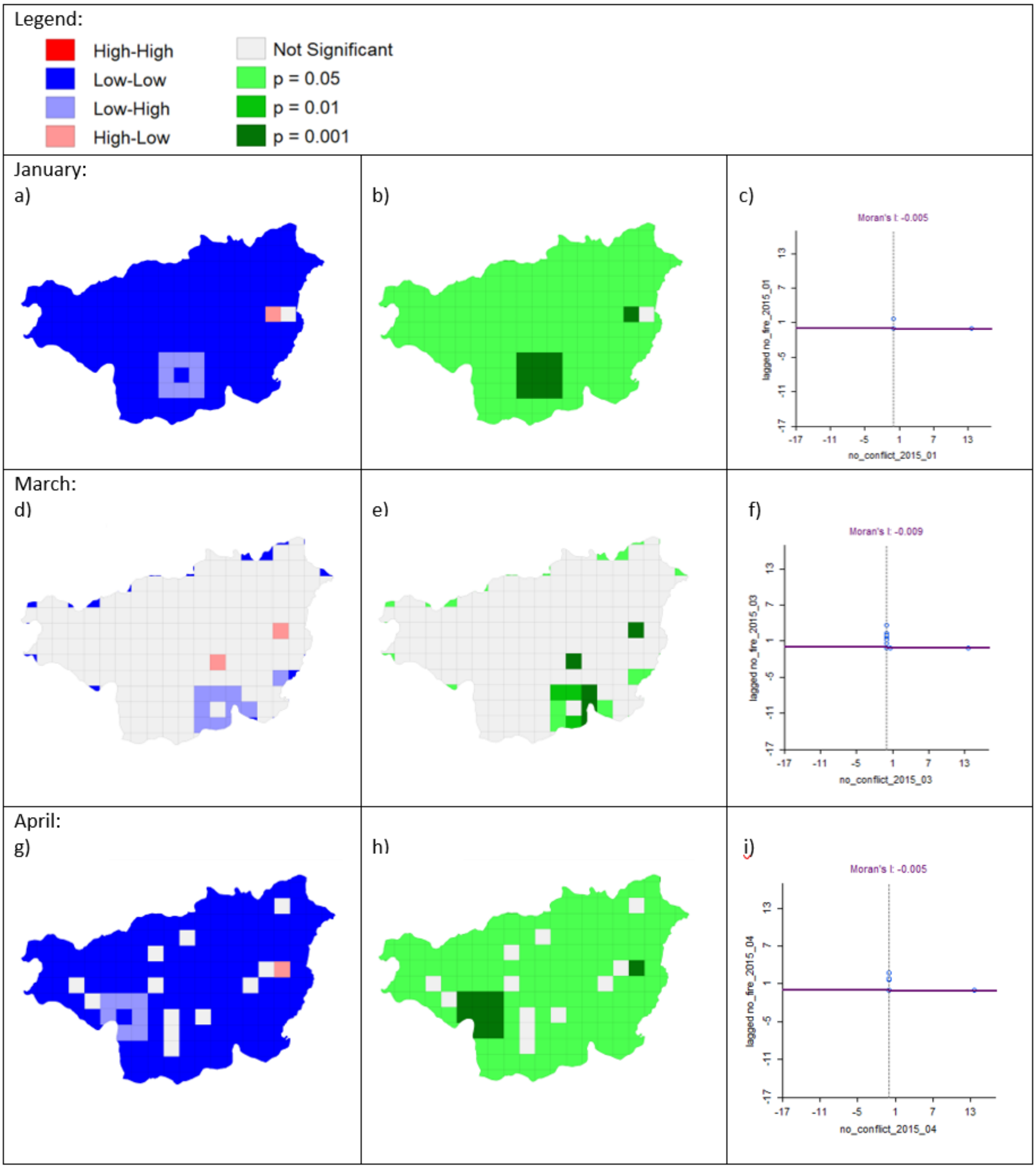
Table A3. Distribution of fire and conflict on the land cover classes *von IPCC land categories and CCI-LC classification* of Diyarbakir and Manisa from 2001 to 2021 (a) and for 2015 (b).

	Manisa, 2001-2021		Diyarbakir, 2001-2021			
	No. of Fires / Landcover	Fires (%) / Landcover	No. of Fires / Landcover	Fires (%) / Landcover	No. of Conflict / Landcover	Conflicts (%) / Landcover
Settlements	28	0.0120	32	0.0019	89	0.5460
Agriculture	2155	0.9221	17012	0.9910	70	0.4294
Grassland	18	0.0077	69	0.0040	0	0.0000
Bare areas	28	0.0120	31	0.0018	0	0.0000
Forest	108	0.0462	5	0.0003	0	0.0000
Shrubland	0	0.0000	0	0.0000	0	0.0000
Sparse vegetation	0	0.0000	2	0.0001	4	0.0245
Water	0	0.0000	15	0.0009	0	0.0000
Total	2337		17166		163	

a)

	Manisa, 2015		Diyarbakir, 2015			
	No. of Fires / Landcover	Fires (%) / Landcover	No. of Fires / Landcover	Fires (%) / Landcover	No. of Conflict / Landcover	Conflicts (%) / Landcover
Settlements	0	0.0000	1	0.0005	37	0.7708
Agriculture	122	0.9760	2027	0.9961	11	0.2292
Grassland	1	0.0080	4	0.0020	0	0.0000
Bare areas	1	0.0080	2	0.0010	0	0.0000
Forest	1	0.0080	1	0.0005	0	0.0000
Shrubland	0	0.0000	0	0.0000	0	0.0000
Sparse vegetation	0	0.0000	0	0.0000	0	0.0000
Water	0	0.0000	0	0.0000	0	0.0000
Total	125		2035		48	

b)



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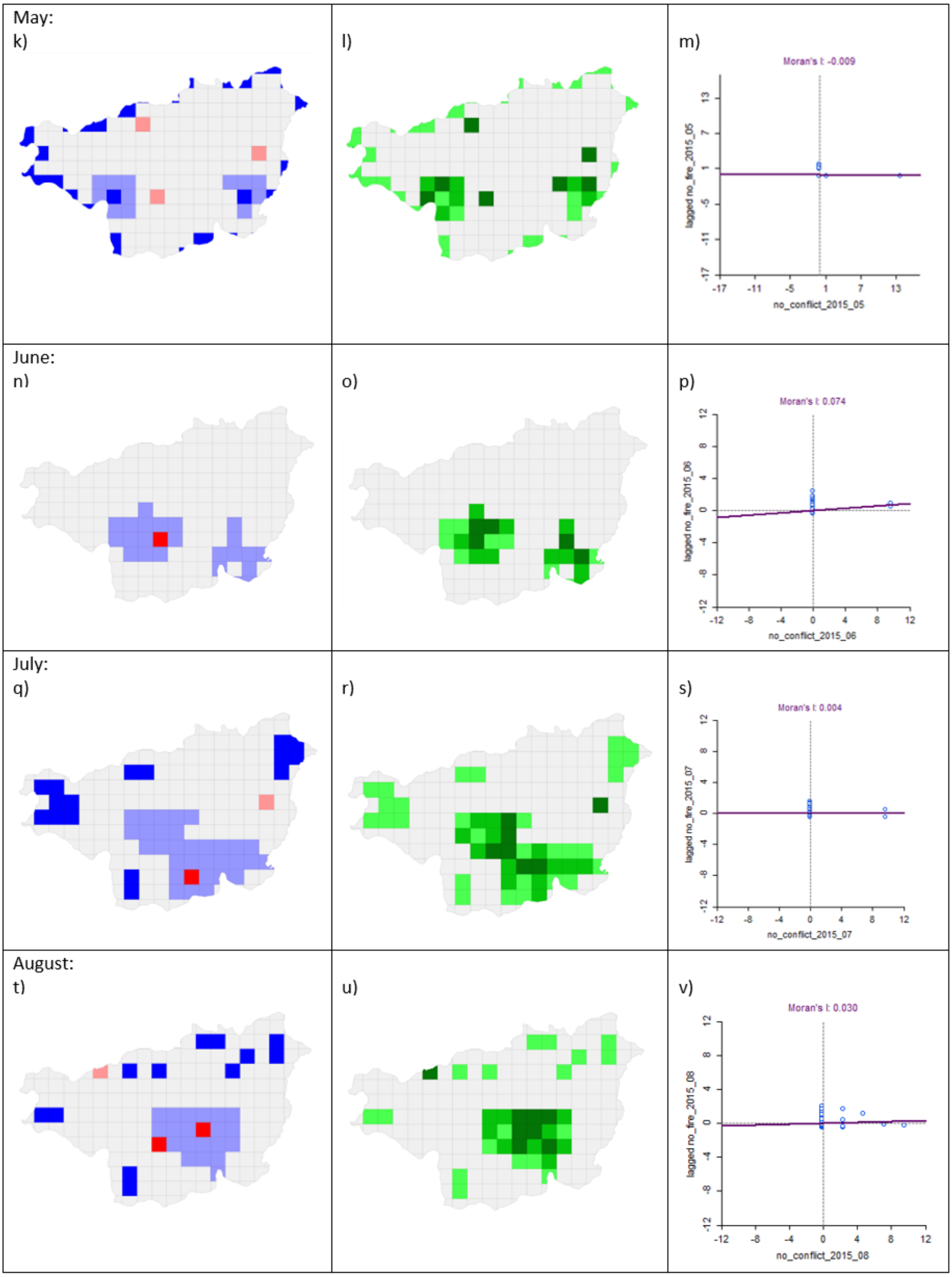

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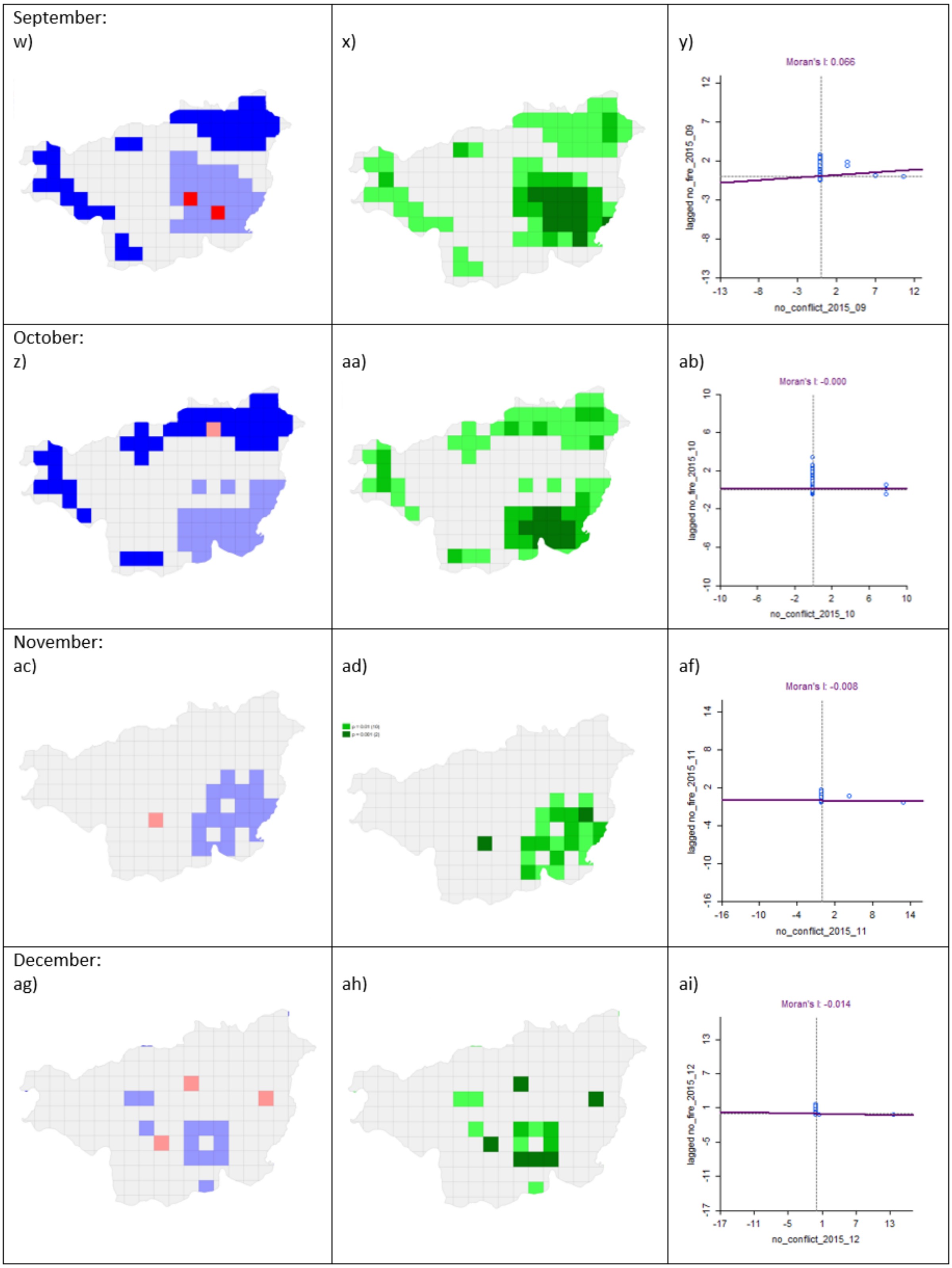

Figure A2. Results of bivariate local relationship January to December of 2015 in Diyarbakir.

Table A4. Number of conflicts and fires, as well as the climatic factors of total precipitation, average surface and air temperature and FWI per month in 2015 in Manisa (a) and Diyarbakir (b).

a)

	No. of Fires/ Month	Total Precipitation (mm)/ Month	Mean Surface temp. (°C)/ Month	Mean Air temp. (°C)/ Month	Mean FWI/ Month
January	1	127.18	3.04	3.76	0.05
February	1	73.16	4.62	4.97	0.16
March	2	89.58	8.92	8.73	0.73
April	0	39.37	11.31	11.02	5.79
May	0	49.04	19.57	18.95	21.96
June	2	41.64	22.14	21.01	13.65
July	1	8.16	27.36	25.97	42.40
August	3	9.56	28.07	26.45	32.32
September	22	20.18	24.84	23.93	30.69
October	87	65.31	17.21	16.78	14.39
November	4	75.71	11.37	12.32	11.50
December	2	12.24	4.81	5.89	4.65

b)

	No. of Fires/ Month	Total Precipitation (mm)/ Month	Mean Surface temp. (°C)/ Month	Mean Air temp. (°C)/ Month	Mean FWI/ Month	No. of Conflicts/Month
January	1	68.39	1.12	1.69	0.05	1
February	0	104.96	3.70	4.15	0.16	1
March	4	116.74	6.83	7.21	0.72	23
April	1	64.55	11.06	11.35	5.71	31
May	2	47.22	18.06	18.32	21.75	14
June	56	22.24	25.64	24.78	13.85	2
July	390	1.25	31.62	29.79	42.68	2
August	270	1.42	30.45	28.97	32.74	12
September	638	3.26	25.89	26.01	30.42	7
October	625	112.90	17.74	17.84	13.96	3
November	38	42.55	8.31	9.56	11.23	4
December	11	44.83	2.48	3.79	4.53	31