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Governance, war, and rain: Statistical analysis to evaluate agricultural dynamics in Northern Syria.

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Governance, war, and rain: Statistical analysis to evaluate agricultural developments in Northern Syria.

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

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Abstract

In the conflict zone of Northern Syria, agriculture is the livelihood of a major part of the population. Nevertheless, the reasons for changes in agricultural land are manyfold. This paper looks at two areas in North Syria which have been under Syrian governance until the Syrian Civil War (2011) and were contested territory until 2016. Since then, the Rojava area has been governed by the PYD, a Kurdish political party advocating social ecology and promoting the diversification of crops. The Euphrates Shield, in contrast, is controlled by Syrian oppositional forces backed by Turkey, where most of the cropland consists of monocultures of wheat. By looking at cropland extent in these two areas over a 22-year timespan (2000 – 2022), this paper aims to study changes in cropland extent to political governance, conflict, and precipitation. The data for this project was derived from a model that classifies satellite images to different land use classes using plant phenology. Through statistical analyses, cropland extent is related to conflict events, differences in governance, and precipitation data. No significant correlation between governance and cropland extent was found. Precipitation is found to influence only Rojava. It was argued that this could be due to the inability to irrigate in the area, while it is possible in the Euphrates Shield through water supplies from Turkey. As for conflicts, it is found that both areas are affected by events such as the Arab Spring and the Civil War. Only the Euphrates Shield area is found to be influenced by the Turkish military operation in 2016 and to have a statistically significant difference in land use comparing pre-conflict years (2000 – 2011) with conflict years (2011 – 2022).

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Abbreviations/Glossary

DYHC = Double Yearly Harvest Cropland
ES = Euphrates Shield, Study area
IS = Islamic State, Terror militia
LULC = Land Use / Land Cover
NDVI = Normalized Difference Vegetation Index
NPP = Net Primary Production
PYD = Kurdish Democratic Union Party
Rojava = Autonomous Region of North and East Syria, in this case refers to the study area
SYHC = Single Yearly Harvest Cropland

1 Introduction

The intertwinedness of humans and land is undeniable. As Long et al. (2021) mentioned, land is the spatial carrier of anthropogenic activities, a fundamental factor in socio-economic development, and a survival resource for all humans. Today, about one-third of the world's land mass is used for agriculture, while two-thirds are split equally between forest and other land including barren and desert areas, urban land, and infrastructure (FAO, 2023). Intensive land use and land exploitation for food production have become issues affecting the global community. These changes are known as land use and land cover (LULC) changes and are often caused by human activities. They are of great interest as these changes have considerable implications in many areas. Such areas include the land-atmosphere/climate interactions (i.e. emittance of carbon to the atmosphere), negative effects on river communities, and soil erosion to name a few (Almohamad, 2020; Cooper et al., 2013; Nedd et al., 2021; Smith, 2008).

Eklund et al. (2017) explained, changes to land systems can either occur slowly (such as urbanization) or rapidly with sudden implications due to e.g. environmental and political changes or armed conflict. In areas with sudden LULC changes due to armed conflicts, it is often hard to conduct studies as it might be impossible or too dangerous to do physical measurements (Eklund et al., 2022). In these cases, remote sensing can be used to obtain data. This is a practice, where data that has been remotely sensed, i.e. collected through a device that is not in physical contact with the observed object/phenomenon (such as satellite images or aerial photography), is used for analysis (Al-Fares, 2013). Although remotely sensed data might not be as accurate as ground measurements it is a good way to study remote or inaccessible areas (Li et al., 2022).

This paper focuses on an area that is difficult to access for physical measurements: The Autonomous Region of North and East Syria, Rojava, home of the majority of the Kurdish population in Syria. This is a region affected by a civil war as well as multiple Turkish military operations throughout the last decade. To get a proper overview of the area it is important to introduce the political landscape in Syria.

As Zaamout (2020) explained, Syria is deeply divided. The country is torn between hundreds of armed factions fighting for different values. These can mostly be divided into three groups: Syrian regime militias, militant Islamist groups, and Kurdish groups. This paper focuses on one Kurdish group, the Kurdish Democratic Union Party (PYD) which governs the *Autonomous Region of North and East Syria* (hereinafter called Rojava). As well as the Syrian National Army (SNA), a Syrian oppositional group, backed by the Turkish armed forces. The SNA governs the *Euphrates Shield* area in northern Syria. While a more detailed description of Rojava and the Euphrates Shield is given in the *Background* section below, the agricultural policies are discussed here.

The PYD's base principles are vastly different from the Syrian government and rely on the concept of social ecology, which tries to reconnect humans with nature, thus also having a much more environmentally friendly, sustainable, and diversified approach to agriculture (Hunt, 2021; Öcalan et al., 2022). After a trend of rural-to-urban migration in the 2000s, the PYD was able to revive and diversify the agricultural production in Rojava in the early 2010s (Dinc & Eklund, 2023; Zaamout, 2020). This was achieved through repeasantization, increasing processing capacity, redistribution of state-owned farmland, and diversification of crops (Zaamout, 2020). The production of cotton in the area fell but vegetable, spices, lentils, and bulgur wheat production increased. Regional food provisioning was encouraged through the rise of regional markets and price caps were imposed to prevent impossibly high prices (Jongerden, 2022; Knapp et al., 2016).

Contrary to this, in the Euphrates Shield area agriculture consists of fruit and olive trees, and one-third of arable land is used for wheat production (Knapp et al., 2016). While the most common agriculture is wheat, barley, lentils, and chickpeas are also common. Parts of the produce are exported to Turkey for further processing (Baker, 2021).

It has not been looked into how agriculture changed in the areas under Turkish influences. Instead, previous studies focused on creating datasets about agricultural productivity, looking at agricultural changes in a different or bigger area, and relating agriculture to the many conflicts in Syria (Eklund et al., 2017; Jaafar et al., 2015; Li et al., 2022; Mohamed et al., 2020; Zaamout, 2020). Eklund et al. (2017) and Jaafar & Woertz (2016), for instance, compared agricultural productivity in regions under IS control in Iraq and Syria. In other papers Eklund et al. (2016, 2022) investigated agricultural changes during the conflict in Iraqi Kurdistan and related agricultural changes in Syria to droughts. In the latter study, it was found that the droughts in 2000 and 2007 – 2009 strongly affected agriculture, however, the region quickly recovered from these extreme events.

Li et al. (2022) identified changes in agriculture that could be attributed to the Civil War. This was done by using a spatially explicit panel regression analysis to quantify and later exclude the effects of precipitation on cropland changes. This study found that cropland usage showed a greater variability and spatial heterogeneity during wartime, with some regions having improvements in agricultural development and others losses (Li et al., 2022).

In a paper published by Lio & Liu (2008) the relationship between governance and agricultural productivity was examined. They examined a dataset consisting of 127 countries (including Syria). Using various cross-country datasets and mathematical and statistical analysis their findings show that given the same agricultural capital stock and land a farmer in a country with better governance produces more. These findings are in line with the results found by Bayyurt & Arıkan (2015), who examined governance and agriculture in European countries. Galiè et al. (2017) on the other hand, conducted a six-year study in pre-conflict Syria, which identified that rural women's empowerment through barely breeding improves household security, by conducting projects with twelve Syrian women. As it is not possible to conduct such analysis or field work, this paper relates governance to agriculture by looking at the development of cropland extent throughout the timespan and identifies singular events of governance which affected agriculture.

To examine if and how the Turkish conflicts affected agriculture, this study aims to relate the agricultural changes in the Rojava and Euphrates Shield region to policy and governance, as well as precipitation. This will be achieved by taking datasets by Eklund et al. (2017, 2020, 2021) that contain raster data about single- and double-year harvest cropland (i.e. cropland that is harvested once or twice a year) and performing multiple t-tests and correlation analyses. The exact research question and how it will be achieved, as well as which other factors will be researched, are explained in the following *Aim and Research Questions* section.

1.1 Aim and Research Questions

This thesis aims to study changes in cropland in two study areas in relation to conflict, and precipitation, and political governance. This is achieved by answering the following research questions:

1. What correlation exists between single year harvested cropland between the two areas?
2. What correlation exists between double year harvested cropland between the two areas?
3. How are single and double year harvested cropland in the same area related?
4. What correlation exists between cropland extent and precipitation?
5. What difference is there between agricultural land use before and after the Civil War?

These research questions are answered by comparing a time series of agricultural land use, which contains classified data obtained through a model relying on satellite data, in each area when it was under the control of different parties. First, the Syrian government controlled the areas (2000 – 2011), then it was contested during the civil war (2011 – 2014), following years of mixed control between IS, Syrian rebel groups, and the PYD (2014 – 2016) and lastly control of Syrian opposition groups in the Euphrates Shield area and control of the PYD in the Rojava region (2016 – present). The thesis follows the hypothesis that agricultural land use has more prosperous developments in the Rojava region compared to the Euphrates Shield since the diversified and sustainable approaches by the PYD favour agricultural flourishing. Since the current governance in the areas only go back to 2016 however, it is difficult to find a trend in governance. While research questions 1, 2, and 3, are set to find a long-term trend, this paper will also look at single events where governance affected agriculture. Furthermore, precipitation and conflict are expected to have strong influences on agricultural land use in both areas.

After introducing the topic this paper gives a political background while also highlighting important political and environmental events during the studied timespan. The *materials and methods* section will give an overview of the data used and introduce the study area. Following this, the section will explain the different steps of the analysis. The *results* section showcases the computed results, which are then discussed in the following *discussion*. Furthermore, the results will be related to relevant literature as well as finding links to recent developments. Lastly, the discussion will consider uncertainties and errors and give recommendations for future research. The conclusion highlights the most important findings and discussion points, and answers the research questions and aim.

2 Background

Before the Syrian civil war northeast Syria was exploited by the Syrian government, being one of the poorest regions in Syria. This region is nowadays known as Rojava, consisting of three cantons: Afrin (northwest), Kobane (central north), and Cizire (northeast). Paradoxically, Rojava is very rich in natural resources and fertile soils. Being known as the country's breadbasket, its agriculture was responsible for one-third of Syria's economic strength. During these times, the regime forced these regions to produce their main agricultural commodity. In Cizire this meant monocultures of wheat. Afrin and Kobane were rather used for fruit and olive production. Anyhow, one-third of arable land in Kobane was used for wheat production. Furthermore, the Syrian government subsidized agricultural production in these areas. Following the Syrian civil war, the Rojava region liberated itself from Syrian control. (Knapp et al., 2016)

2.1 The Autonomous Region of North and East Syria

In 2011 the Arab Spring revolutions shook the Arab world while also making global shockwaves (Grinin & Korotayev, 2022). Thereafter, a civil war broke out in Syria (2011 – 2014), which brought a multitude of local and global implications. Locally, the civil war led to the destruction of infrastructure and displacement of millions of Syrians, a humanitarian crisis and ethnic division, while fragmenting the power in the country and favouring the rise of extremism. Zaamout (2020) goes on to explain that the Syrian civil war affected the global community through a refugee crisis, leading to regional instability and a proxy war. Moreover, the political instability lead to the rise of the Islamic State (IS), a terror organization accountable for many global terrorist attacks. The political vacuum left in many Syrian regions, however, also gave possibilities for other minorities to rise (Federici, 2015).

After the Syrian Army withdrew its troops from North and East Syria in 2012 the Kurdish Democratic Union Party (PYD) emerged as a key player in establishing a Kurdish autonomous region (Federici, 2015; Zaamout, 2020). By the end of 2013, what was unimaginable just a few years earlier had become reality: a local self-governance of the Kurdish minority in the Autonomous Region of North and East Syria, also known as Rojava.

2.1.1 Ideology and Leadership Style

The Social Contract of the Rojava Cantons was established on the 29th of January 2014. Through 95 articles this constitution creates a new social contract reliant on mutual and peaceful coexistence and existence between all levels of society and ethnicity (*The Social Contract of the Autonomous Regions of Afrin, Jazira, and Kobane*, 2014). The articles are based on principles of equality and environmental sustainability. The book *Social Ecology and the Rojava Revolution* (Öcalan et al., 2022) explains the three main pillars of Rojava: direct democracy, women's liberation, and social ecology.

Direct democracy refers to a style of democracy where every eligible citizen is allowed to vote on all decisions and laws through initiatives and referendums (Bowler et al., 2020). Secondly, the PYD follows the framework of Jineology, women's science. Jineology is based on the oppression Kurdish women have experienced in patriarchal and colonial history and it criticizes how the power in monotheistic religions, the state, and capitalism in general is in the hands of men (Neven & Schäfers, 2017; Öcalan et al., 2022). The goal of Jineology is to restore the power of women as a core part of society.

First defined by Murray Bookchin, social ecology is a philosophical thought that advocates a complete reordering of society to disrupt all hierarchical structures. Through this, a moral economy shall be created that reharmonizes humanity with nature while encouraging diversity, creativity, and freedom (Öcalan et al., 2022).

2.2 Operation Euphrates Shield

Turkey fears its national security is endangered through the Rojava Revolution flourishing at its southern border, as this could inspire the Kurdish movements in Turkey. Thus, it sees the PYD and Rojava as a threat to its own country, labelling the PYD as a terrorist group. Because of these reasons, Turkey has conducted four military operations on Syrian territory, with the support of Turkey-backed opposition groups (Baker, 2021). All four operations lead to the formation of interim governments in these areas. Since the second, third, and fourth military operations occurred in 2018, 2019, and 2020 it is difficult to see a trend in agricultural changes on a timespan as short as 3-4 years. Therefore, it was chosen to use an extended timespan to examine the agricultural changes, starting from the first military operation in 2016: Operation Euphrates Shield.

Operation Euphrates Shield focused on a 98-kilometer gap between Afrin canton and Kobane canton that is of strategic importance (Knapp et al., 2016). This operation aimed to prevent the unification of these two cantons, which would give Rojava a direct connection to the Mediterranean Sea, as well as weaken the IS present in the area (Al-Hilu & European University Institute, 2021). It was the first Turkish military operation in Syria, conducted from August 2016 to March 2017. It entails an area of 2415 km^2 which is controlled by Turkey-backed Syrian oppositional forces today (*Relations between Türkiye–Syria / Republic of Türkiye Ministry of Foreign Affairs*, n.d.). The area includes parts of the northern Aleppo region, which is one of the most productive agricultural regions in Syria.

After the Operation, Turkey helped establish stability in the region. This was partly accomplished through building projects, training military and police officers in Turkey, helping build a justice system in the region, and reviving the agricultural sector in the region (Yeşiltaş et al., 2017). Nevertheless, Turkey is also discriminating against Kurds in these areas, having multiple military outposts in the region, and changing the demographics in the area to weaken the Kurdish population (Al-Hilu & European University Institute, 2021; Baker, 2021). Furthermore, Turkey is confiscating products such as crops and causing forced starvation by regulating the water flow from the Euphrates River (Baker, 2021).

2.3 Timeline of important events

Figure 1 below shows important events that affected agriculture in this region of Syria. This will make it easier to interpret and understand the agricultural developments during the analysis. These events can be categorized into two categories: Water stress and political stress. The political stressors have already been explained in the introduction and background section. They entail the Arab Spring and the start of the civil war in 2011, the ongoing civil war from 2011 – 2014, and Operation Euphrates Shield in 2016.

Water stress includes both, events of water scarcity but also water abundance. Droughts and extreme precipitation have been recorded and are projected to increase with climate change. Syria is already very prone to water stress, which will just increase in the future. In the period studied in this paper, however, water stress is found in the form of droughts in the years 1999, 2008, and 2017, which negatively affected agriculture. Excessive precipitation, which positively influences agriculture, on the other hand, has occurred in the years 2012, 2018, and 2019 (Figure 5).

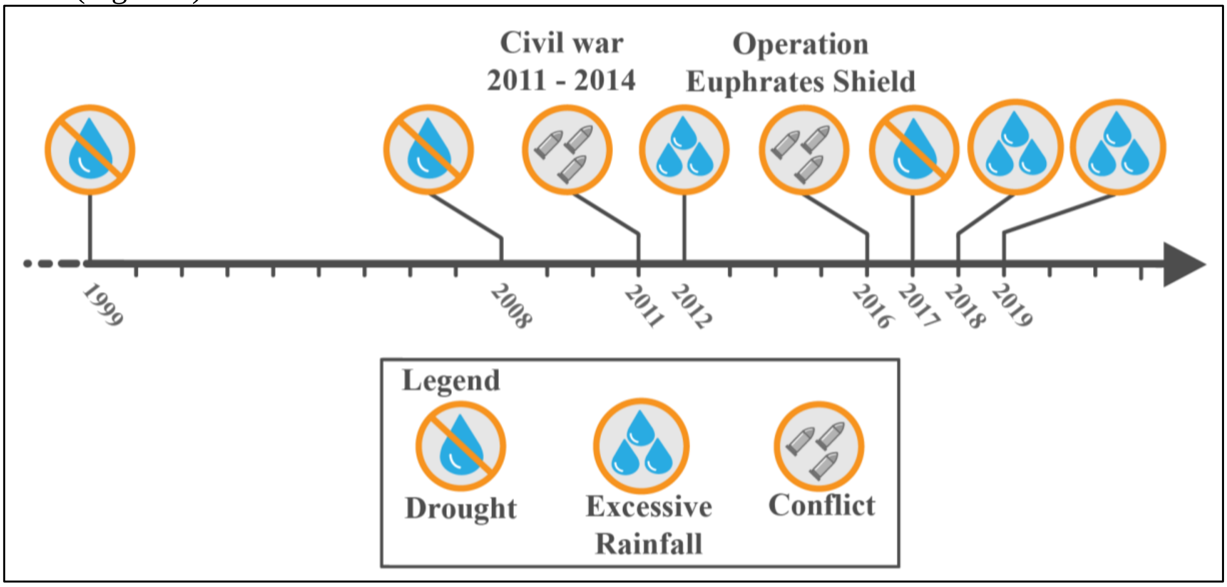

Figure 1: Timeline of important political & environmental events.

3 Methodology

3.1 Data description

Table 1 below shows all the data used in this project. The first two datasets: *i* (Eklund et al., 2020) and *ii* (Eklund et al., 2017, 2021), contain modelled data of LULC categorized into bare soil, cropland (single harvest) – crop fields which are harvested once a year, cropland (double harvest) – crop fields which are harvested twice a year, and natural vegetation. For simplification, single year harvest cropland will be abbreviated to SYHC, while double year harvest cropland will be DYHC in this study. The categories bare soil and natural vegetation were excluded from the analysis since only cropland was studied in this project.

Both datasets (*i* and *ii*) rely on the same model, which uses the phenology of different vegetation types to distinguish between cropland and other vegetation types (Eklund et al., 2017). A plant's phenology is characterized by net primary production (NPP) changes on a seasonal scale, which can be recorded by satellite imagery with a high temporal resolution. Using these the peaks of NPP it can be differentiated between the different categories (as a single harvest cropland will only have one peak while a double harvest cropland will have two) (Eklund et al., 2017). The data used for each model differs, while dataset *i* used MODerate resolution Image Spectroradiometer (MODIS) product MOD09 collection 6, dataset *ii* used MODIS MOD13Q1 and MOD13Y1 collection 6. Both datasets cover the period from 2000 – 2016, however, only dataset *ii* covers 2017 – 2022. It was chosen to use dataset *i* for the timespan 2000 – 2016, and dataset *ii* for 2017 – 2022. The reason for this was that dataset *i* has been accuracy assessed while dataset *ii* has not.

The areas of governance in Syria were obtained from the Rojava Information Center and included multiple polygon layers dividing Syria into territories under different governance. Lastly, Precipitation data from WorldClim was downloaded in a 2,5 ArcMin spatial resolution. Since harvesting times for wheat and barley, as well as other grainy crops is in April/May the precipitation of the previous year generally influences the next year's harvest (Eklund et al., 2020). Thus, precipitation values from 1999 to 2021 were used in this study.

Table 1: Data used in this Project.

Data Name/Description	Data Type	Resolution	Date	Source
Annual LULC and harvesting frequency maps for Iraq/Syria, 2000-2016	Raster file	250m	Nov. 2020	Eklund et al., 2020
Annual LULC and harvesting frequency maps for Iraq/Syria, 2000-2023	Raster file	250m	2023	Eklund et al., 2017, 2021
Areas of governance in Syria	Shape file	N/A	2024	Rojava Information Center
WorldClim average monthly precipitation between 1999-2021	Raster file	2,5ArcMin ~ 4km		Harris et al., 2020

3.2 Study Area

Syria is a country found along the eastern coastline of the Mediterranean Sea. It has a total area of 185,180 km^2 (Al-Fares, 2013). Climatically, Syria is affected by the four seasons. While the east is characterized by a warm semi-arid/desert climate, a warm Mediterranean climate is found in the west, according to the Köppen Climate Classification (Mohamed et al., 2020). Summer is generally hot and dry while winter brings colder and wetter weather, with January being the month with the most precipitation. Precipitation is highest in Syria’s north-western parts and decreases towards the south and east, higher precipitation is found in more elevated areas (Al-Fares, 2013).

In the north, Syria borders Turkey. Here the study area for this project is located (Figure 2). The Euphrates Shield region (ES) is shown in orange and the Rojava study site is in yellow. Rojava was split up into two areas, one east and one west of the ES. As precipitation and temperature change from east to west this was done to yield the most similar conditions for both areas. The area west of the ES is smaller since only this area is controlled by the PYD after Turkey intervened in the Afrin region west of it. The study area east of the ES is not located adjacent to the Euphrates Shield area since the dataset used reported many missing values in that area. Due to the conflict in the region, regional borders of Rojava change over the years. This change, however, was not considered when choosing the study sites since it was not possible to find open-source geoinformation about the regional border developments in a sufficient spatial and temporal scale.

The ES has a total area of 2409 km^2 while the Rojava site entails 2372 km^2. The whole study area is within the Euphrates River basin, with the river flowing through parts of both sites (Al-Fares, 2013). Together with precipitation, it is the main water source and crucial for agricultural productivity in the area. The Euphrates River enters Syria through its northern border with Turkey, thus Syria is constrained by the amount and quality of water provided by Turkey (Al-Fares, 2013). This amount was agreed on in 1987. Since 2021, however, Turkey has been letting less water pass through the border which negatively affects agriculture in the Euphrates River basin (Ligios, 2023).

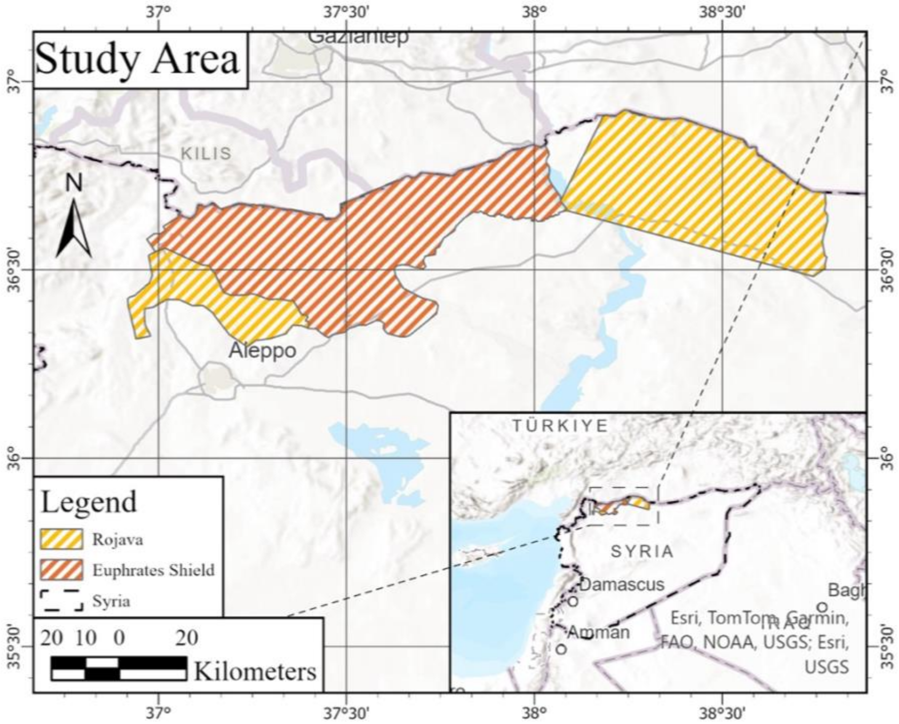

Figure 2: Study Area with yellow showing Rojava and orange the Euphrates Shield.

3.3 Data Processing

All data was downloaded and imported into ArcGIS Pro (v. 2.7.0). First, the study areas were defined and clipped so that two layers resulted — one with the study area in the Rojava region and the other showing the ES area.

Datasets *i* (containing 2000 – 2016) and *ii* (containing 2017 – 2022) were clipped to the study areas, resulting in one layer per study area and year. An attribute table was created for each Raster and the number of cells for the categories *SYHC* and *DYHC* per year were extracted and imported into Microsoft Excel (v. 16.84).

The precipitation data was downloaded and also clipped to the study area extent. The monthly data was summed to obtain yearly rainfall by using the *raster calculator* tool. Finally, the average of all raster cells in one study area was computed and extracted to obtain one value for precipitation per study area and year. The data points were imported to Excel, where further analysis was carried out.

In Microsoft Excel, the data was plotted as graphs to be able to identify differences between the study area and timeframe. Furthermore, the standard deviation and mean were calculated for the precipitation dataset to create a precipitation variability chart. All years deviating one standard deviation or more from the mean were identified as years of unusually low (drought) or unusually high (abundant precipitation) rainfall. This was used in Figure 1 for the important environmental events.

The statistical analysis was conducted using R (v. 4.4.0). Taking the data from Excel, first, the Shapiro-Wilk Normality test was used to check whether the data was normally distributed. Once this was assured a two-sample T-test between the Rojava study area and the ES study area was undertaken to check whether there is a statistically significant difference in agriculture. A t-test is the ideal statistical test in this case since it will determine whether there is a significant difference between two groups, which will explain whether the observed differences are due to chance of represent a real effect. Furthermore, the sample size of 22 is a good fit for the t-test as it should not contain more than 30 samples (Rogerson, 2001). The null hypothesis (H_{0A}) states that there is no difference in agricultural land use between the two study sites. The alternative Hypothesis (H_{1A}) states that there is a difference in agricultural land use between the two study sites. Furthermore, two paired t-tests were conducted to find out whether the use of SYHC changed between the stable period before the Arab Spring protests in 2011 and the period characterized by war (2012-2022). Since the civil war and the Arab Spring protests strongly disrupted Syria in 2011 the data points of 2011 were not included in the analysis. The null hypothesis (H_{0B}) for the paired t-tests was that agricultural land use did not change in the areas. The alternative hypothesis (H_{1B}) was that agricultural land use changed in the areas.

Next, a correlation analysis using Pearson’s correlation was conducted, which gives the direction and strength of a relationship between two groups, as well as whether it is statistically significant or not (Rogerson, 2001). This was done between the annual precipitation in the area and ES/Rojava. Similarly, a correlation analysis between single harvest and double harvest in each study area was conducted to try to identify whether single and double harvest are correlated to each other or not. This will give information on whether similar policies are implemented for single and double harvest cropland. Since Pearsons Correlation assumes a linear relationship, this was visually validated trough scatterplots. Finally, scatterplots for each correlation of above 0.5 were included in the appendix.

4 Results

Figure 3 below shows the agricultural area used for SYHC in Rojava (yellow) and the ES (orange) plotted with average yearly precipitation (blue). Generally, SYHC in both areas follows the same pattern. In the year 2000, SYHC has a low point. The agriculture increases in 2001. After a smaller dip in 2002 a static development from 2003-2007 is observed. In 2008 a big drop is noticed. 2009 and 2010 show an increase in agriculture while this drops again in 2011 and 2012. After 2012 an erratic movement is found with strong increases and sharp decreases following each other. The lowest value in the whole timespan is found in 2016 with 245 km^2 for Rojava and 409 km^2 for the ES, followed by a small increase in 2017 and 2018 and the peak of land used for agriculture with single yearly harvest is in 2019 (1909 km^2 in Rojava and 1525 km^2 in the ES). 2020 also shows very high values. In 2021 and 2022 a big drop in land use is found. Generally, SYHC changes seem to have a lower amplitude in the ES area, which means lower high points and higher low points than Rojava.

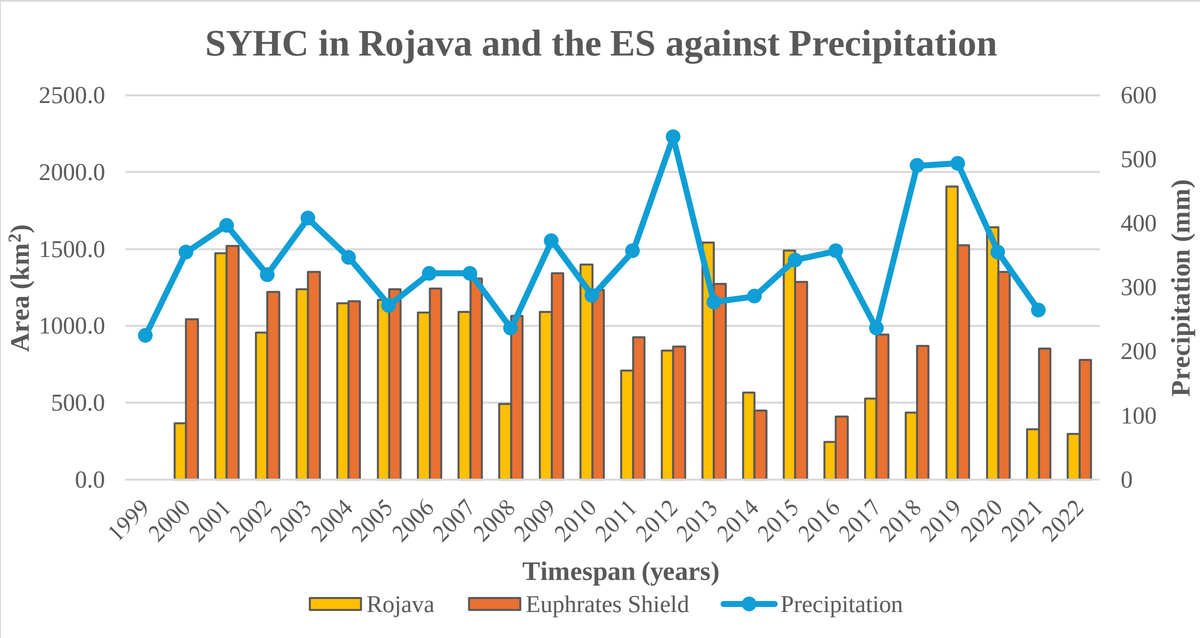

Figure 3: Single yearly crop harvest extent in Rojava and the Euphrates Shield area, and Precipitation between 2000-2022.

Figure 4 shows the DYHC for Rojava (yellow) and the ES (orange), as well as Precipitation (blue). In 2000 DYHC had very low values, the lowest value for Rojava is recorded here (4 km^2). There is a strong increase in 2001, with the peak of DYHC in Rojava (63 km^2), followed by a drop in 2002. An increase in DYHC is noticed in 2003 and 2004, followed by another decrease in 2005. 2006 and 2007 show higher DYHC values for Rojava while it stays relatively low in the ES. After another drop in 2008 an increase in both areas is found for 2009, 2010, and 2011. 2010 shows the highest DYHC value in the ES with 38 km^2. In 2012 a notable decrease is found. While it stays consistent until 2014 in Rojava, the ES is identified by increases and decreases until 2016, where the lowest amount of DYHC is found in the ES with 2 km^2. In Rojava 2016 shows higher values compared to 2015 and 2017. After 2017 an increase in both areas is noticed, which dropped slightly in 2021 but increased in 2022.

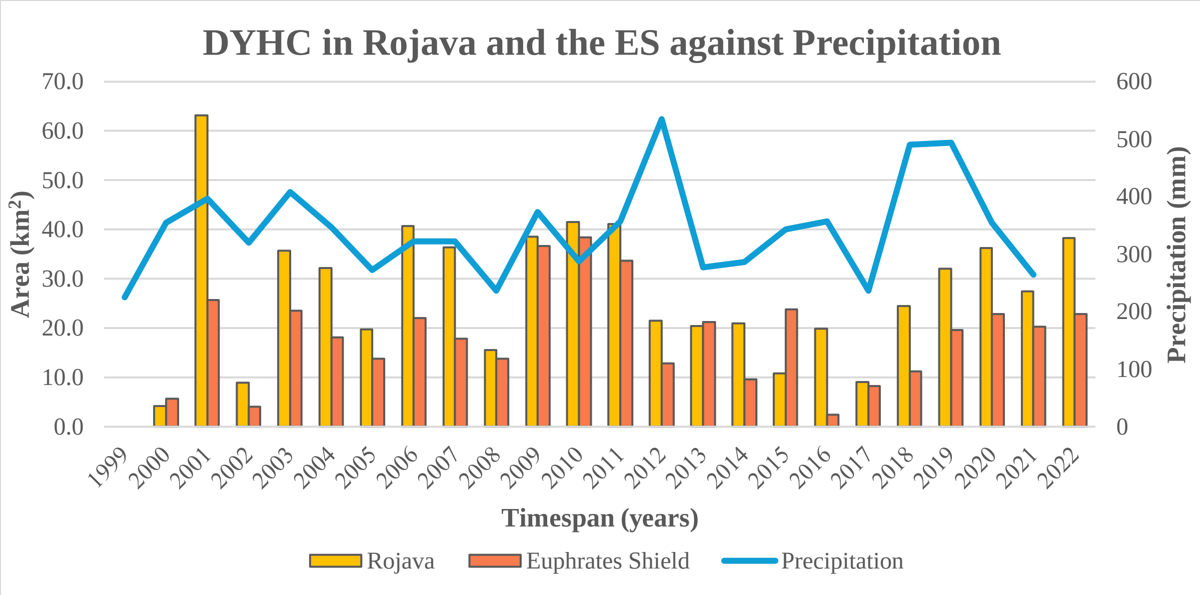

Figure 4: Double yearly crop harvest extent in Rojava, the Euphrates Shield area, and Precipitation between 2000-2022.

As for Precipitation (Figure 5), the lowest precipitation was found in 1999 with an average of 225 mm. It then increases in 2000 and 2001 but 2002 recorded lower precipitation values. After an increase in 2003 precipitation decreased in 2004 and 2005. Generally, each year's precipitation is close to the overall average of 342 mm until 2012, which was the wettest year (535mm). One exception is 2008, where lower precipitation is recorded. The following years again follow the overall average until a year of little precipitation in 2017, followed by two years of strong precipitation in 2018 and 2019. For 2020 and 2021 precipitation values are closer to 342 mm again. Looking at Figure 5, 3 years recorded precipitation values lower than one standard deviation (83mm) from the mean (342mm), which were identified as droughts. These years are 1999, 2008, and 2017. Furthermore, there are 3 years which are more than one standard deviation above the mean. These years of high precipitation are 2012, 2018, and 2019.

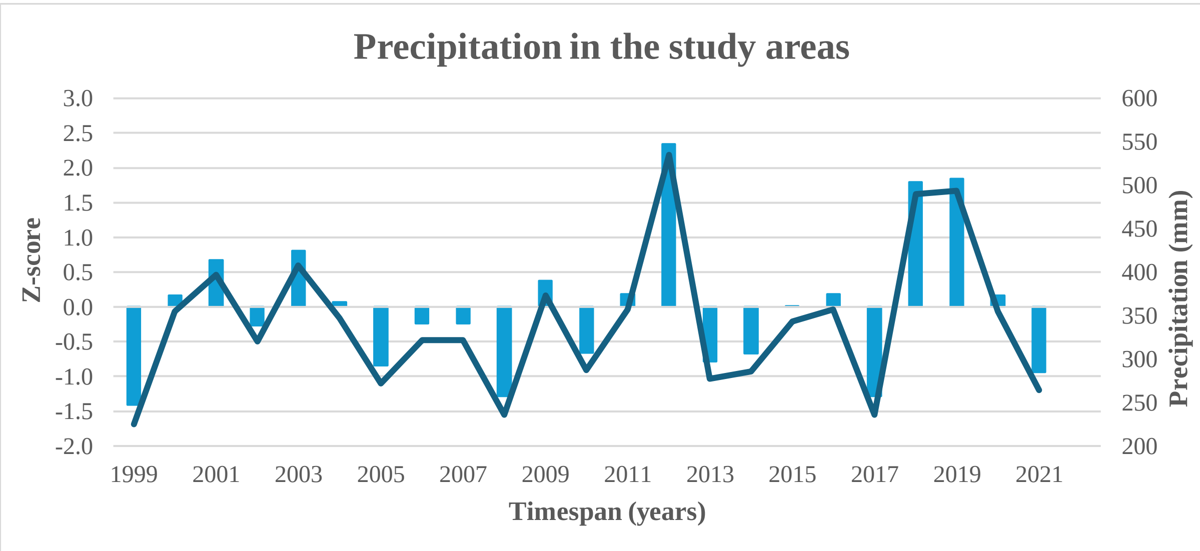

Figure 5: Precipitation in the study area using standard score to identify years with water scarcity or abundance, with the z-score showing the annual deviation of precipitation from the mean (342mm) using one standard deviation (82mm).

4.1 Statistical Analysis

Table 1 in the Appendix shows the results of the Shapiro-Wilk normality test which shows that all data follow a normal distribution. The two-sample T-test conducted between the SYHC in each area shows a p-value of p = 0.25 (Table 2). Thus, the null hypothesis, which states there is no difference in agricultural land use between the two study sites, is failed to be rejected. The two-sample T-test which was conducted for DYHC in both areas reported a p-value of p = 0.01 (Table 2). This means the null hypothesis is rejected in this case.

Table 2: Results of the two-sample t-tests with p-value and whether the Null Hypothesis (H_{0A}) or the Alternative Hypothesis (H_{1A}) was accepted.

Parameters tested – two-sample t-test	P-value	Hypothesis
SYHC in Rojava vs. Euphrates Shield	0.25	H_{0A}
DYHC in Rojava vs. Euphrates Shield	0.01	H_{1A}

The paired t-tests comparing SYHC and DYHC in the same area gave results much lower than the significance interval of 0.05, with Rojava showing a value of 6.18e-9 and the ES showing a value of 2.41e-14 (Table 3). This means the null hypothesis, that agricultural land use did not change in the areas, is rejected in both cases. Two paired t-tests were conducted to see whether SYHC before and after the Arab Spring show a significant difference. For Rojava, a p-value of p = 0.51 is found while for the ES a p-value of p = 0.02 is found (Table 3). The null hypothesis is rejected for the ES while it is failed to be rejected for Rojava.

Table 3: Results of the paired t-tests with p-value and whether the Null Hypothesis (H_{0B}) was accepted or not.

Parameters tested – paired t-test	P-value	Hypothesis
SYHC in Rojava vs. DYHC in Rojava	$5.21e^{-9}$	H_{1B}
SYHC in ES vs. DYHC in ES	$1.82\ e^{-14}$	H_{1B}
SYHC Rojava 2000 – 2010 vs. SYHC Rojava 2012 – 2022	0.51	H_{0B}
SYHC ES 2000 – 2010 vs. SYHC ES 2012 – 2022	0.02	H_{1B}

The results from the correlation analysis are found in Table 4. The Pearson correlation coefficient explains the strength of the correlation between the two datasets, the stars show if it is a statistically significant relation with "*" showing the relation is significant ($p<0.05$), "**" showing a high significance ($p<0.01$), and "***" showing a very high significance ($p<0.001$). Table 2 in the Appendix shows the p-value for each correlation.

This was conducted between SYHC and DYHC in both areas and gave a result of 0.83 for SYHC and 0.71 for DYHC. When correlating precipitation to each study area, a positive correlation in the area of Rojava is found with a value of 0.61. Similarly, the correlation between the precipitation in the ES and SYHC is also positively correlated, with a correlation value of 0.36. The correlation analysis between DYHC and precipitation gave the results of 0.03 for Rojava and 0.03 for the ES. Comparing SYHC to DYHC, a correlation of 0.37 and 0.47 is found for the Rojava and the Euphrates Shield area, respectively (Table 4). The regression graph for SYHC (Figure 1, Appendix), shows an R^2 value of 0.68, for DYHC an R^2

value of 0.5 (Figure 2, Appendix), and for SYHC in Rojava and Precipitation, an R^2 value of 0.37 is found (Figure 3, Appendix).

Table 4: Results of the correlation analyses with the correlation coefficient and significance level.

Correlation tested	**Correlation coefficient**
SYHC Rojava vs. SYHC Euphrates Shield	0.83
DYHC Rojava vs. DYHC Euphrates Shield	0.71**
SYHC Rojava vs. Precipitation	0.61**
SYHC Euphrates Shield vs. Precipitation	0.36
DYHC Rojava vs. Precipitation	0.03
DYHC Euphrates Shield vs. Precipitation	0.03
SYHC Rojava vs. DYHC Rojava	0.37***
SYHC Euphrates Shield vs. SYHC ES	0.47***

5 Discussion

To get a better picture of why and how the changes in agricultural cropland have occurred over the 22-year timespan it is important to put them into context with the environmental and political events (Figure 1). Thus, this section is split into subchapters that look at the different factors influencing land use and relates them to the statistical analysis as well as relevant literature. Furthermore, SYHC and DYHC are discussed separately, since they show different trends. This will make the following discussion clearer. Next, the discussion will focus on the differences and similarities found between SYHC and DYHC in both areas and within the same area. Following that, this chapter considers uncertainties as well as gives recommendations for future studies.

5.1 Drought and cropland extent

For single yearly harvest cropland, a visual analysis shows a relation to precipitation in some events, while other events are not seen in the SYHC developments. After the drought of 1999, SYHC was very low in 2000, which shows the direct effects of the drought. The droughts of 2008 and 2017 however, do not seem to have such a strong impact on SYHC in the following year. However, this paper calculated droughts by identifying which years are below one standard deviation from the mean precipitation over the 22-year timespan (Figure 5). While this paper identified trends in precipitation in northern Syria, Li et al. (2022) looked at precipitation over all of Syria. They identified seasons of droughts and found that 1998 – 2000, 2007 – 2009, and 2014 were seasons of drought. If this is considered, the impacts of the 2007 – 2009 drought can be seen in the 2008 cropland extent. This is in line with the findings of Eklund et al. (2022) who found strong decreases in 2000 and 2008 and a general correlation between drought and cropland extent. Furthermore, Li et al. (2022) found decreases followed by strong increases in cropland extent for the first two drought periods.

For double yearly harvest cropland, no visual correlation between precipitation and cropland extent is found. While the year 2000, following the 1999 drought, shows very small cropland used for double-harvest crops, a similarly low value is found in 2002 when there were normal conditions. One study discussing the geopolitics of fire, conflict, and land in the Kurdistan region of Iraq found that the severe drought of 2008 led to a sharp decrease in cropland area, which subsequently increased in the following years (Eklund et al., 2021). While the drought mainly affected the Rojava region, for both areas a decrease in 2008 and an increase in the following years was found. Moreover, the drought in 2017 did not significantly affect cropland extent. While droughts generally have a negative impact on cropland extent, years with higher precipitation favour crop growth, leading to increases in cropland extent. Such events are discussed in the following section.

5.2 Abundant precipitation and cropland extent

The events of strong precipitation in 2012, 2018, and 2019 all resulted in a strong increase in agricultural land in the following years with 2019 and 2020 showing by far the largest area of SYHC. In line with this, Schon et al. (2021) found nearly a doubling in wheat and barley production from 2018 to 2019. Generally, lack or abundance of precipitation influences SYHC in the Rojava region more than in the Euphrates Shield. This indicates that Rojava is better at adapting to strong precipitation but worse at managing a year with little precipitation compared to the ES. This in turn can be related to the fact that Turkey has started to manage the water network in the areas it influences (Al-Hilu & European University Institute, 2021). Water supply makes irrigation possible and thus the ES area can adapt to drier years. This is not possible for Rojava, which mainly relies on water from precipitation or the Euphrates River. One study found that the whole agricultural system in Syria is generally adapted to droughts and can thus bounce back quickly from such stress (Eklund et al., 2022).

For the years 2021 and 2022 low values of SYHC are found especially in the Rojava region. The main reason for this are the water restrictions from the Turkish government. Ligios (2023) explains, that Turkey does not abide by the 1987 treaty where it is agreed, that Turkey lets 500 m^3 of water pass the border to Syria every second through the Euphrates River. Instead, since 2021 the dam recorded values closer to 200 m^3 per second (Baker, 2021). This forces the communities in Rojava to constrict water for irrigation and thus damages the cropland extent and productivity (Ligios, 2023). These findings are an example of how governance affects cropland extent. Contrary to SYHC, the abundance of precipitation in 2012, 2018, and 2019 did not affect DYHC.

Analysing precipitation and DYHC, only a weak correlation is found. With -1 being the minimum and 1 the maximum value the correlation coefficient can have, values of 0.05 (Rojava) and 0.03 (ES) show close to no correlation at all (Table 4). When looking at SYHC however, a positive correlation of 0.61 is found for Rojava and 0.36 for the ES (Table 4). This indicates that an increase or decrease in rain leads to an increase or decrease in SYHC. While this relation is stronger for the Rojava region, to a smaller extent it is also true for the ES region. The smaller correlation for the ES can be explained by the irrigation situation mentioned above. Nevertheless, Table 4 shows that the correlation for ES is not significant. Thus, the fourth (4) research question can be answered: Precipitation strongly affects single-yearly harvest cropland in Rojava while a moderate but not significant correlation is found for the ES area. Double year harvest cropland does not show any correlation with precipitation.

5.3 Political events and Land use

Looking at major political events, the Arab Spring and the start of the civil war in 2011 show a direct effect on agriculture, as lower values are found in both areas for the years 2011 and 2012. While the civil war did not seem to affect agriculture in 2013, low values were found in 2014. The sharp increase in 2013 can be attributed to the abundance of rain in 2012 discussed above. Operation Euphrates Shield in 2016 again disrupted cropland extent strongly. In this year the lowest values for SYHC were recorded in both areas even though average precipitation was recorded for 2015 and 2016.

SYHC is generally found to fluctuate more in the years after 2011. This can be explained by two reasons. Firstly, the years before 2011 were stable years of Syrian governance and the years after 2011 were years of conflict. Secondly, the Syrian government subsidized agriculture in the years before the Arab Spring (Knapp et al., 2016). This means that in those years agricultural land use was not as strongly dependent on external factors such as rainfall since the productivity was facilitated by the government. To confirm this hypothesis a paired t-test between the years prior to 2011 and the years post 2011 was conducted. As shown in table 3 a p-value of 0.51 for Rojava is found, which means the datasets are not significantly different, thus the null hypothesis is accepted. No difference in agricultural land use is found before and after 2011. For the ES, a p-value of 0.02 is found, which is below the threshold of 0.05 and thus significantly different — concluding that in the ES agricultural land use was significantly different before and after the civil war.

These results are similar to the findings of Li et al. (2022), who analysed the effects of the Syrian civil war on the cropland extent in the whole country. They found that the whole of Syria shows a higher interannual variability of cropland extent after the start of the civil war. Furthermore, another study looking at LULC changes between 2010 – 2018 confirmed the rapid changes in LULC during this period (Mohamed et al., 2020). It is however not clear why it was not possible to find the same trend for the Rojava study site. Contrary to these studies, Eklund et al. (2021) found, that periods of conflict generally lead to an increase in cropland. This study, however, looked at an area in Iraq. Nevertheless, this is important to mention, as the reasonings for an increase of cropland during conflict times is explained to be relatively stable temperature and average-or-higher precipitation. Although this paper found little precipitation in 2017, generally precipitation values after 2011 were in line with or above the long-term average. Thus, this explanation is not upholding in the case of Syria. Notably, Eklund et al. (2021) conclude that the effects of conflict on cropland extent vary between different cases – such as this one.

Comparing DYHC to conflicts, it is found that the Arab Spring and the start of the civil war did not have a direct effect on the 2011 or 2012 harvests. Nevertheless, lower values of DYHC are found in the years from 2012 – 2018. The cropland extent in those years, however, does not seem to be unusually low. While Operation Euphrates Shield did not affect DYHC in Rojava it did affect it in the Euphrates Shield area strongly, with the lowest value for DYHC found here. Contrary to SYHC, DYHC fluctuates strongly throughout the timespan and visually it is not possible to see a difference between pre-conflict and conflict years. As the fluctuations of DYHC do not seem to follow a trend, doing a paired t-test to compare years before and after the conflict was deemed not necessary. In conclusion, the fifth (5) research question is answered: agricultural land use underwent significant changes in single yearly harvest cropland in the Euphrates Shield area while no significant changes are found for SYHC in Rojava and DYHC in both areas.

5.4 Discussion of Statistical Analysis

Even though SYHC in Figure 3 shows a similar trend for Rojava and the ES, many differences can be identified in the years before 2016 and even stronger differences after 2016. To investigate whether these differences are significant and how strongly the datasets correlate a two-sample t-test and correlation analysis were conducted. The result from the two-sampled t-test gives a p-value of 0.249 which overshoots the 0.05 threshold by manyfold. This means there is not enough evidence to reject the null hypothesis. Hence, there is no significant difference between the study areas. For the same data, a correlation of 0.83 is found (Table 4). This answers the first (1) research question: there is a strong positive correlation between single year harvest cropland in both areas.

For DYHC however, the statistical analysis showed a value of $p = 0.013$. As the p-value is below the threshold of 0.05 the null hypothesis is rejected for DYHC. Double yearly harvest cropland extent over the study period is significantly different in the two study areas. This is also seen visually in Figure 4, where DYHC in most years strongly differs between both areas. The correlation found for DYHC between both areas is 0.71 (Table 4). Thus, the second (2) research question can be answered: double yearly harvest cropland in each area differs. Even though a strong correlation is found, it is seen as irrelevant.

When comparing SYHC and DYHC in each area, a correlation of 0.37 and 0.47 is found for Rojava and the ES, respectively, indicating a weak correlation for Rojava and a moderate correlation for the ES area. While it was assumed that SYHC and DYHC follow the same pattern with DYHC covering a smaller area, the analysis showed that the correlation is not as strong as expected. The paired t-tests in Table 3 show that both areas have a p-value that is lower than the confidence interval by manyfold. Hence, the alternative hypothesis is accepted, which states that agricultural land use between both groups is different. This answers the third (3) research question: Single- and double-year harvest cropland are not related to each other.

Additionally, the positive correlation found between them is not significant. The aforementioned paper, from which the data for this project was obtained, examined conflict and land use in Syria and Iraq (Eklund et al., 2017). This paper found a conversion from DYHC to SYHC between 2000 – 2015, with areas controlled by the IS reporting a conversion of 25% while the agricultural areas in Syria and Iraq had a conversion of 52%. These trends could not be found in this research. This could be because this paper focused only on a small area, hence smaller sample size can give a different result.

5.5 Uncertainties

First, it has to be clarified that this paper looked at the cropland extent in the area as a proxy for productivity. A larger amount of cropland thus means more produce. While this might be true to some extent, many more factors influence agricultural productivity.
This paper discussed agricultural land use by analysing conflict, governance, and precipitation. Agricultural land use and productivity are, however, affected by many more factors. A great presentation of these is given by Mohamed et al. (2020). As explained in their paper, the conflict has many more negative effects on land use. These include loss of population (forced migration, people fleeing, or deaths) which leads to a lack of working power and thus decreased land use. Poor water use and management during times of conflict are other factors described by Mohamed et al. (2020). Moreover, different parties involved in the war seized agricultural land and imposed high taxes and shortages of fertilizers and energy. All leading to more expensive farming which is not economically viable anymore. Additionally, Eklund et al. (2022) argue, that the Yellow Rust outbreak in 2010 affected agriculture in the following seasons.

Talking about the data, it has to be mentioned that while datasets *i* and *ii* by Eklund et al. (2017, 2020, 2021) rely on the same model, the input data is different. Although dataset *ii* (including 2017 – 2022) also included the years 2000 – 2016 it was chosen to only use the timespan which was missing in dataset *i*. This was done since the first dataset (2000 – 2016) had been accuracy assessed while the second dataset including 2017 – 2022 had not been accuracy assessed. As Eklund et al. (2017) explained, the model has a total accuracy of 80% and thus a margin of error of 20%. This margin is a further reason for uncertainty, which might influence the findings.

Furthermore, taking data from different models always leads to a certain amount of error. This can be seen as the second dataset showed a higher amount and variability of raster cells within the same study area. While all cells combined showed a total area of around 1880 km^2 for the first dataset, the total area increased to 1900 to 2200 km^2 for the second. The second dataset had a higher variability in the amount of raster cells per year. While the first dataset had a variability of ±40 km^2, the second one had a variability of over 200 km^2 between different years. It has to be discussed, that the study areas chosen within Rojava, especially the borders of this area, were contested during the conflict and thus could possibly not have been used for agriculture in some of the years. To get a more exact picture of cropland extent, it would have been more beneficial to look at scaled values, which take the yearly changes into account. However, this was hardly possible since no open-source geoinformation about the regional border developments in a sufficient spatial and temporal scale could be found.

It was not possible to find a difference in agricultural land use between Rojava and the ES area. Partly this is the case since many factors influence agriculture. Partly, however, this is because the areas have been under changing governance for the past decade. Since the areas are only under control of their current governance since 2016 it was not possible to do a statistical analysis on that timeframe because it is too short. The smaller the sample size in a statistical analysis, the larger the potential for flaws in the result. Thus, doing a statistical analysis of only six data points would leave a large potential for false results. Furthermore, six years is not a large period for political change to occur. To be able to more accurately assess the effects of governance on agriculture it would be desirable to have two areas with a long period of different governance. This would make it possible to select a period where normal environmental and political conditions prevailed. Unfortunately, this is not the case for Syria. Since the topic is still of high relevance it was chosen to attempt to investigate it in this thesis. Instead, this paper tried to identify trends in the yearly cropland extent in both areas, as well as relate cropland extent to specific events of governance, which are discussed above.

To obtain two study areas that are as similar to each other as possible it is desirable to have one study area and the other study area extending towards the east and west from it, since the precipitation and temperature changes from east to west in Syria. This was tried to achieve with the ES area being in the centre and the Rojava site extending to the east and west. However, the Rojava study area in the west is much smaller than in the east. This comes from the fact that the western Rojava site entails all the area that is under PYD control. While there is the ES area north and east of it, the Syrian government controls the southern area around Aleppo and oppositional forces control the Afrin region to the west.

Moreover, the eastern part of the Rojava study area is not directly attached to the ES area. Although originally this was planned, the study area had to be changed because the dataset covering 2017 – 2022 had many no-data values in this area and thus it could not be used. This could either be because of clouds blocking the satellite from retrieving data or be caused by the Euphrates River which flows through that area. The satellite might have had issues with differentiating the river from other land cover and thus identified the area as having no data.

Finally, the precipitation data has to be discussed. As explained above, monthly precipitation data was downloaded and summed to achieve yearly precipitation. Instead of summing total precipitation in one calendar year (as done here) a closer correlation to SYHC could have been found by summing one growing season's precipitation. As the biggest harvest period is in May this would mean summing precipitation from June to May (the following year). The reason this paper chose to sum precipitation from January to December is because double cropping was also considered, which has the second harvest in October. Thus, taking the yearly average resulted as the best compromise. Additionally, it has to be mentioned that the precipitation data was obtained from a model, as there are no actual measuring stations in this area. Although models can be very good, they are still not as precise as ground-truth measurements, which is another factor that could influence the outcome.

5.6 Future Studies

While this study looked at the total amount of agricultural land in one year it did not identify areas that were abandoned or revived. Future research should focus on identifying these areas. Li et al. (2022) for instance, found that areas located closer to urban areas generally found higher values of land abandonment. By focusing on a smaller area, such as the one in this report, a lot of information about the trend of land abandonment during conflict could be found. Another interesting approach would be creating a model that can differentiate between crop types. Through this, it would be possible to identify crop dynamics in the area, whether a specific crop type increased or decreased, and why this change might have happened. This could be achieved by using a specific plant's phenology, similar to how the dataset used in this paper was created. Lastly, it would be of interest to focus on areas where agriculture increased during years of conflict, as Dinc & Eklund (2023) and Li et al. (2022) described in their papers. This could reveal trends in either of the regions that could be related to governance.

6 Conclusion

Through the analysis of single- and double-year harvest cropland, this study tried to identify changes in agriculture that can be attributed to political governance, conflict, and precipitation. With statistical analysis, this paper answered the research questions, which helped in resolving the general aim. (1) Single yearly harvest cropland strongly correlates in both areas, which indicates no apparent difference in agricultural governance. (2) Double yearly harvest cropland, however, is found to be statistically different. Nevertheless, it is assumed that this trend is not related to governance but rather to other factors influencing cropland extent. (3) There is found to be a difference between single- and double-yearly harvest cropland in the same area. This disproves the theory that the same political governance is applied in one area – or rather that it has the same effects. (4) Precipitation is found to strongly affect single-yearly harvest cropland in Rojava while a moderate but not significant correlation is found for the Euphrates Shield area. For double yearly harvest cropland, no correlation is found with precipitation. Lastly, it was tested whether a difference in cropland extent before and after the Arab Spring can be found. (5) Here it was identified that significant changes occurred for single yearly harvest cropland in the Euphrates Shield region, while no significant changes were found for the Rojava region or double yearly harvest cropland in either region. While most of the results are in line with similar literature, some different findings have been discussed.

The above-mentioned results show that it was not possible to find links between governance and cropland extent. With the example of the Turkish water blockade from the Euphrates River, this paper shows events of governance which do affect agriculture, even though no prominent trend could be found. Precipitation is found to affect SYHC in Rojava more strongly than in the Euphrates Shield. Conflict, however, only seemed to affect the Euphrates Shield region. It is argued that the implications of governance on agriculture are hard to measure as agriculture is affected by many different factors. While it was possible to find links between cropland extent and conflict as well as precipitation, it is harder to measure governance, as it is difficult to factor policies into an empirical analysis. Nevertheless, this study found relevant trends that affect agricultural productivity in the region of North and East Syria.

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8 Appendix

Table 1: Normality Test of Datasets with W statistic and P-value.

Dataset	W statistic	P-value
SYHC Euphrates Shield	0.92	0.07
DYHC Euphrates Shield	0.96	0.54
SYHC Rojava	0.95	0.27
DYHC Rojava	0.95	0.36
Precipitation Euphrates Shield	0.93	0.09
Precipitation Rojava	0.93	0.12

Table 2: Significance level of correlation analysis.

Correlation tested	P-value
SYHC Rojava vs. SYHC Euphrates Shield	0.25
DYHC Rojava vs. DYHC Euphrates Shield	0.01
SYHC Rojava vs. Precipitation	0.002
SYHC Euphrates Shield vs. Precipitation	0.09
DYHC Rojava vs. Precipitation	0.88
DYHC Euphrates Shield vs. Precipitation	0.88
SYHC Rojava vs. DYHC Rojava	$5.21e^{-9}$
SYHC Euphrates Shield vs. SYHC ES	$1.82\ e^{-14}$

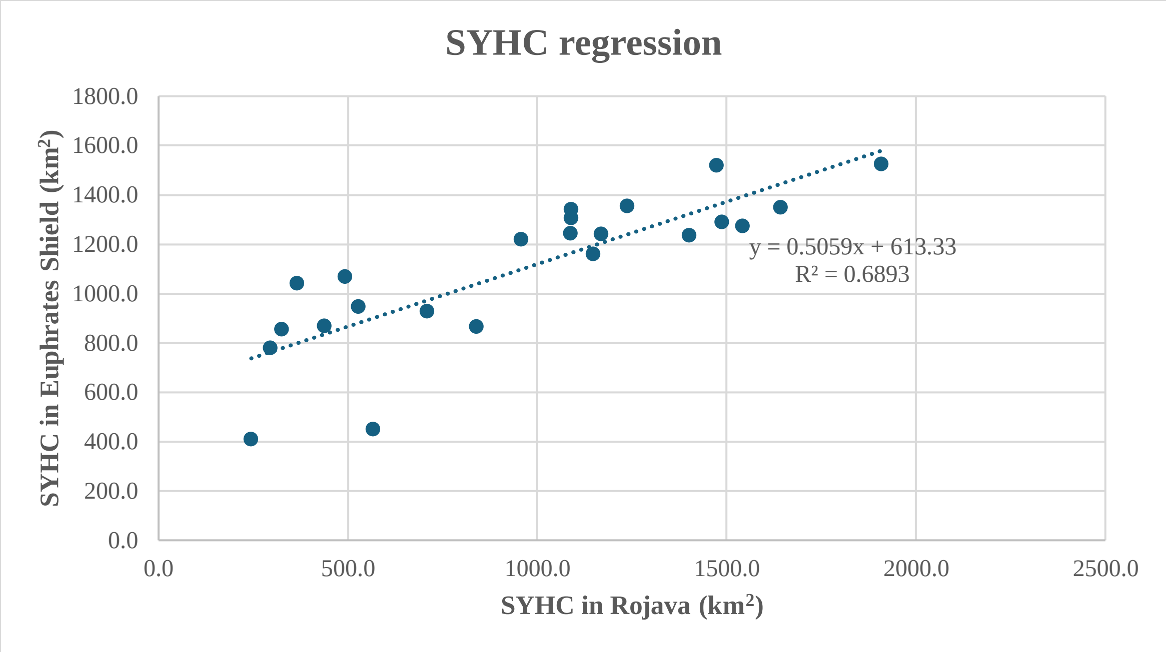

Figure 1: Regression between SYHC in Rojava and the Euphrates Shield.

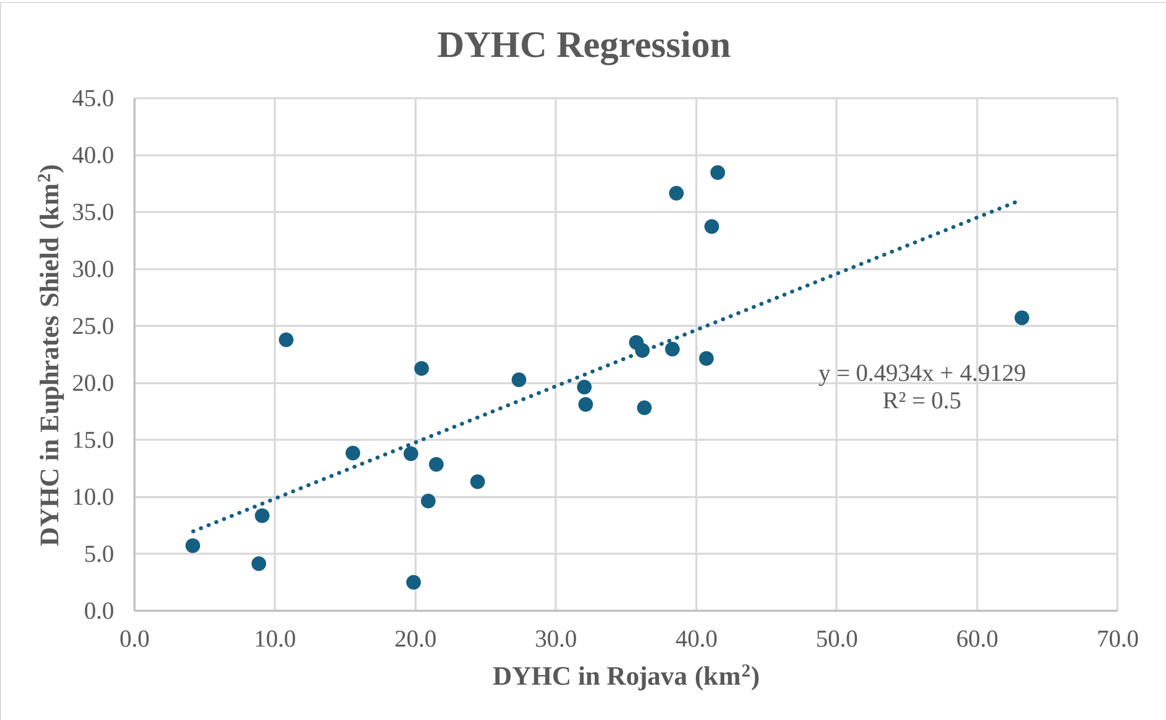

Figure 2: Regression between DYHC in Rojava and the Euphrates Shield.

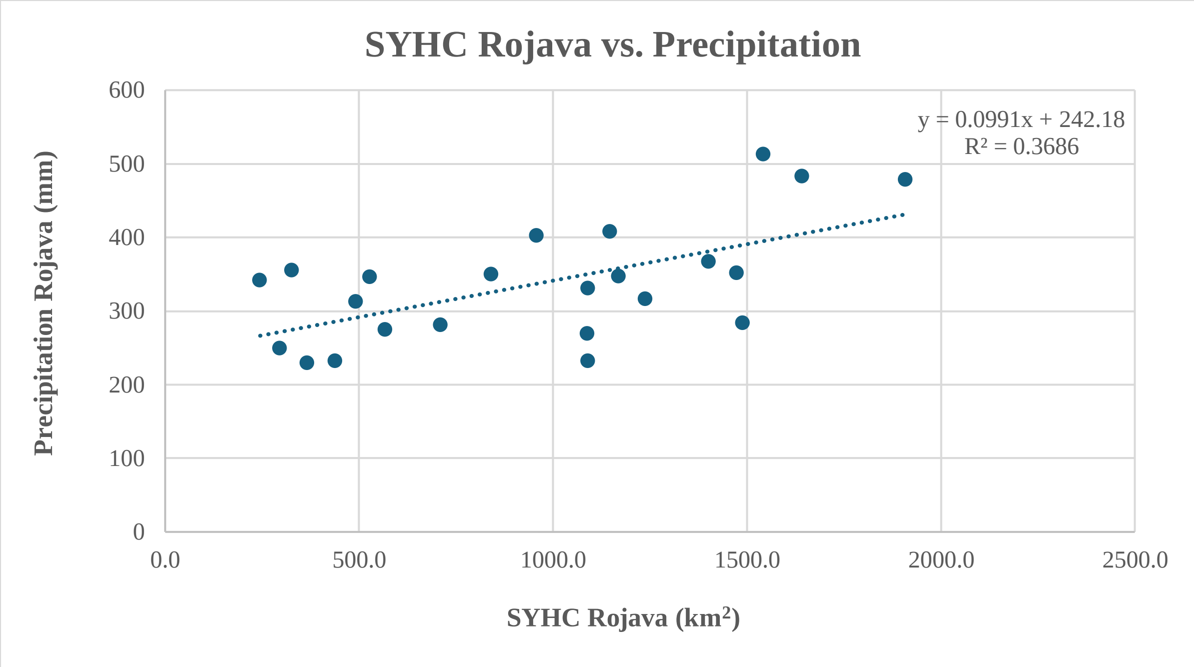

Figure 3: Regression between SYHC in Rojava and precipitation in Rojava