Master Thesis in Geographical Information Science nr 127

Using remote sensing and land abandonment as a proxy for long-term human out-migration.

A Case Study: Al-Hassakeh Governorate, Syria

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In memory to the 100,000 civilians that died in the Syrian War

and to my grandmother Hildegard Reimer

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Abstract

The topic of human migration and displacement has become more important in recent years and will continue to do so in the following decades. Voices become louder claiming that climate change is a driving factor for increased displacement and migration. Increasing unsuitable living conditions due to unpredictable weather patterns and increased number of extreme events are putting pressure on the socio-economic situation of countries. The Syrian war which started in 2011 has widely been discussed across governments, academia, NGO's and civil society. Hypotheses exist that climate change was a key driver, which led to the onset of the war. The debated drought of 2008 was said to have led to the displacement of 1000's of people from the countryside to the cities. The sudden rise in population in the cities led to increasing unemployment and dissatisfaction across the Syrian population.

In this study, my aim was to use remote sensing and earth observation to assess whether migration took place in the north-eastern governorate Al-Hassakeh before the war. I made use of vegetation indices derived from satellite images to look at the trend of vegetation health. Moreover, I investigated land cover changes using a land cover data set comprised of four classes (Bare Soil Single Crop, Multi Crop, Other Vegetation). Finally, by combining the two, I have assessed whether long-term out-migration took place using land abandonment as a proxy indicator in Al-Hassakeh Governorate from 2000-2015.

I found a decrease in vegetation health in two out of four sub-districts, namely Ras-Al-Ain and Al-Hassakeh. In the case of the former, the observed decreasing vegetation health was predominantly centered in between ephemeral waterbodies, while in Al-Hassakeh, the decrease was located in the southern part of the sub-district. The land cover did not significantly change in aerial extent, but I found a gradual decrease in Multi Crop across the whole governorate. Furthermore, I found that overall, the Single Crop class extent shifted northwards and closer to ephemeral waterbodies. Based on my analysis, long-term out-migration has only occurred in the southern part of Al-Hassakeh Governorate and more frequently so before the drought in 2008.

The results suggested that long-term out-migration did take place before the war. However, the highly debated 'additional' migration as a result of the drought in 2008 remains questionable. I argue that it is more likely that a combination of factors ranging from policy changes and decisions, a continuous lack of access to freshwater and groundwater depletion on top of the slow climatic changes resulted in the observed out-migration. This study confirmed that remote sensing and earth observation are useful tools to assess vegetation and land cover trends. I have shown that a combination of methods can further be utilized to model possible human out-migration. The findings of this study specifically related to migration, however, are yet to be confirmed with other data.

Keywords

Human migration, remote sensing, Syria, conflict, proxy indicator, land cover change, land abandonment, vegetation indices, EVI

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1. Introduction

The current discussions within the European Union, the United Nations and other international organisations on ever increasing human migration have dominated the news in the most recent years. Newspapers, social media and tv programmes were filled with images from overcrowded refugee camps, simple fishing boats filled with people and violent scenes of civil conflicts in numerous countries. With globalisation continuing, human migration will also continue and is most likely to amplify due to a variety of factors, which have been attributed to societal changes, better economic possibilities, conflicts but ever more due to an intensification of unsuitable living conditions as a result of climatic changes. The need for modelling human migration patterns will become ever more important in the following decades due to the exacerbation of these factors. The Groundswell Report, released by the World Bank Group suggested that more than 140 million people will at least be internally displaced and on the move by 2050 (Rigaud, et al., 2018). As highlighted in the report, it is the first of its kind that attempts to predict human migration due to climatic changes using three case studies. Although the results are likely and follow a logical methodology, it is necessary to conduct more empirical research to predict and understand human migration not just at a global and general scale but also at a regional scale.

Extreme weather events, in particularly drought, can have a significant impact on human migration and displacement but it remains a complex relationship and the ability to move is closely bound to the social and economic conditions of individual households, communities as well as the countries as a whole (Kniveton et al., 2009). The relocation of people can be a source for civil unrest in the destination areas due to unexpected resource pressures (Abel et al., 2019; Adger et al., 2018), particularly in countries that are led by weak governments and that are dominated by numerous ethnicities (Dukhan, 2014; Adaawen et al., 2019; Wirkus & Piereder, 2019). Adaawen and co-workers mention different critical pre-conditions that may be present and escalate the situation with the incoming migration flows. The Fertile Crescent (corresponding to the countries of Syria, Lebanon, Israel, Palestine, Jordan, Egypt as well as the south-eastern part of Turkey and Cyprus) has experienced several extreme droughts in the last century and an average temperature increase of 1 C° has already been recorded (Kelley et al., 2015). Based on the above, the Fertile Crescent is a good location to quantify whether climate change is a key if not the most important driver leading to additional human migration.

In 2021, the Syrian War will have been ongoing for more than 10 years, leaving millions of people displaced and a whole generation traumatised. Until today, it is not completely clear what led to the final onset of the war. Numerous hypotheses suggest that climate change and the extreme drought period in 2008-2009 had resulted in additional rural-urban migration and that the number for unemployment rates in the cities had dramatically risen which led to non-satisfactory conditions for the Syrian population (Gleick, 2014; Schweizer, 2015). Other scholars claim that policy changes, population growth and an intensification of unsustainable farming methods were responsible for that dissatisfaction giving rise to the still ongoing war (Kelley et al., 2014; De Châtel, 2014; Selby, 2019). Selby (2019) provided an in-depth summary of the ongoing debates, recognising that the 'meteorological drought' certainly affected the agricultural sector in 2008. However, Selby (2019) also showed that a general decrease in crop yield since 2001, especially in Al-Hassakeh Governorate, was attributed to the extreme overuse of freshwater sources (groundwater and surface waters) and the degradation of land. Clearly, the socio-economic situation of Syria had an impact on the ability of the agricultural sector to recover from the severe period of drought. Reliable data on internal population migration and displacement is difficult to obtain in countries with limited data infrastructure, making it almost impossible to rely on and work with population data. Hence, alternative methods are essential to carry out proper analyses on migration. Remote Sensing (RS) and Earth Observation have shown to be useful in filling some gaps of the missing population data having successfully been used amongst a great variety of scholars and for different types of migration (Cameron, 2018; Löw et al., 2015; Eklund et al., 2017b; Rigaud, et al., 2018).

This thesis seeks to contribute to the complex nexus of climate, migration and conflict using Syria as a case study. Making use of earth observation and RS techniques, the results will complement existing studies and give a better understanding whether the severe drought in 2008-2009 may have led to additional human migration. In the study, I focused on assessing the changes in relative vegetation health and land cover over time and model land abandonment as a proxy for long-term human out-migration. My overall aim was to investigate whether I could find land abandonment (using it as a proxy for long-term human out-migration) due to a continuous negative trend in vegetation health resulting in an according land cover change. I applied the Mann-Kendall test on enhanced vegetation index (EVI) images and calculated the aerial change in land cover using an existing land cover dataset. I wanted to give a better understanding of whether people have increasingly left the rural and poorer regions and provide a generally applicable method to model people movement. Given the scope of such a study, I constrained the research area to Al-Hassakeh Governorate and its sub-districts, in the north-eastern part of Syria and only focused on the time period from 2000-2015.

The above I sub-divided into the following three objectives. I wanted to:

1. Assess the trend of vegetation cover using EVI in Al-Hassakeh Governorate between 2000 and 2015 and identify areas where a significant trend was observed.
2. Determine the land cover changes in Al-Hassakeh Governorate between 2000 and 2015.
3. Investigate whether long-term out-migration had occurred at certain locations prior to the war within Al-Hassakeh Governorate using land abandonment as a proxy indicator.

2. Background

2.1 Migration and Displacement

Human migration has taken place throughout the last millennia and is part of human history. The causes for moving have varied case by case but in general climatic, socio-economic factors and conflicts have been significant drivers of national/international migration and displacement.

As defined by the International Organisation for Migration (IOM)

Migration is: *"The movement of persons away from their place of usual residence, either across an international border or within a State."* (IOM, 2019) and;

Displacement is: *"The movement of persons who have been forced or obliged to flee or to leave their homes or places of habitual residence, in particular as a result of or in order to avoid the effects of armed conflict, situations of generalized violence, violations of human rights or natural or human-made disasters"* (UN, 1998)

The key difference between displacement and migration lies in the idea of voluntary action and the ability to decide whether one relocates or not. Displacement means to unwillingly relocate to another (sometimes unknown) place while migration is a planned and perhaps long-term decision (Adger, Safro de Campos, & Mortreaux, 2018). The IOM released a report suggests a potential increase in human migration due to an increase in extreme weather events (Brown, 2008). It is necessary to differentiate between slow-onset and rapid-onset displacement and the thin threshold between slow-onset displacement and permanent migration. Extreme weather events often result in a short-term but rapid-onset displacement where the affected are forced to leave their homes behind. For example, the most recent wildfires in Australia (2020) and Hurricane Katrina in the United States (2005) forced thousands of people to immediately leave their homes (Sastry & Gregory, 2014; du Parc & Yasukawa, 2020). On the other hand, the long-term effects of climate change are slowly but continuously destroying the living conditions of certain areas (eg. small developing island states (Betzold, 2014)) leading to slow-onset but long-term displacements eventually leading to permanent migration. Depending on climate vulnerability, countries have taken different approaches to adapt to changes and cope with natural disasters. Here, climate vulnerability is defined according to Adger et al., (2018) as "*the degree to which a system is susceptible to and is unable to cope with the adverse effects of environmental change*".

Different countries have different opportunities to adapt/respond to the effects of climate change, which may decrease or increase their vulnerability. For instance, the Netherlands, a country that is mostly located below sea level, has built an extraordinary amount of dikes and dams to prevent inundation and constant flooding of the country (Popering-Verkerk & Buuren, 2017). On the other hand, sea level rise and drought have enhanced the climate vulnerability of developing countries like Bangladesh and the Sahel region in Africa which may have increased the potential for migration (UN., 2016).

Another aspect to consider is the different kinds of displacement and migration, which can happen. Zickengraf (2018) revisits the concept of immobility and trapped populations, which is often forgotten in migration studies. The people suffering the most from climate change are also frequently those that do not have the resources to migrate and are trapped in areas with increasingly unfavourable living conditions. As a result, seasonal or partial-migration may be the only option due to the lack of sufficient resources to permanently leave (Rigaud, et al., 2018). This is to say that parts or sometimes the whole family decide to leave their home for a specific period (one or two years) to seek employment elsewhere. According to the Groundswell Report, particularly the poor populations, commonly living in the countryside and relying on agriculture are not able to migrate over long distances (Rigaud, et al., 2018). In summary, migration and displacement have many forms and are not following a specific pattern. Again, the socio-economic situation of the people who are displaced or wish to migrate generally influences the ability to move.

A recent review by Wirkus & Piereder (2019) reports that although early warning systems for natural hazards (eg. droughts, flooding, tsunamis) and conflicts exist in a majority of countries, they can only be successful if communication between government and academics on the one side and the general society on the other is effective. The review further mentions that countries most prone to drought and food insecurity are those where a significant lack of trust and hence communication between the different spheres is common (Wirkus & Piereder, 2019). This lack of trust and ongoing population growth leads to recurring conflicts and possible displacement. Thus, depending on the socio-economic situation of a country migration can happen.

2.2 Remote Sensing and Proxy Indicators

In general, RS is useful to detect land cover changes over time and space. An abundance of methods has been used to assess the state of vegetation, soil conditions and agricultural fields in particular (Jaafar & Ahmad, 2015; Goga et al., 2019; Almamalachy et al., 2020; Karthikeyan et al., 2020). Before satellite systems were in place, manual and ground samples on crop yield, soil information and physical samples were collected to inform about the conditions of the land. With the first artificial satellites in the 1950's and throughout the last century, RS systems have become so advanced that fieldwork can easily augmented allowing aerial analyses to cover a much larger area. The spatial, spectral and temporal resolution of the newer satellites are detailed enough to visualise for instance the immediate effect of a flooding event. A dam break in Laos in 2018 was detected immediately by the disasters program of NASA in collaboration with USAID and the Asian Disaster Preparedness Centre (NASA, 2018) and data were provided to emergency rescue facilities on the ground for support. Land cover change occurs naturally but more frequently due to human interference as the previous example shows. It is those changes that easily can be identified using RS products. Satellite-based algorithms and classification schemes were developed over time in order to obtain quantitative data over a larger scale and less time-consuming way (Zang Shuying et al., 2014).

Very commonly, land cover and land use are terminologies that are used interchangeably. However, it is important, to distinguish between the two, especially from a RS and earth observation perspective. Land cover is the physical appearance of the land, such as grassland, forest or water. On the other hand, land use can include more than one land cover class. Commonly, farmland, natural restoration areas or plantations are used as land use classes (Bakx et al., 2012).

Of course, direct human movement cannot be detected using RS, however, in the form of so-called "proxy indicators" some observations can be made. The review of Ghaffarian et al., (2020) provides a clear definition on proxies: "*Proxies use observable features in RS data which are used to capture and extract information of interest that is not directly visible or measurable but is correlated with the former"*. The review points out the importance and frequency of using indirect measurements also in other research fields, such as disaster risk management and environmental sciences in general. For example, rural-to-city migration can be investigated using night-time lights (Li et al., 2016). An intensity of night-time light over time can, for instance, be associated with an increase in inhabitants in a given area.

Out-migration, on the other hand, is more difficult to observe. Often, it is a limited number of people for individual areas that decide or are forced to move, and this out-migration may not be long-term but only seasonal as outlined in the previous section (Zickgraf, 2018). The proxy 'farmland abandonment' or simply land abandonment takes upon this challenge. By investigating the relative area of active- and in-active farmland, something can be said about whether areas have been abandoned or not. According to Eurostat farmland abandonment is defined as: "*the cessation of agricultural activities on a given surface of land."* (Eurostat, 2014). Unfortunately, no temporal component is associated in this definition. For the purpose of this study, I adopted the definition of Yin et al., (2018) where farmland abandonment is referred to as: "*agricultural land that has not been used for a minimum of two to five years".* Yin et al., highlight, however, the complexity of distinguishing abandoned land from long-term fallow periods. Hence, for the purpose of this study, areas that are continuously abandoned for more than two years will be classified as abandoned.

In the past, two common ways were used for assessing land abandonment. The first method is based on trend analysis of vegetation changes (using vegetation indices) and detects changes in indices over time. However, it was pointed out by Löw et al., (2015) that applying this method remains challenging as it is not clear whether changes in indices relate to land abandonment. Sometimes, index values may even increase as grasses or shrubs may grow on the land that was abandoned (Löw et al., 2015). A second common approach is the land cover trajectory (LCT) method. This is to say that classification is being undertaken on multi-seasonal images over a set of years. While being rather accurate, LCT remains time consuming and is highly data intensive. Furthermore, given the sometimes sparse amount of available data, this method cannot be applied everywhere. Classification algorithms are most commonly used based on non-parametric machine learning algorithms such as the random forest (Eklund, et al., 2017).

Eklund et al., (2017a) made use of the normalised difference vegetation index (NDVI) to assess land abandonment in Syria and nearly all of Iraq and found this to be a precise and simple way to distinguish between active and non-active cropland. Most vegetation indices are based on the fact that a healthy vegetation cover tends to absorb most of the incoming sunlight in the red part of the electromagnetic spectrum and reflect the green and near infrared (NIR) part.

From the previous paragraph it becomes clear that RS and vegetation indices in the context of environmental-displacement and migration are a useful tool to detect societal changes using land cover change as an indicator. Vegetation indices have commonly been used since the 1960's to assess the chlorophyl content and the green biomass within the vegetation canopy (Jensen, 2007). The most commonly known indices are the already mentioned NDVI and EVI. These two vegetation indices use the advantage of the inverse relationship between the near-infra red and the red surface reflectance, which is associated with healthy vegetation. The EVI corresponds to a modified NDVI including additional factors to correct for the soil and account for possible aerosol scattering into the red band. The equations for both NDVI (1) and EVI (2) are shown below:

$$1) \qquad NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

Where NIR= Near infra-red surface reflectance and Red = Red surface reflectance and;

$$2) \qquad EVI = \frac{(\mathrm{NIR} - Red)}{(\mathrm{NIR} + \mathrm{C1} * \mathrm{Red} - C2 * Blue + L)}$$

Where C1 and C2 are coefficients to correct for aerosol resistance and L is the soil adjustment factor.

When using proxy indicators for migration studies, it is important to consider the existing land use management measures since crop rotation and fallow periods need to be taken into account when assessing farmland. Strictly looking at vegetation indices for whether an area is abandoned or not is not advised due to the natural annual variability of cropland. Furthermore, agricultural policy changes may have a large impact on whether an agricultural field can be cultivated or not (Kraemer, et al., 2015; Selby, 2019; Keilany, 1980). While the changes in land use and land cover can be detected using RS, it is more speculative why land is being abandoned over time. A common motivation is the prospect of finding a better life elsewhere, due to better job opportunities. This pattern has been observed in the past when a country transforms from an agricultural-based to an industrially orientated economy (Baldwin & Bettini, 2017). Not only is the attraction of better jobs a factor for migration (a pulling factor) but as well is the degradation of the land due to overexploitation and climatic changes (rising temperatures) making agriculture no longer profitable (pushing factor) (Prishchepov et al., 2012; Yin, et al., 2018). Land degradation is a slow and continuous process and it is mostly exacerbated by more frequent extreme weather conditions such as droughts and flooding (Kelley, Mohtadi, Cane, Seager, & Kushnir, 2015; Selby, 2019).

Cattaneo and Peri (2016) found that although out-migration is common, the choice of destination is dependent on the socio-economic situation of a country and its people. Specifically, it was found that so-called "low-income" countries show no enhanced movement within the country or internationally and, if any migration takes place it occurs within a close distance. On the other hand, a trend for migration due to increasing temperature was observed for the middle-income countries. Finally, land abandonment also tends to occur in countries which experience an overall population decline. Eastern Europe is one region where the constant migration of the young workforce to neighbouring countries has led to the continuous decline of the overall population (Baumann, et al., 2011).

As I have previously shown in section 2.1, multiple types of migration and displacement occur. While in one year, the studied area may show no active farmland, the next year, this may already be different. This could be attributed to a year with a fallow period, a year of seasonal migration or short-term displacement due to an extreme weather event. The discussion above shows the complexity of migration, displacement and land use practices but also highlights the opportunity for RS and its products to add valuable information to the topic. Combining the concept of land abandonment with the different types of migration and land use management, this study only looks at long-term out-migration (> 2 years) and excludes seasonal and short-term migration. Farmland being continuously inactive for more than two years are said to be abandoned and are associated with long-term human out-migration.

2.3 The Syrian Conflict

The recent developments in the Middle East such as the Arab Spring, the civil war in Libya and the most recent escalations in the territorial Nagorno-Karabach conflict have increased Europe's focus on human migration, its cause and ways to assess and model future migration patterns. The war in Syria has been ongoing since 2011. Figure 1a) shows a map of Syria to provide the geographical context. Millions of people were forced to leave their belongings and land behind and seek refuge within Syria and in neighbouring countries, such as Turkey, Jordan and Iraq. Current Figures, released by the United Nations Refugee Agency (UNHCR), suggest that in addition to the people outside of Syria, up to 6 million citizens are currently displaced within the country. What was the onset of this ongoing humanitarian crisis? Was it predictable and thereby avoidable? Numerous hypotheses and opinions exist (De Châtel, 2014; Kelley et al., 2015; Selby, 2019), and no definite consensus has yet been reached.

The book '*Syrien Verstehen* Geschichte, Gesellschaft und Religion' (Understanding Syria) describes Syria's history from the birth of the prophet Mohammed up to today and provides the social and political context on what led up to the first riots in 2011 (Schweizer, 2015). Initial rebellious movements in the cities such as Hama, Homs and Dara were the onset of a yet unresolved war between multiple groups, tribes, races and ethnicities and has by now turned into a proxy war on the cost of society in Syria and the overall development of the country. However, numerous reports and other scientific papers suggest that it was not an unexpected upheaval (De Châtel, 2014; Selby, 2019; Dukhan, 2014; Fröhlich, 2016; Schweizer, 2015). Selby and De Châtel noted that mismanagement, in addition to long-term failure of agricultural policies and sudden changes in the economic strategy of the country, led to an ongoing degradation of the land. Furthermore, groundwater depletion and decreasing crop yield per land unit was observed. On top of the above changes in the early 2000's, the period of 2008-2009 was reported to be the longest and most severe drought on record, having a significant impact the crop yield (FAO, 2017). Statistics, released on the World Bank Data Portal, reported a drop in crop yield by almost 75 % between 2006 and 2008, dropping from 2000 kg/ha (wheat in average) to 860 kg/ha, respectively. In terms of actual cereal production, while in 2007 more than 5,000,000 metric tons of cereal were produced, this decreased to only 2,684,688 tons in 2008 (FAO, 2017). Comparing this with the average annual wheat harvest of 4,154,445 metric tons per year (MOAAR, 2010) as reported by the Ministry of Agriculture and Agricultural Reform (MOAAR), the significance of the drought in 2008 becomes visible (Appendix 8.1). Based on other statistics from the World Bank, it can be seen that since the early 2000's Syria reports a decreasing trend for wheat, barley and cotton production, which may be due to numerous reasons, such as land degradation, groundwater depletion, and policy changes (Selby, 2019).

RS and common vegetation indices have been used previously to assess the development of relative crop yield in the Fertile Crescent (Jaafar & Ahmad, 2015; Eklund et al., 2017a). Below, Figure 1b shows the NDVI and rainfall for Al-Hassakeh Governorate (AHG) in 2008 (HDX, 2020), both being far below the long-term average. It was found that Al-Hassakeh the far north-eastern governorate experienced a much higher loss in average compared to the other governorates. All rainfed crops failed in the year of 2008, which meant that most of the wheat and barley was lost and only irrigated fields had some output (MOAAR, 2010). Even though more than 80 % of the total agricultural fields in Dair-Ezzor, Al-Raqqa, Al-Hassakeh were being irrigated (Jaafar & Ahmad, 2015), the output in 2008 still showed a significant drop. Selby (2019) mentions the significant losses of the neighbouring countries but no or only little out-migration was observed during the drought period. On the other hand, in AHG, the UN estimated that 40,000-60,000 families that migrated into the urban areas in 2009.

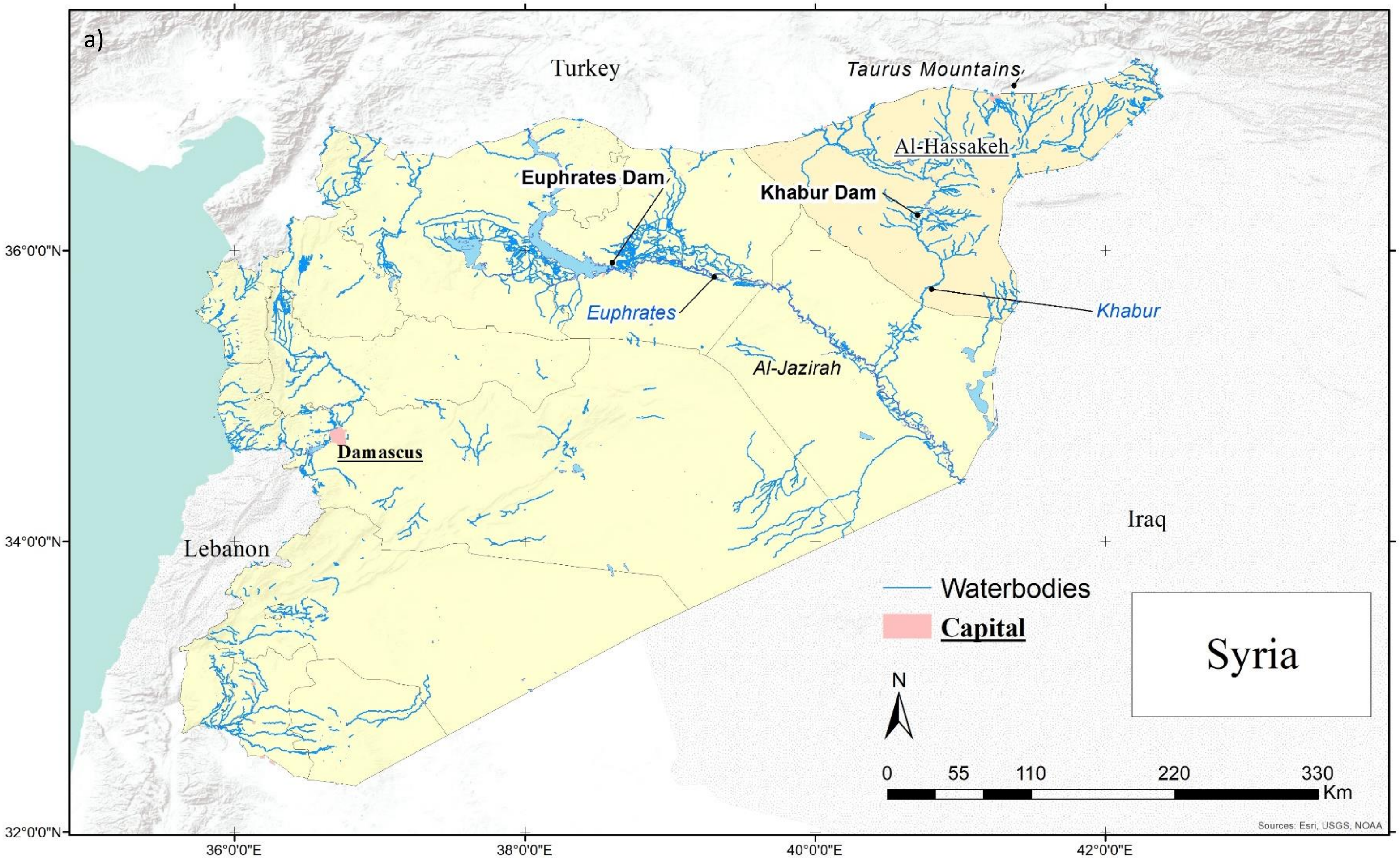


Figure 1a) Overview of Syria

b)

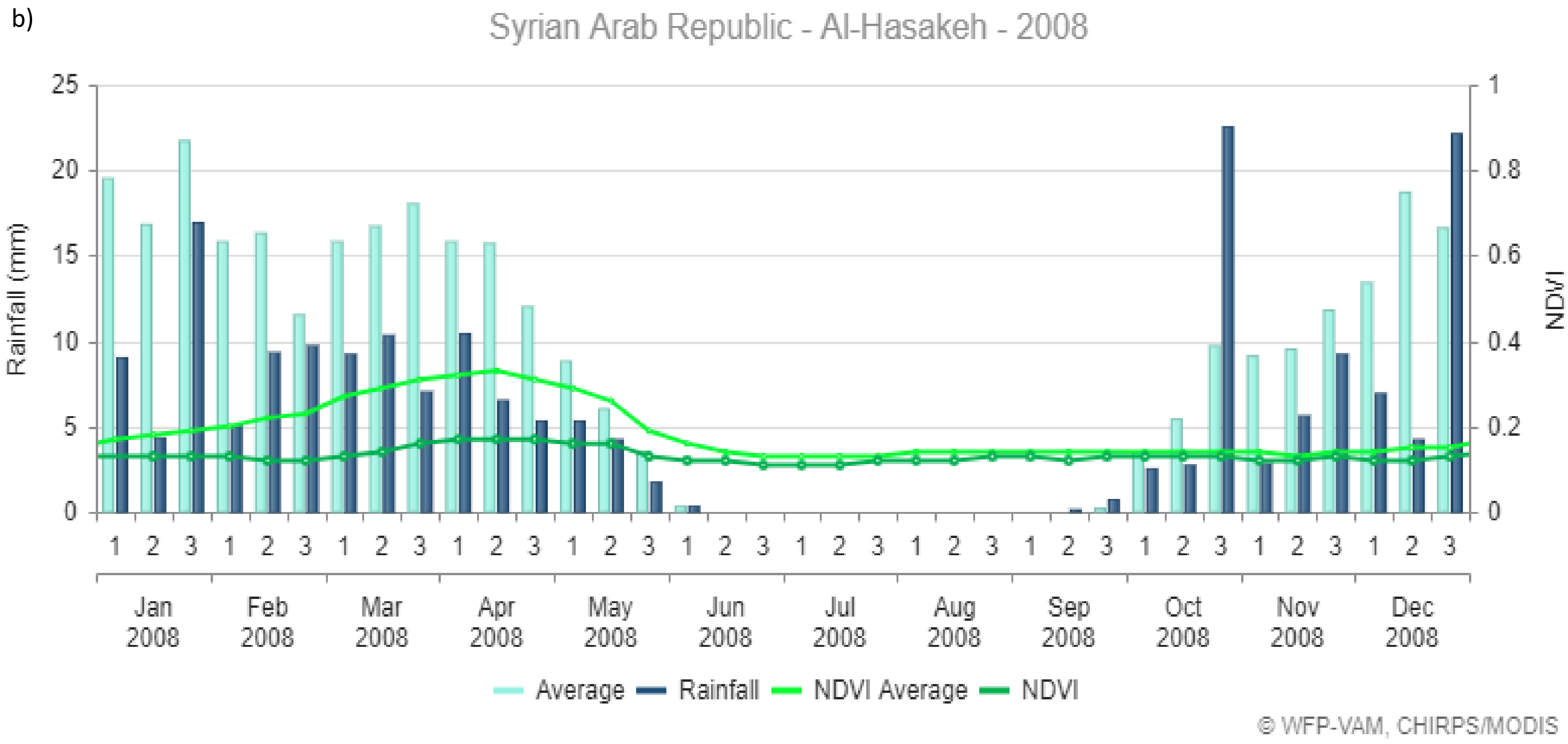


Figure 1b) Precipitation and NDVI of Al-Hassakeh Governorate in the year of 2008 compared to long-term average (HDX, 2019)

Humanitarian Data Exchange (HDX): https://dataviz.vam.wfp.org/seasonal_explorer/rainfall_vegetation/visualizations#-.

Access rights were clarified and granted through email communication

2.4 The Syrian Agricultural System and Policy Development

Throughout millennia, Syria has undergone changes in agricultural development focusing on different crops and using different practices. Multiple policy changes in the agricultural sector were made after the Second World War starting with the Land Reform in 1958. The "big landlords" were expropriated from a majority of the land, they had been given under the rule of the French authorities (Keilany, 1980). After modifications made by the Baath Party to the reform in 1963 and 1968, the land was partially and slowly allocated to landless, simple tenants and agricultural labour with a fixed area, dependent on the family size (Sadiddin, 2009). The construction of fertiliser plants and a tractor assembly factory was a reaction of the government to counteract the lack of development in the agricultural sector. The Euphrates Project also implemented in the 1960's resulted in the construction of dams along the Euphrates and Khabur rivers (Figure 1a) (Hinnebusch et al., 2011). Beneficiaries further away from direct water sources were given access to irrigation facilities against an annual fee which led to an intensification of agriculture. After years of intensive cultivation of wheat and barley in the steppe areas, groundwater resources got more and more depleted until a new policy banned any cultivation only allowing grazing and the ownership of livestock on these areas in 1989 (Chatty, 2010). Furthermore, it was no longer permitted to irrigate any summer crops.

The following decades were driven by self-sufficiency and a "state-led export promotion" strategy (Sarris, 2003), which was to say that export was primarily controlled by the state. In the second half of the 90's, the government endorsed a new reform, liberalising the market and allowing for private sector exports. As statistics have shown (Sarris, 2003), the strategy was successful leading to a rise in GDP of more than 4 % in the 90's until the first big drought period in 1999 and the peak of oil production in 1995. With the death of president Hafez al-Assad, the last land reform was implemented by his son Bashar Assad in 2000 and 2001 when all state farms were finally privatised, and export was legalised. Trade agreements were made regionally and with the EU (Hinnebusch et al., 2011).

The core of the Syrian agricultural Farming System is the annual agricultural plan, which evaluates the amount of output that is needed from the agricultural sector the following year (Sadiddin, 2009). The annual agricultural plan determines how much of the so-called seven strategic crops are required to meet the demand of the state. The strategic crops can be sub-divided into those that have to be sold to the state (cotton and beets) and those that can also be sold privately (wheat, barley, chickpeas, lentils, olives). Dependent on the geographic location and climatic conditions, the different crops are intensively cultivated.

Under the FAO, Wattenbach (2006) published a detailed report on the identified Farming Systems existing within Syria. The country is divided into five agro-ecological zones and six Farming Systems. Figure 2 gives an overview of each agricultural zone. The Governorate of Al-Hassakeh falls within the Farming System of the northern and north-eastern plains (zones 2 and 3) making up the biggest fraction of the country and Farming System number six towards the southern part of AHG. Farming Systems Nr

3. and Nr. 6 are located within different climatic zones, resulting in differing rainfall availability. While Farming System Nr. 3 is commonly used for agricultural purposes, Farming System Nr. 6 does not receive enough rainfall to grow crops without irrigation (Figure 2). Therefore, it is not uncommon that these areas are used for grazing rather than permanent cultivation. Notably, the majority of land is classified as reform land and remains state owned. Fees in the forms of rents and irrigation fees have to be paid on an annual basis. Farming in AHG unlike the rest of the northern governates is dominated by a mix of rainfed irrigation as well as private irrigation with only 3 % falling under the public irrigation scheme along the rivers (Wattenbach, 2006).

The northern governorates including Al-Hassakeh are responsible for almost 80 % of the production of the most dominant strategic crops namely wheat, cotton and barley (Wattenbach, 2006) and fall under the Farming System Nr 3. In 2002, in 84.7 % of the total arable land was under cultivation, of which 60 % was rainfed. This Farming System was highly dependent on seasonal workers coming from all over the country to make sure that fields were efficiently used. Especially poor households depended on seasonal work opportunities. The liberalization of the market and the intensive use of available water resources have resulted in a steady decrease for both irrigated and non-irrigatied wheat in Al-Hassakeh (Appendix 8.1). A report published by the United Nations stated that poverty was exacerbating in the early 2000's, particularly in the rural regions of the northern governorates (El Laithy & Abu-Ismail, 2005). The intensification of agriculture, the liberalization of the market, the changes in land rights, and the depletion of freshwater resources were all contributing factors to poverty exacerbation (Selby, 2019).

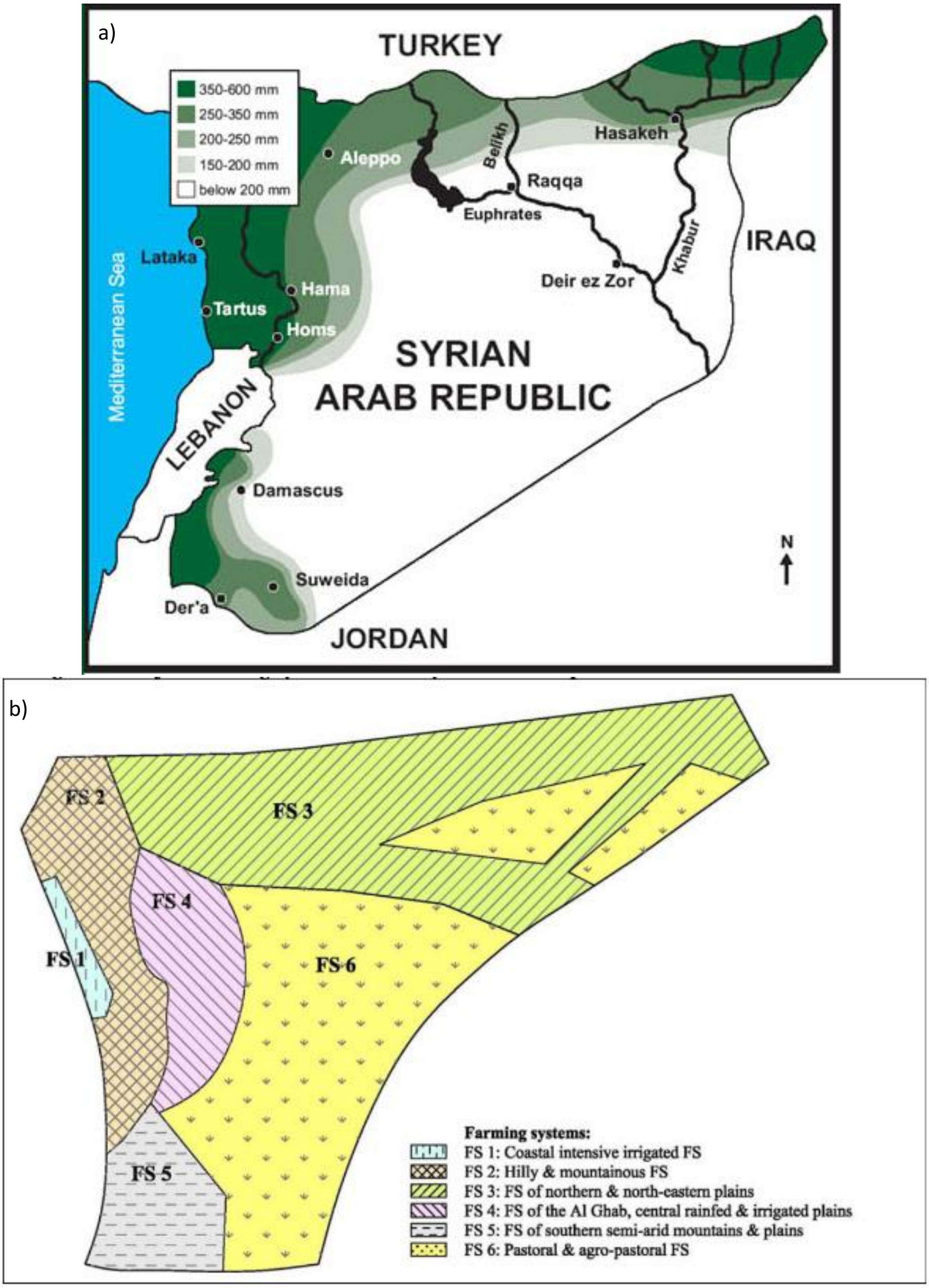


Figure 2. Agro-Ecological Zones of Syria a) (FAO, 2003), Farming Systems b) (Wattenbach, 2006)

3. Methodology

3.1 Study Area

The governorate of Al-Hassakeh is located in the far Northeast of Syria (Figure 3) and is made up of 4 sub-districts (Al-Malikeyyeh, Quamishli, Al-Hassakeh and Ras-Al-Ain). The total area cover of AHG corresponds to 23,131 km^2. The coordinates for the centre of Al-Hassakeh are 36.6°E, 40.8°N. The governorate shares borders with Turkey in the North and Iraq to the East. The topography of Syria is dominated by the Great Rift Valley and divides the country into two regions surrounded by mountain ranges in the western region. Al-Hassakeh is predominantly flat and in the far south it continues into Al-Jazirah (Figure 1a, 3), which is the start to the great Syrian Desert. The sub-districts corresponding to Al-Malikeyyeh and Quamishli are more mountainous while Al-Hassakeh sub-district has the greatest area and is flat only having a few elevated areas like for instance the Abd-al-Aziz Mountain (Figure 3).

On the Turkish side of the border, the Taurus mountain range which extends across southern Turkey has ensured a continuous source, supplying the transboundary rivers such as the Khabur and Euphrates with freshwater (Figure 1a) (Hole & Zaitchik, 2006). Based on the Köppen-Geiger climate classification system, AHG is divided in three climate zones: Hot-summer Mediterranean climate (Csa), hot semi-arid climates (Bsh), cold semi-arid climates (Bsk) (Koeppen, 1936). The climate in this area is variable, largely differing in annual rainfall and average temperature. The north-eastern sub-districts Quamishli and Al-Malikeyyeh experience up to an average of 600 mm/yr (Bsh & Bsk) of rainfall while the Al-Hassakeh sub-district only receives up to 200 mm/yr (Csa) (Figure 2). In terms of the mentioned agro-ecological zones and Farming Systems respectively, it can be said that the former (Bsh & Bsk) fall within the top three agro-economical zone and Farming System Nr 3. while the Hot-summer Mediterranean zone largely falls within the first two agro-economical zones and is largely made up of Farming System Nr 6. It is particularly in the latter region that agriculture largely relies on irrigation from the present rivers and groundwater through illegal wells.

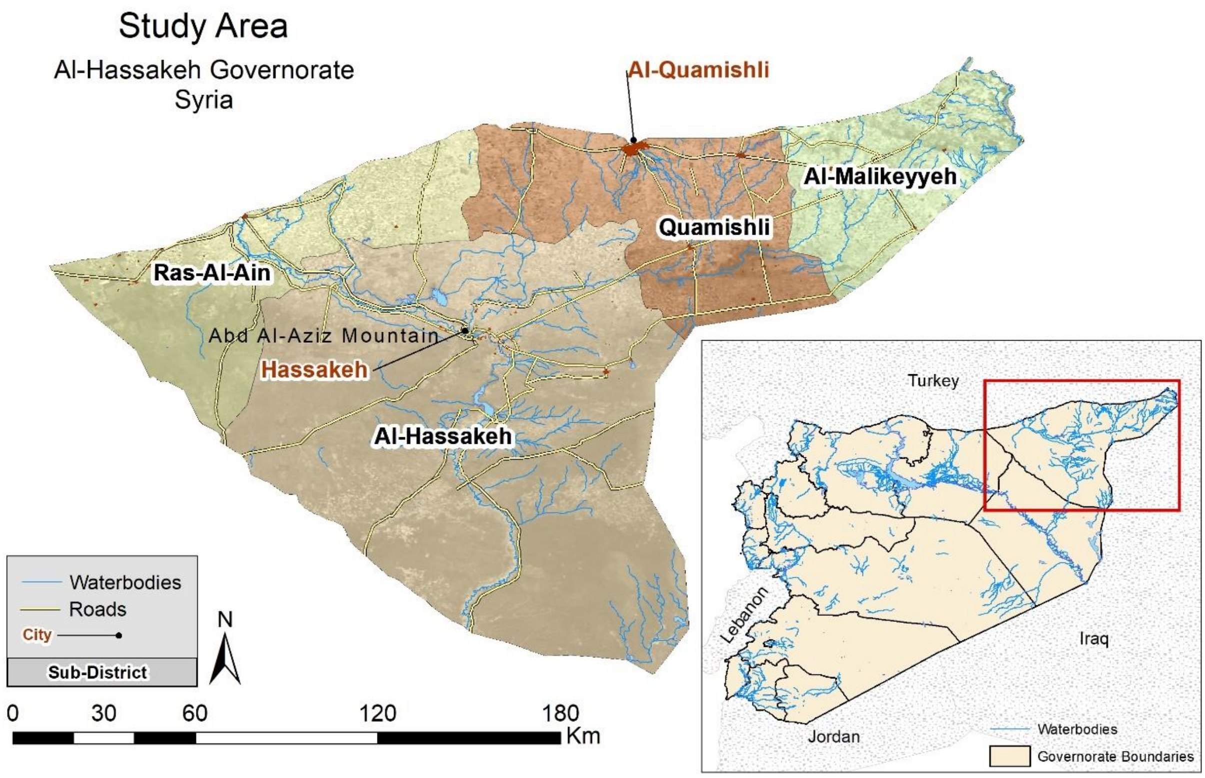


Figure 3. Study Area: Al-Hassakeh Governorate, Syria.

In AHG, the crop seasons can be divided into two, summer and winter. Winter crops include barley and wheat, which are important crops for Syria both for household consumption and trade. As it can be seen from Figure 1b, on average very little precipitation is observed during the summer months, making it necessary to irrigate all crop types during that season. Given I also wanted to investigate the impacts of drought, I decided to focus only on the winter crop harvest season (March-May), when crops (particularly wheat and barley) are more commonly rainfed (Wattenbach, 2006). The effects of sufficient precipitation throughout the growing season would be visible in the forms of good crop yields, which would also be somewhat reflected in the EVI. Figure 4 gives an overview of crops being grown in Syria and the time periods when individual crop types are harvested. Both wheat and barley are at their maximum vegetation cover in April and May. These crops contribute the most to agricultural production in AHG.

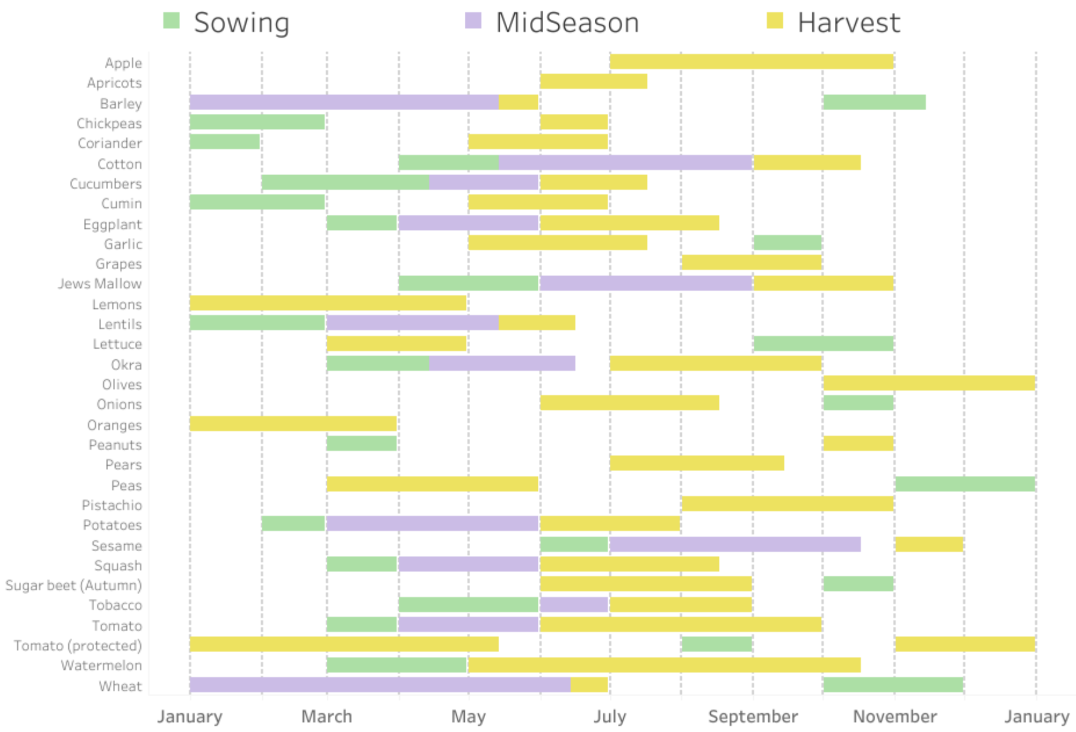


Figure 4. Crop Calendar Syria[1]

3.2 Data

I have utilised three different sources of data in addition to ancillary data for display to successfully meet my objectives.

3.2.1 MODIS products MOD13Q1

For this study I made use of the available MOderate resolution Imaging Spectroradiometer (MODIS) product MOD13Q1 which includes two layers: the EVI and the NDVI with a spatial resolution of 250 m and a temporal resolution of 16 days. More specifically, I obtained one image per month from the EVI layers of the MODIS Terra products for the months March-May corresponding to the Julian dates 065, 097 and 129 from the "Application for Extracting and Exploring Analysis Ready Samples (AppEARS)", which is managed by the National Aeronautics and Space Administration (NASA), the United States Geological Survey (USGS) and the U.S. Department of Interior (NASA & USGS, 2020). Unlike the NDVI, EVI saturates much slower and is not as disturbed by soil reflectance (Jaafar et al., 2015; Jaafar & Woertz, 2016; Karthikeyan et al., 2020; Eklund et al., 2015), which is useful when undertaking research in arid areas.

3.2.2 Land Cover Dataset

The already classified Land Cover Dataset (LCDS) was provided by Eklund et al., (2017b). The dataset has a spatial resolution of 250 meters and was created based on NDVI images with a temporal resolution of 8 days. Its temporal extent is from 2000-2016 but I only used the data until 2015. The land cover

[1] http://www.fao.org/emergencies/resources/maps/detail/en/c/889469/

maps are divided into 4 classes: Bare Soil, cropland (Single Crop), cropland (Multi Crop) and Other Vegetation. The classification itself is based on the distinct phenological behaviour of different land covers over the seasons rather than the spatial differences in surface reflectance. The dataset was developed based on a random forest non-parametric machine learning using GRASS GIS v.7.0 with 500 trees. Training data were manually assessed using Landsat images at a spatial resolution of 30 meters for the assessment (Eklund, 2017b).

3.2.3 Landsat Images

I obtained Landsat images from the USGS Earth Explorer also managed by NASA and the United States Geological Survey (USGS, 2020). After multiple tries, I decided to only set the file and row path to 171 035 because other file and row paths did not fully cover AHG or due to cloud cover there were not enough images available for the selected time period. (Figure 5). The maximum cloud cover, I set to 10 % to obtain as clear images as possible. Additional criteria were to only select images from March and May and to only use L1T products. The Level-1 imagery available has been corrected for topographic displacement by incorporating a number of ground control points. Images have also undergone radiometric and atmospheric correction based on the Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS) algorithm (USGS, 2020). I chose the L1T products to avoid the excess of pre-processing that would have been required (Young, et al., 2017). As with the MODIS images, I selected the three months (March-May) to capture the peak of the winter crop harvesting period. The respective location of the tile selected is shown in the inlet of the figure below (Figure 5).

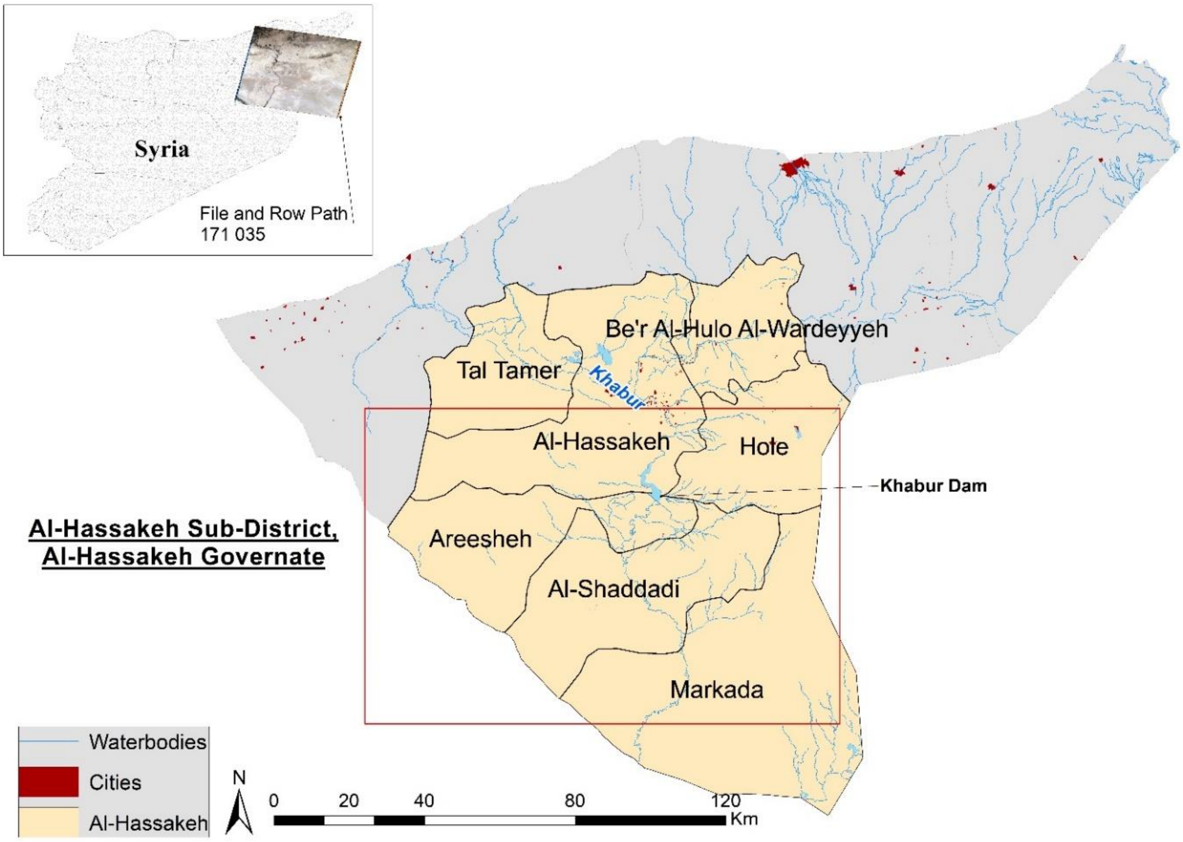


Figure 5. Relative location of selected file and row path of Landsat images (the red box marks the scene shown in the Landsat time series in the results section)

3.2.4 Ancillary Data

The remaining ancillary data to provide the necessary political, administrative and geographical context, I obtained from the Humanitarian Data Exchange Platform (HDX, 2020), which is managed by the United Nations Coordination for Humanitarian Affairs (OCHA) and the Database of Global Administrative Areas (GADM, 2020). The administrative boundaries were all obtained from the GADM database including Syria, Turkey, Iraq, Iran and Lebanon. The shapefiles corresponding to population, infrastructure and the waterbodies I downloaded from HDX. Finally, the administrative level 3 (sub-district level) boundaries, hence, I also retrieved these from the HDX Platform.

3.3 Vegetation Trend Analysis

For the time-period of 2000-2015 I downloaded EVI images for the months March-May (three images per year) (Figure 6). For each year I calculated the average EVI per year by calculating the mean of the three images and then multiplied the images by a scaling factor of 0.0001 to normalise the EVI product allowing for easier comparison across the years and with other studies (Didan et al., 2015). The average EVI per year was calculated rather than the maximum EVI, given I was interested in the seasonal average for the chosen time period and not the maximum EVI itself.

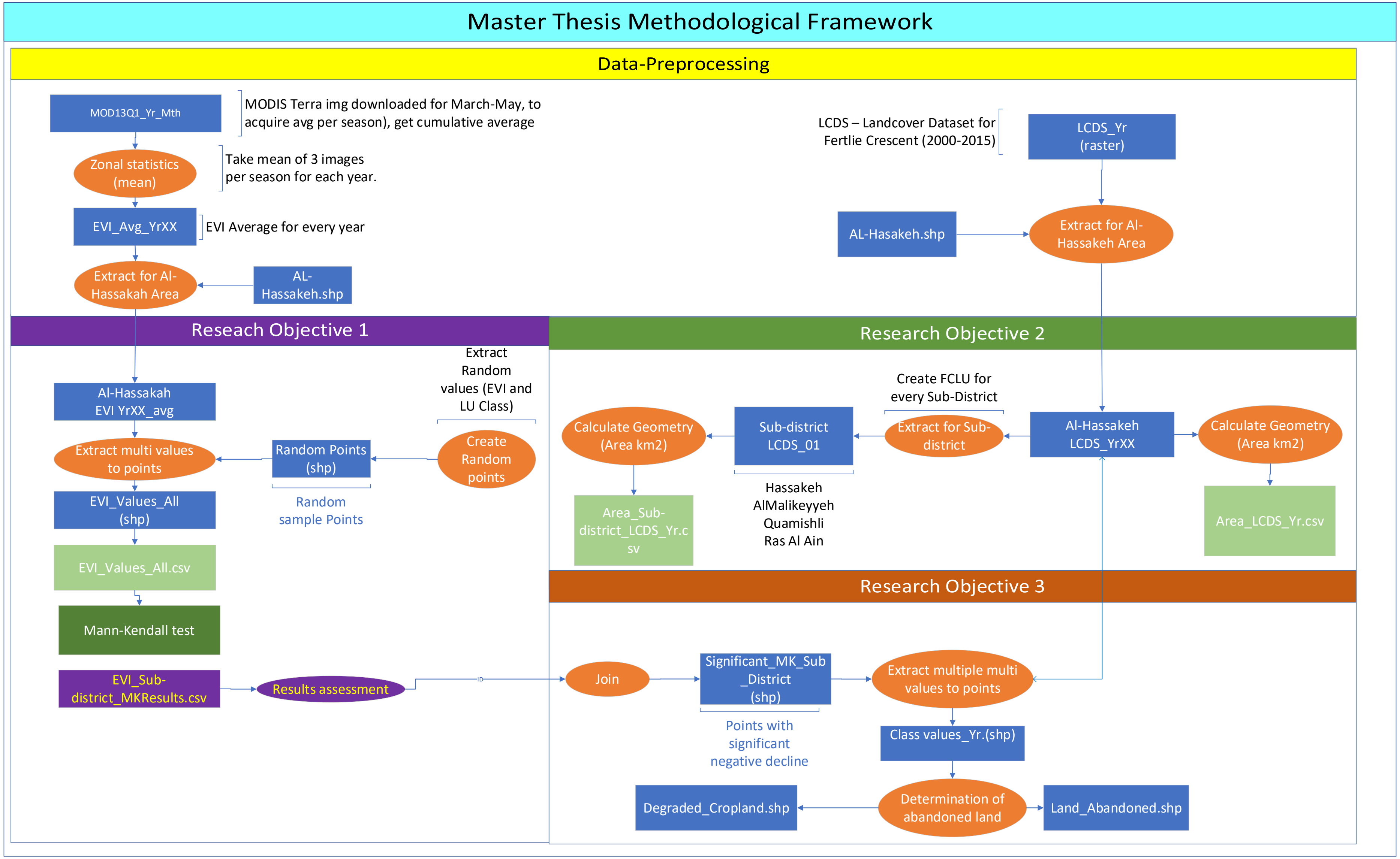


Figure 6. Methodological Framework of individual research objectives

Following, I clipped the average EVI for each year to the extent of AHG (Figure 6). In order to investigate whether an overall change in land cover and vegetation health at certain areas of Al-Hassakeh took place, I created 2000 random points on the extent of the LCDS cropland (Single Crop and Multi Crop) from 2001 for the different sub-districts with a minimum spacing of 500 m (2 pixels). The reason, why I chose 2001 for the stratified sampling was because 2001 had the maximum extent of cropland for the whole study period. This was to ensure that all points originally were cropland in the beginning of the assessment. The number of points per sub-district, I based on the share of each sub-district respective to the total area of AHG. Table 1 provides an overview of the areas and number of sample points for each sub-district. Less than 500 points each were allocated to the three smaller sub-districts (Quamishli, Al-Malikeyyeh, Ras-Al-Ain) while more than 1000 points were located in Al-Hassakeh sub-district. I extracted the average EVI values for each year. In the diagram shown in Figure 6, I have visualised the step by step approach to prepare the data for statistical testing. Following, I utilised the Mann-Kendall Test for the spatial-temporal assessment of whether significant changes in vegetation cover and corresponding land cover change could be observed at specific locations and times.

The Mann-Kendall test is a statistical method to assess the monotonicity of data, which is assumed to be independent from each other and evenly distributed (Kendall, 1975). The test determines whether a temporal upward or downward trend can be observed in the sample data. Note that this trend might not be linear but simply continuous. The null hypothesis states there is no monotonic trend while the alternative states the opposite. RStudio and the inbuilt mk.trend function was utilised to undertake statistical analysis. A two-sided test was utilised to detect both positive or negative and the confidence interval was set to 95 %.

Table 1. Area coverage and corresponding number of sample points: Sub-districts of Al-Hassakeh Governorate, Syria

Sub-District	Area (km^2)	Percentage	Nr of points
Hassakeh	12621.08	54.65 %	1093
Ras Al-Ain	3811.88	16.50	330
Quamishli	4026.55	17.44	349
Al-Malikeyyeh	2634.68	11.41	228
Total	23,094.19	100	2000

Figure 7. shows the script that I wrote for this study. After inserting the raw EVI values (csv file) as a data frame I applied the Mann-Kendall test function using a two-sided test. While it is simply applied on one set of data, I had to add a loop function to undertake the test on each point (column) of the data frame. The test results, I exported to a csv file after adding an ‘ID’ field. The ‘ID’ field allowed me to join the results with the sample point feature class. Whether a point shows a significant trend is reported by the p-value using a 95 % confidence interval. The direction of trend is further specified by the S value, where a negative value indicates a decreasing trend and a positive value the opposite.

```
install.packages("trend")
install.packages("g.data")
library(trend)
library(readxl)
setwd("D:/MasterThesis/DataSMK_Testt")
EVI <- read_excel("D:/MasterThesis/Data/MK_Test/EVI.xlsx")
View(EVI)
## Apply the Mann Kendall Test to all Pointss in dataset
MK_Test<- lapply((2:26),function(x)mk.test(as.numeric(unlist(EVI[,x])),"two.sided",TRUE))
## Convert List to a dataframe ready for export
MK_DF <- data.frame(matrix(unlist(MK_Test), nrow = length(MK_Test), byrow = T ))
colnames(MK_DF)<- c("data.name","p-value","statistic","null.value","parameter","S","varS","Tau","alternative","method","p-value")
##Save File

sink("MKTest.cFsv")
print(MK_Test)
sink()
```

Figure 7. RScript to conduct Mann-Kendall Test

3.4 Land Cover Change Analysis

The Land Cover Dataset (LCDS) for each year (2000-2015) I clipped the LCDS to the extent of AHG and the individual sub-districts to investigate the change in land cover over the period under investigation (Figure 6). The aerial extent of the different classes over a defined area in km^2, I calculated for each year of the study period. The same procedure I repeated on the areas of each sub-district so that it was possible to get a more detailed overview of where and when particularly land cover changes had taken place.

3.5 Land Abandonment and Out-migration Analysis

The same 2000 points used for the Mann-Kendall test in section 3.3 I used to extract the according land cover class from the LCDS dataset. I focused on the points that showed a significant decline (Mann-Kendall test) to identify whether land abandonment had taken place or experienced a significant decline in vegetation health only (Figure 6). To assess whether long-term out-migration had taken place I have considered two possibilities:

1. If the class continuously transformed to Bare Soil (>2 years), this point not only showed a degradation in vegetation cover but was also said to be abandoned and long-term out-migration had taken place.
2. If the EVI values showed a significant trend in either direction but there was no overall class change (≤ 2 years) then the vegetation status had ‘simply’ improved/declined and an increased/decreased output in agricultural output is inferred.

4. Results

4.1 Vegetation Trend Analysis

Out of the 1093, 186 points had a significant test result all except one with a negative trend (indicated by the negative S value). Hence, 185 points out of 1093 suggest that 17.1 % of all measured points showed a negative trend while only one point (0.001 %) showed a positive trend. The majority (75 %) of significant points were located in the southern part of the Hassakeh sub-district below the Khabur Dam (Figure 1a, Figure 8 – below the red line). For Quamishli, Al-Malikeyyeh and Ras-Al-Ain, 349, 228 and 330 points, respectively, were assessed (Table 2). Al-Malikeyyeh and Quamishli sub-districts only had 1 and 6 data points with a significant test result, respectively and I did not further investigate these two sub-districts. In Ras-Al-Ain, 30 data points of the total 330, corresponding to 9 %, had a p-value below the significance interval. Furthermore, the S value was negative for all data points. Looking at the Figure below, it can be seen that all 30 points are embedded between the dominant waterbodies in one area of Ras-Al-Ain sub-district (Figure 8).

All of the other points, which were considered in the test did not reveal any continuous trend neither in the positive nor in the negative direction. This means that the remaining points showed no statistically significant change in vegetation health during the period of 2000-2015.

Table 2. Mann Kendall Test Results for Al-Hassakeh Governorate sub-districts

Sub-District	**Nr of total points**	**Trend[2]**	**Positive/Negative**	**% Decreasing trend**
Al-Hassakeh	1093	186	1/185	17.1
Al-Malikeyyeh	228	1	1/0	0.4
Quamishli	349	6	1/5	1.7
Ras-Al-Ain	330	30	0/30	9.0

[2] This column represents the number of assessed sample points which showed a significant trend was observed at a 95 % confidence interval

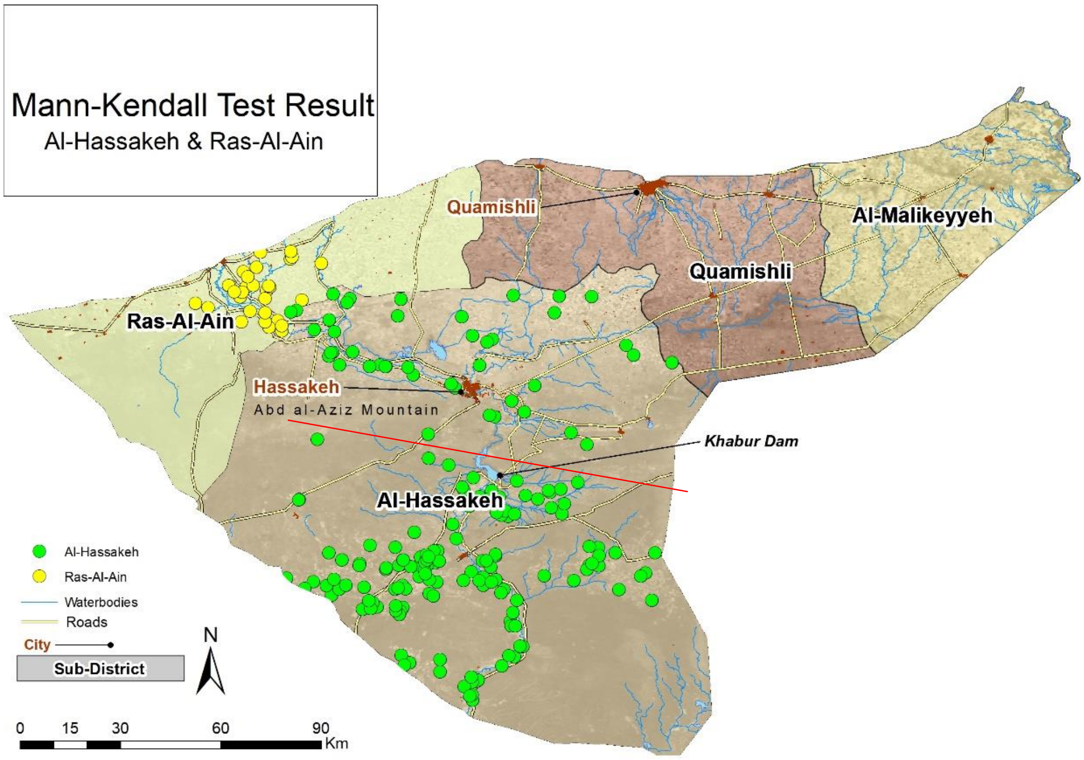
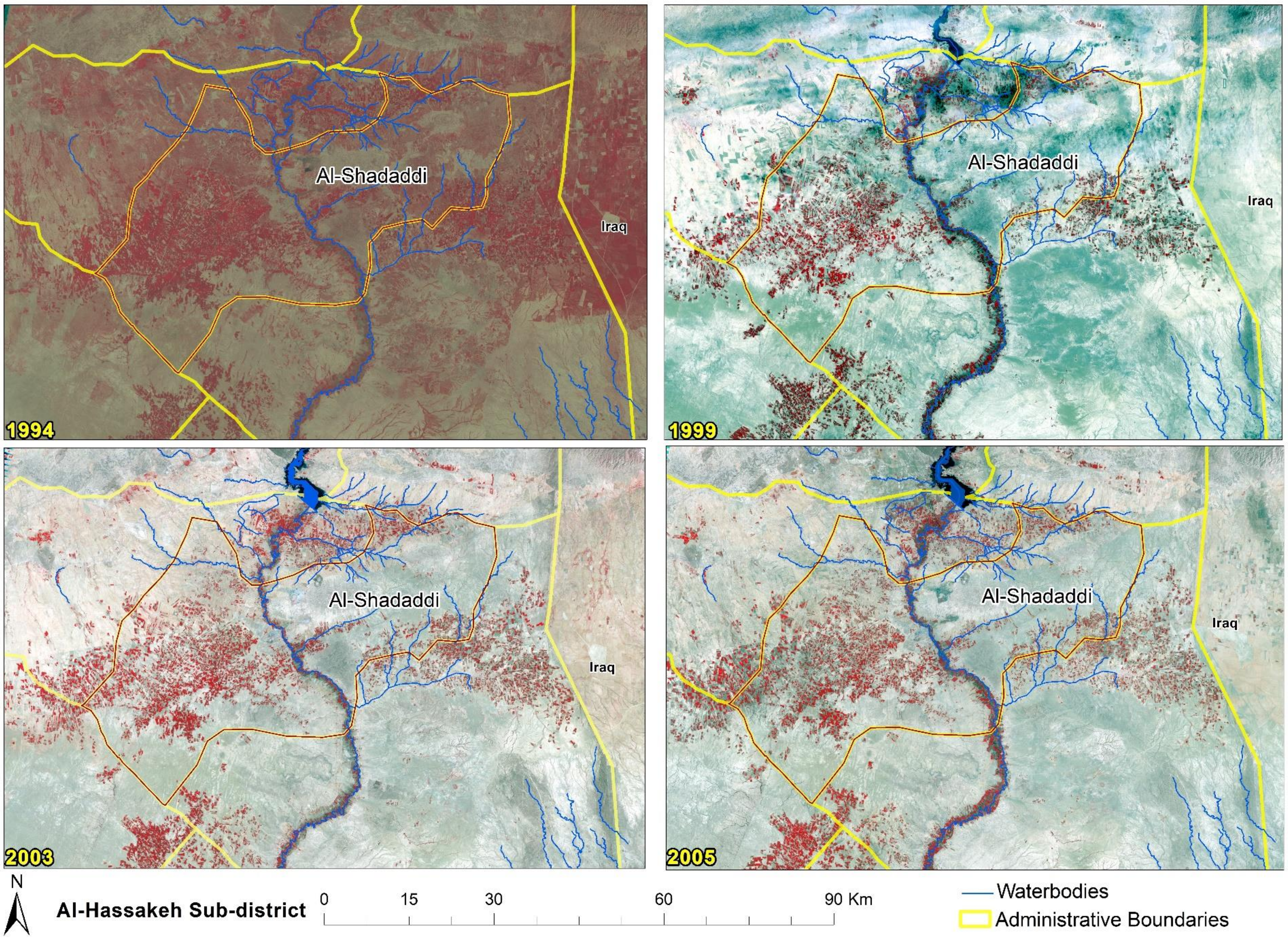
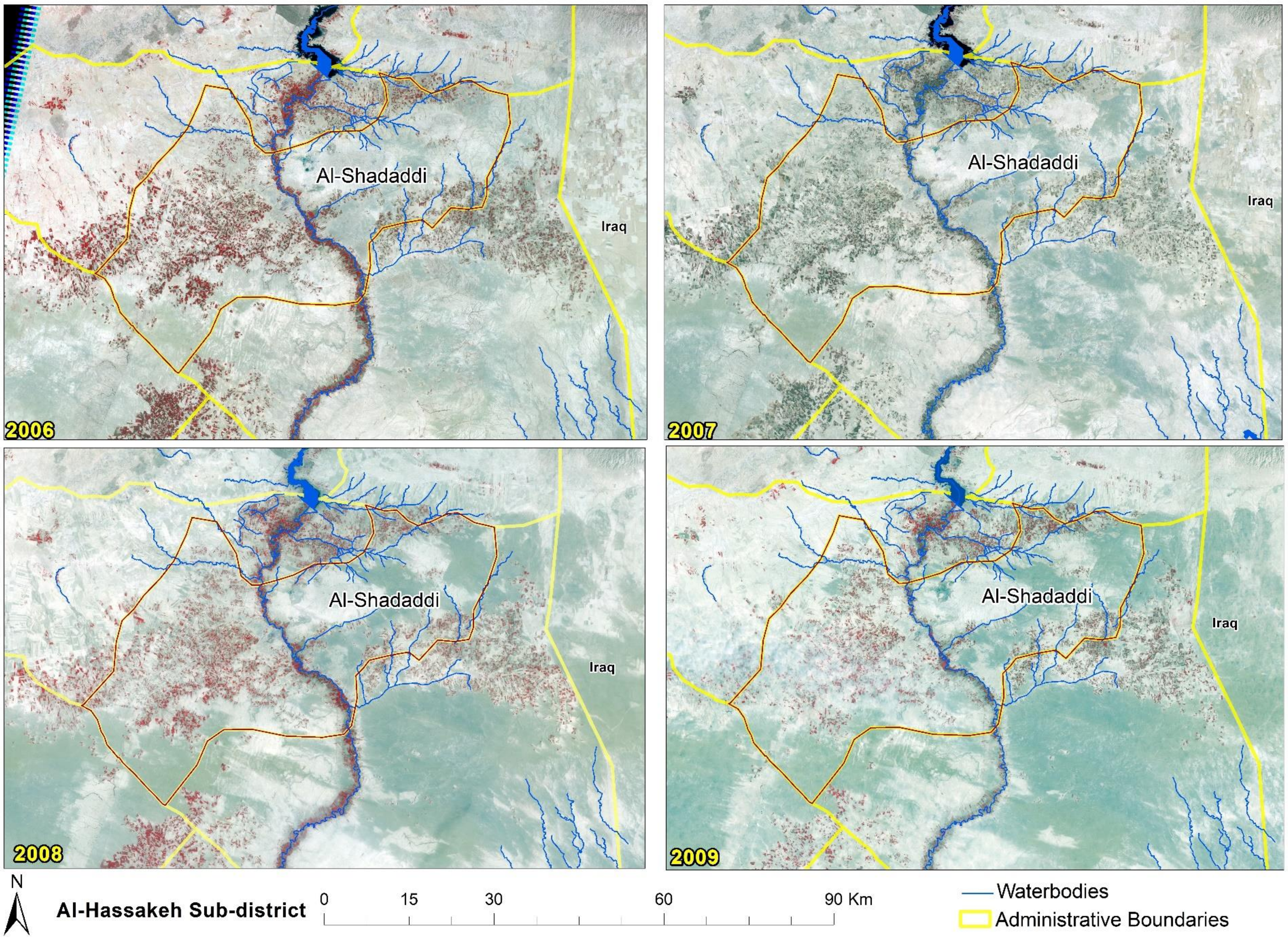


Figure 8. Data points showing a significant test result. All points show a negative S value. The red line marks the southern part of the Al-Hassakeh sub-district.

The time series of Landsat images at 30 meter spatial resolution from 1994 to 2016 covering southern Al-Hassakeh sub-district is displayed in Figure 9. The red square in Figure 5 shows the relative location of the enlargement of the area, which is shown in the Landsat time series (Figure 9). The false-colour composites highlight the decrease in vegetation health (showing less NIR reflection) over the years. The reservoir of the Khabur Dam started to become visible in 1999 only.


Al-Shadaddi
Iraq
1994
1999
2003
2005
N
Al-Hassakeh Sub-district
0
15
30
60
90 Km
Waterbodies
Administrative Boundaries


Al-Shadaddi
Iraq
2006
Al-Shadaddi
Iraq
2007
Al-Shadaddi
Iraq
2008
Al-Shadaddi
Iraq
2009
N
Al-Hassakeh Sub-district
0 15 30 60 90 Km
Waterbodies
Administrative Boundaries

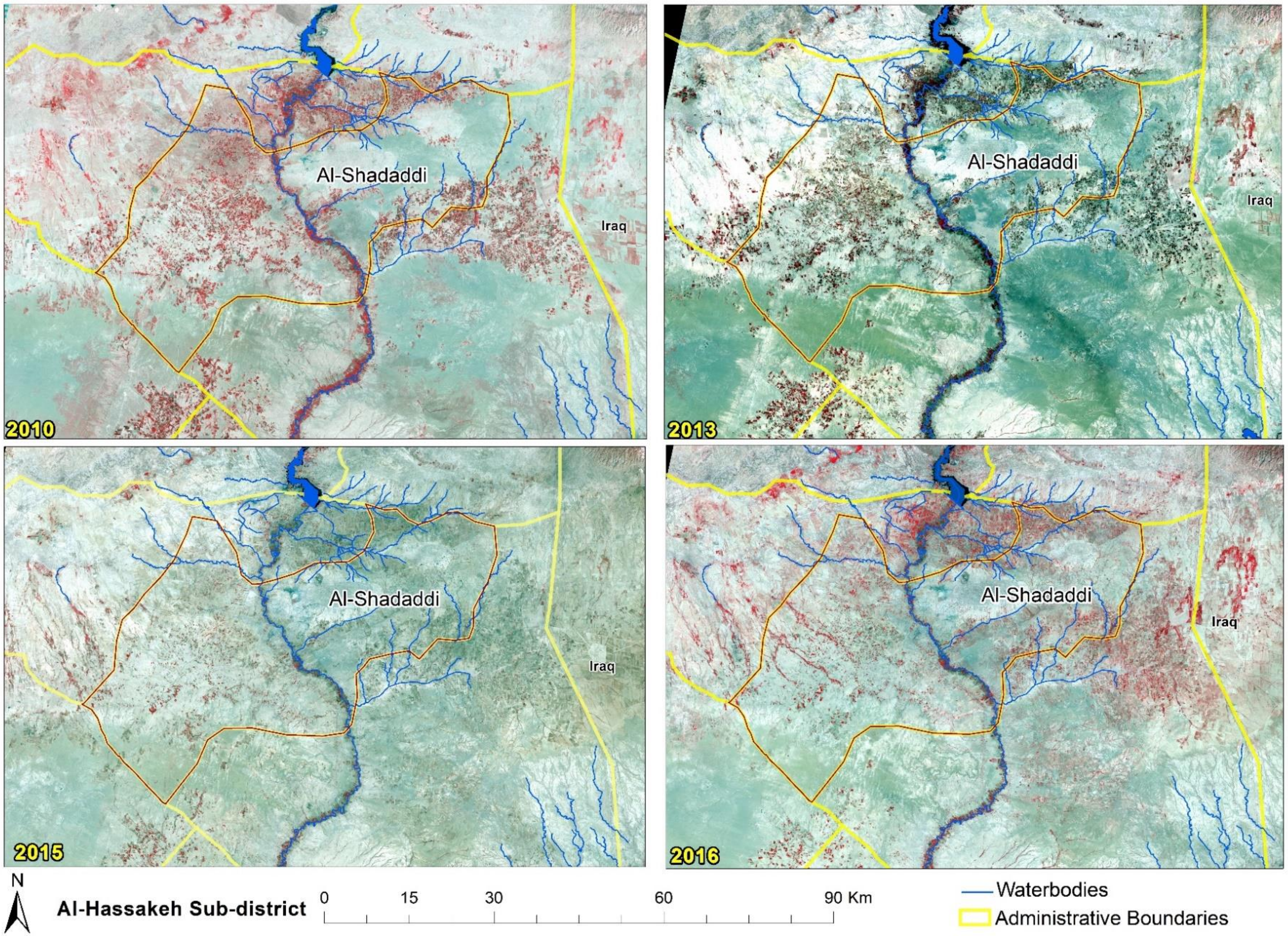


Figure 9. False-colour composite Landsat timeline of Al-Shadaddi in Al-Hassakeh sub-district ranging from 1994-2016 showing land abandonment

4.2 Land Cover Change Analysis

4.2.1 Al-Hassakeh Governorate

For AHG a limited change in land cover could be observed over the whole study period (Figure 10). The extent of Bare Soil depended on the intensity of the dry season. For instance, 2000, 2002 and 2008 and 2011 were particularly dry. The Single Crop class was reasonably stable but increased in the latter years to approximately 9000 km^2 in 2015. Multi Crop and Other Vegetation steadily decreased making up less than 3 % in average for the case of the Other Vegetation class and less than 2 % in the case of the Multi Crop class. Important to note, is the almost complete crop failure in 2008 where the extent of the Single Crop class dropped to 1000 km^2 compared to above 7000 km^2 in an average year and the extent of Bare Soil drastically increased to above 20,000 km^2 (average = 14585 km^2). The classes corresponding to Multi Crop did not go beyond 100 km^2 in the same year but the Other Vegetation class increased slightly.

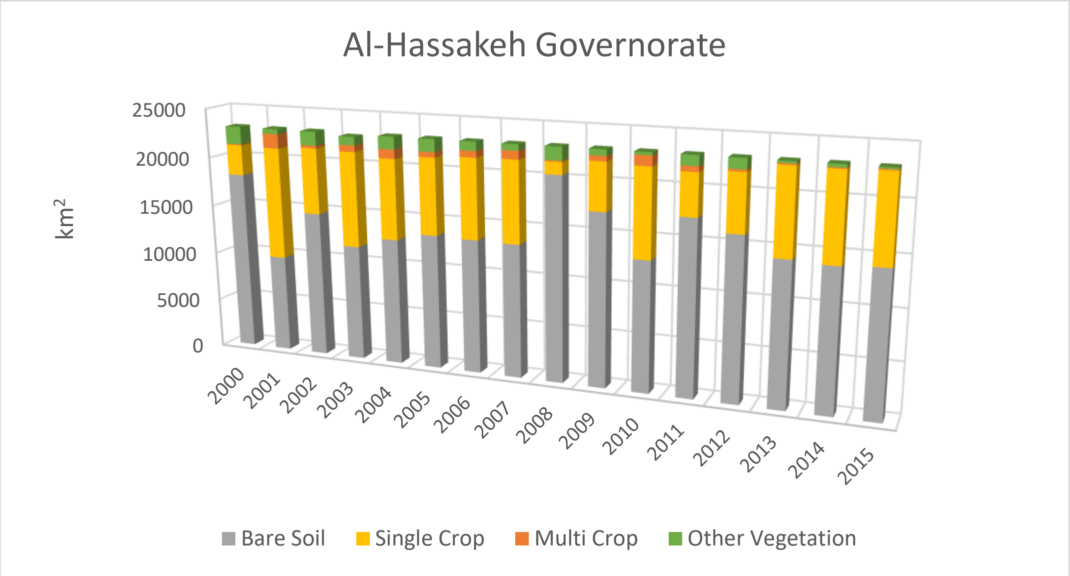


Figure 10. Land cover distribution of Al-Hassakeh Governorate

For comparison, Figure 11 shows the spatial distribution of land cover from the years 2001, 2003, 2008 and 2014. The year of 2001 was chosen for comparison as it shows the largest extent of Single Crop during the whole study period. As it can clearly be seen, the Single Crop class almost completely disappeared from areas that were not in close proximity to a bigger waterbody in 2008. Particularly, in the southern part of AHG, the Single Crop class was reduced to a minimum in 2008 and did not recover in the following years (Figure 11). Here, only 2014 is shown but images of the remaining years (2009-2013) show a similar pattern. Also, to note was the larger extent of Other Vegetation in 2008, which seemed to dominate in the sub-district of Ras-Al-Ain in 2008 (Figure 11). The extent of the Single Crop class showed almost the same extent in 2014 as in 2003, except for the southern and north-eastern extent in Al-Hassakeh sub-district.

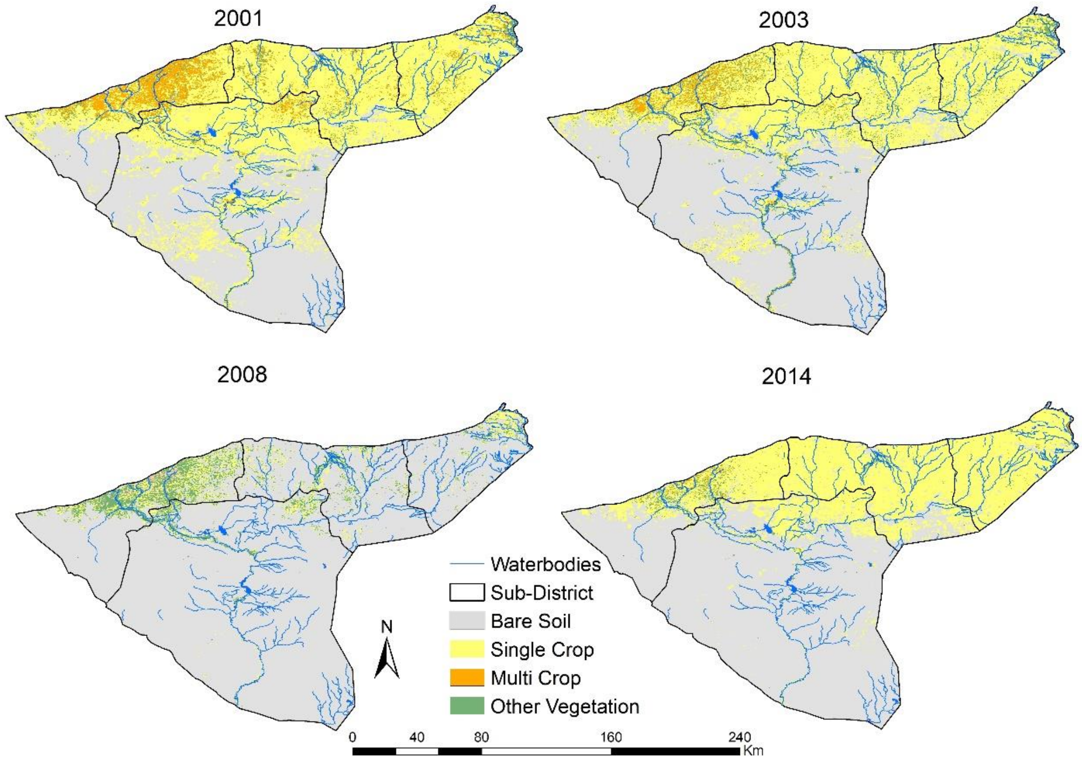


Figure 11. Development of land cover class in 2001, 2003, 2008 and 2014.

4.2.2 Al-Malikeyyeh

Al-Malikeyyeh was dominated by the Single Crop class, with commonly 2000 km^2 being cultivated each year (average = 1939 km^2). Al-Malikeyyeh was particularly badly hit by the drought, with Single Crop and Multi Crop reducing to less than 200 km^2 in that year corresponding to a 90 % loss (Figure 12, Appendix 8.2). The extent of Bare Soil was balanced with the Single Crop class reflecting change from fallow or abandoned land into Single Crop and vice versa. For instance, while in 2000 (dry year) the area corresponding to Bare Soil was almost 1200 km^2 it only was just above 70 km^2 in 2001. Single Crop, on the other hand, in 2000 covered only just above 1100 km^2 but above 2300 km^2 in 2001. Figure 12 and Appendix 8.2 show that the Multi Crop class declined to less than 10 km^2 after the onset of the war in 2011. It is only next to the Tigris River (border to Iraq and Turkey) that Multi Crop remained in the years of 2012-2015. Finally, the class corresponding to Other Vegetation decreased below 100 km^2 after 2008 having the maximum in 2000 with just almost 300 km^2.

Figure 12. Land cover distribution of Al-Hassakeh sub-districts 2000-2015

4.2.3 Quamishli

In Quamishli a similar trend as in Al-Malikeyyeh was observed. Following the same seasonal trend, the class Single Crop had an average of 2445 km^2 with its maximum in 2001 where almost 3500 km^2 was classified as Single Crop. In fact, the area classified as Bare Soil in that year corresponded to the built-up areas in Quamishli City in the far north of the sub-district only. In average the area corresponding to Bare Soil was below 1900 km^2 making up a third of the area (34 %). The classes corresponding to Multi Crop and Other Vegetation were almost negligible (Figure 12). In 2008, Single Crop dropped to 286 km^2 corresponding to just 12 % of the average cropland extent, while the class Other Vegetation increased that year, particularly around the waterbodies. In general, however, the area allocated for Multi Crop and Other Vegetation gradually but continuously declined over the years to below 10 km^2 and 100 km^2, respectively (Figure 12, Appendix 8.2).

4.2.3 Ras-Al Ain

In Ras-Al-Ain a steady rise in the Single Crop class was observed, while the extent of Multi Crop and Other Vegetation generally declined. Typically, in an average year, 1278 km^2 were classified as Single Crop. The other classes (Other Vegetation and Multi Crop) decreased slightly but in general made up a larger fraction than in the other two sub-districts. For instance, in Ras-Al-Ain 9 % of the total area each corresponded to Multi Crop and Other Vegetation in average (360 km^2 and 326 km^2), while in Quamishli and Al-Malikeyyeh these two classes did not cover more than 2 % (Figure 12, Appendix 8.2). Similar to the other sub-districts, the Single Crop class decreased to a minimum in 2008, however, 14 % of the total sub-district area remained Single Crop. While in the beginning of the study period, the Multi Crop class was dominant around waterbodies, it decreased with time and was replaced by Single Crop. In the year of 2008, these areas were replaced with Other Vegetation.

4.2.4 Al-Hassakeh

The Al-Hassakeh sub-district is the largest sub-district of all four (Figure 12, Appendix 8.2). The majority of its land area corresponding to more than 10900 km^2 in average was classified as Bare Soil. In an average year 1400 km^2 corresponded to Single Crop while Multi Crop and Other Vegetation were hardly present and only made up 64 km^2 and 234 km^2, respectively. In 2008, the Single Crop class reduced to less than 200 km^2 (1.5 % of total area) while the class Other Vegetation increased slightly compared to an average year (Appendix 8.2). The Multi Crop class reduced to 4 km^2 only being present close to Al-Hassakeh City. The following years, Multi Crop was only present in the northern part of the sub-district situated approximate to the river. Despite the observed disappearance of Single Crop (Figure 11), the total area corresponding to Single Crop did not decrease in the latter years of the study period. From Figure 12, it can be seen that in the last three years, the area of Single Crop increased continuously. As for the Multi Crop Class, the increase in Single Crop was shifting northwards and closer to ephemeral waterbodies (Figure 11).

4.3 Land Abandonment and Long-Term Out-Migration Analysis

The same points that I assessed in section 4.1 I used to extract the corresponding land cover class values for each year. I focused on the points with a significant Mann-Kendall test result in the sub-districts Ras-Al-Ain and Al-Hassakeh only. Figure 8 shows all the points with a significant result.

4.3.1 Ras-Al-Ain

The points assessed in the sub-district Ras-Al-Ain (n=30) showed a drop in Single Crop during the period of 2008-2012 with only 10 points in average corresponding to Single Crop while increasing again in the later years (Table 3 and Figure 13). Simultaneously, the number of points corresponding to Multi Crop increased in the years 2009-2011. Within the first 8 years of the period, there were no points classified as Bare Soil with the exception of 4 points in 2000. In 2008 and 2009 there were 4 and 2 points, respectively that corresponded to Bare Soil. Finally, as it can be seen from the table below and Figure 13, the number of points corresponding to Other Vegetation increased after the drought with often a third of all points being classified as such.

Table 3 Land Cover Class Distribution of points (n=30) with significant Mann-Kendall test results in Ras-Al-Ain.

Classes	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Bare Soil	4	0	0	0	0	0	0	0	4	2	0	0	1	0	8	1
Single Crop	25	27	21	25	10	15	19	16	8	10	14	12	15	29	12	25
Multi Crop	0	3	1	4	13	6	8	12	2	11	15	8	0	1	0	2
Other Vegetation	1	0	8	1	7	9	3	2	16	7	1	10	14	0	10	2

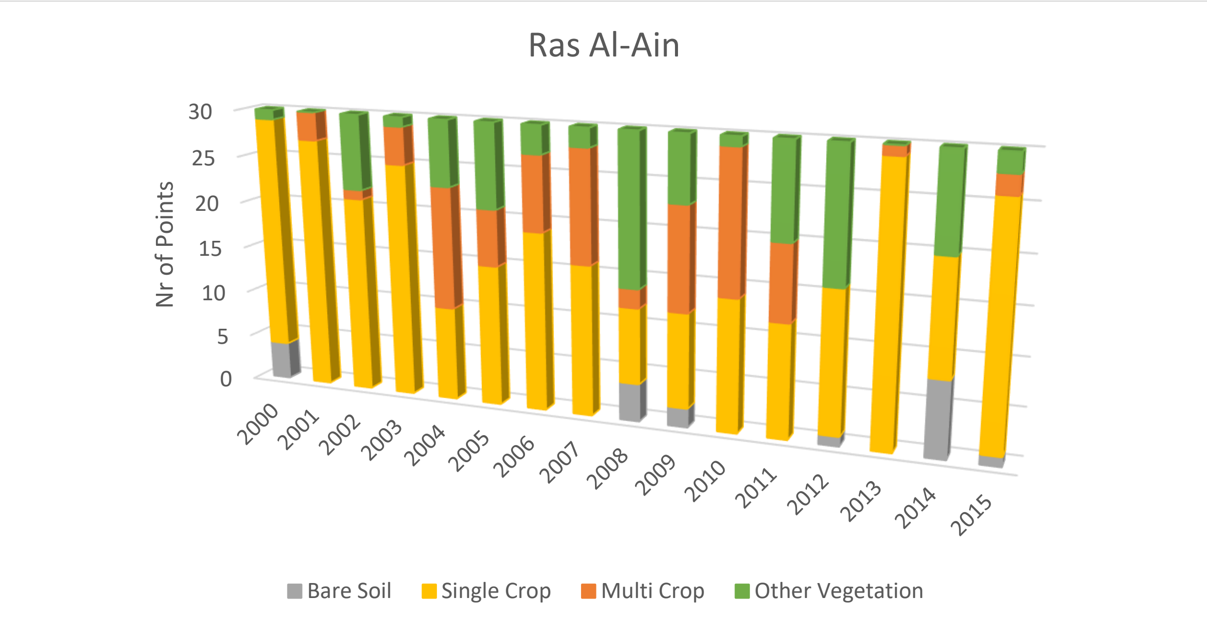


Figure 13. Land cover trend at assessed points for Ras-Al-Ain between 2000-2015

By applying the modified definition of land abandonment from Yin, et al. (2018) to the individual points, I found that no point showed a continuous transformation from Cropland to Bare Soil in Ras-Al-Ain. Hence, in Ras-Al-Ain no land abandonment was detected within 2000-2015 but the relative vegetation health had declined.

4.3.2 Al-Hassakeh

In the Al-Hassakeh sub-district there was an overall drop in Single Crop throughout the study period based on the points that I assessed. In 2001, a maximum of 176 points were classified as Single Crop while in 2008, the year of the drought, only 11 points corresponded to Single Crop (Table 4). After 2008 the number of points classified as Single Crop did not exceed 30 (except for 2010). Multi Crop followed a similar trend with its maximum of 10 points being during the years of 2003-2004. In the years of drought in 2008 and 2011, Multi Crop was absent and remained as such from 2013 onwards. Other Vegetation also continuously declined. Bare Soil, on the other hand, was the only class that continuously increased with more than 160 points from 2008 onward (except 2010 and 2012). Looking at Figure 14 the increase of Bare Soil is clearly visible, while Single Crop reached a new stable range with just above 20 points.

Table 4. Land Cover Class Distribution of points (186) with significant Mann-Kendall test results in Al-Hassakeh.

Classes	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Bare Soil	139	0	96	52	57	87	94	103	163	163	131	164	150	159	159	162
Single Crop	35	176	67	110	98	66	59	55	11	14	43	16	28	24	23	24
Multi Crop	1	6	0	10	10	7	3	4	0	1	2	0	1	0	0	0
Other Vegetation	11	4	23	14	21	26	30	24	12	8	10	6	7	3	4	0

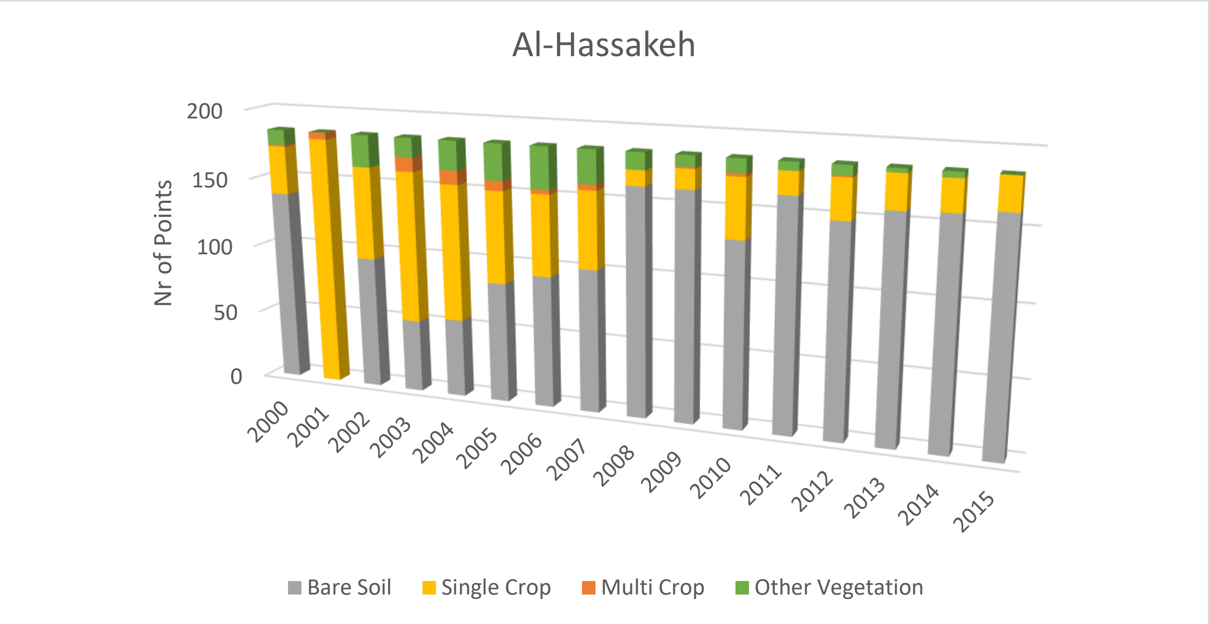


Figure 14. Land cover trend at assessed points for Al-Hassakeh between 2000-2015

After manual assessment, I found that out of the 185 points having a significant trend, 149 points in total fell under the definition of being abandoned by the end of 2015 (continuous transition from being cropland in 2001 to Bare Soil > 2 years). Figure 15 shows the significant points in the sub-district of Al-Hassakeh and the year of abandonment. If a point continuously changed from one of the three other classes to Bare Soil for more than two years, it was classified as being abandoned. Otherwise, the point was classified as a point where a decrease in vegetation health was observed. It is noted that in case that Other Vegetation was the last class before ‘abandonment’ additional care needed to be taken since in the case of pasture and grassland as fodder for livestock could have been overgrazed over time, also resulting in the transition to Bare Soil. During the analysis, however, I found no such transition. While 89 points were abandoned before the drought of 2008, 60 points were abandoned in or after 2008. Of the 89 points 25 points alone were classified as abandoned from 2002 onwards. This is to say that these points were classified as Bare Soil for the remainder of the study period. Table 5 provides a summary of the number of points and their corresponding years of continuous abandonment. It is noted that the majority of points transitioning to Bare Soil and thereby being continuously classified as abandoned are in the years before the drought in 2008.

Table 5. Number of points that were abandoned each year (continuously classified as Bare Soil)

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Points	25	0	11	20	16	17	37	2	0	14	0	1	0	0

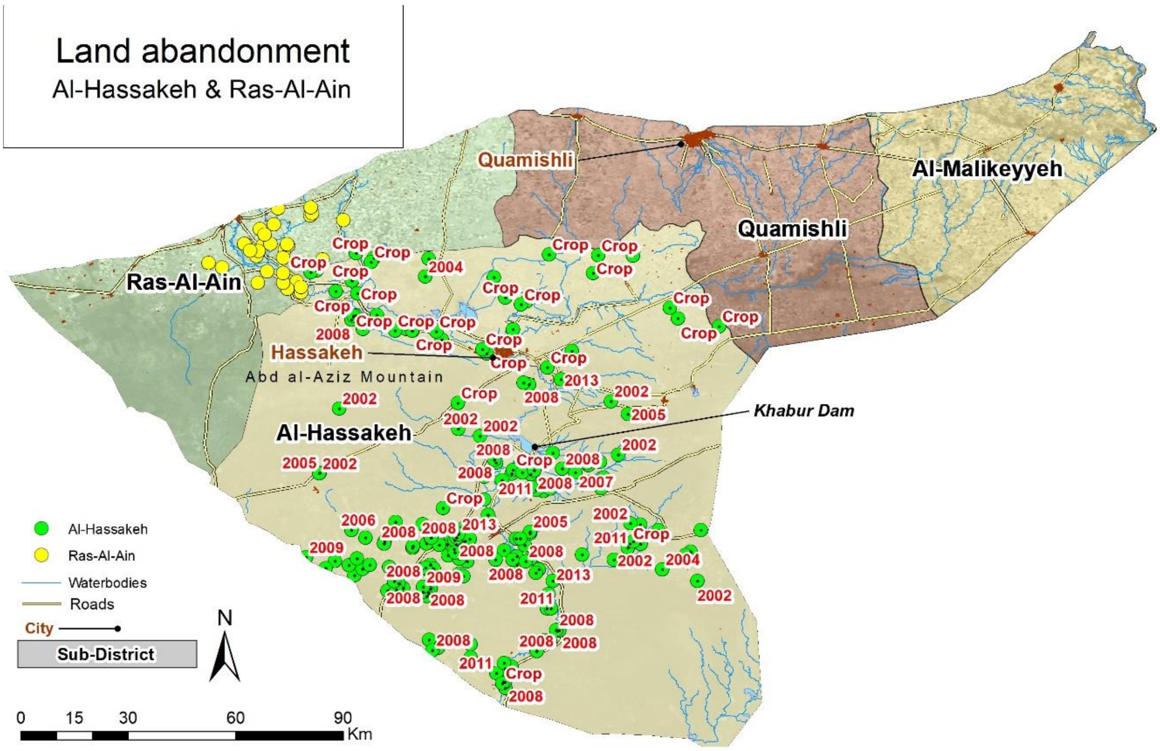


Figure 15. Al-Hassakeh sub-district - Overview of sample points: The year states when the points are considered to have been abandoned and those still stating „crop“ correspond to areas that remained cropland.

Most of the “abandoned” points, are located below the Khabur Dam (Figure 15), regardless of the year of abandonment. In total, 36 points remained cropland in Al-Hassakeh with the majority being located in the northern part of the sub-district (Figure 15). The remaining cropland was also located closely to direct freshwater resources and the Hassakeh City. Despite not showing any land cover class changes, all points showed a decline in EVI corresponding to reduced vegetation health. Due to an absence of a systematic trend in recurring class changes, Individually, I assessed 42 points using the time series of Landsat images, shown previously (Figure 9) to determine whether the sample point was located on an agricultural field which had been abandoned. The majority of those were classified as Single Crop in one year, Multi Crop in another and Bare Soil in other years not showing a continuous land cover trend. I found that all data points which I individually assessed fell under the classification of remaining cropland but showing a decrease in vegetation health (classified as Bare Soil ≤ 2 years).

5. Discussion

5.1 Vegetation Trend Analysis

Generally, the data points with a significant test result showed a negative trend in vegetation health. Within the individual sub-districts there was a large difference. For instance, in Quamishli and Al-Malikeyyeh sub-districts only a few points had a significant trend being following no spatial pattern across the sub-districts. Given the climatic zone and the different topography, it is likely that the sufficient rain due to for instance the Taurus Mountains on the Turkish side of the border (Figure 1a) in addition to the more suitable soil conditions supported the continuous cultivation in those sub-districts (Hole & Zaitchik, 2006). Furthermore, literature suggests that with the ongoing population growth and resettlement of specific tribes, the intensification of the arable land led to a higher agricultural output in the early 2000's onward (Hole, 2009; Chatty, 2010; OHCHR, 2011). Thus, the lack of significant sample points was not surprising. Due to the limited number of points showing a significant trend in Al-Malikeyyeh and Quamishli, I decided to focus on the remaining sub-districts (Al-Hassakeh and Ras-Al-Ain) and undertake more detailed analysis on these.

In Ras-Al-Ain, the majority of sample points, which experience a decrease in vegetation health are located around the Khabur and neighbouring rivers meaning that irrigation had been possible in the past (Figure 8). Looking at the corresponding land cover classes for the assessed sample points, none were classified as Bare Soil until the year of the drought in 2008. Based on the above, it may be that farmers cultivating this land, disregarded agricultural policies and production plans having not engaged in fallow practices and utilised unsustainable cultivation methods as Hinnebusch et al., (2011) and Wattenbach (2006) have previously mentioned. The continuous cultivation would have led to a degradation of the land. Another reason for the decreased vegetation health may be the traditional flooding methodology for irrigation, which has been very common to use (Hole & Zaitchik, 2006). The combination of the two in addition to the changes in water level due to damming and groundwater extraction further upstream on the Turkish side could have led to the observed decrease in vegetation.

The more frequent reduction in vegetation health for Al-Hassakeh sub-district compared to Ras-Al-Ain is most likely due to a combination of factors. Firstly, land reforms and resettlements during the 1960's and 70's and an increasing population from several 10,000's to above 1.2 million people in Al-Hassakeh alone from the 1950's to present resulted in an expansion of agricultural land further away from the rivers, especially into the more arid zones and the rangelands (Sarris, 2003; Hole, 2009). This also included the steppe area south of Khabur Dam, which is typically utilised as grasslands by tribal communities and only has a limited source of freshwater. Hole and Zaitchik (2006) report that the recurring droughts at the end of the 90's and the beginning of the early 2000's led to land degradation. The Landsat images in section 4.1 show clearly the reduction in cropland supporting this statement. It is likely that the expansion of cropland into the rangelands, in addition to groundwater depletion are a key contributing factor to the observed decline of vegetation health in Al-Hassakeh sub-district.

Another possibility for the decline of the vegetation health in particularly southern Al-Hassakeh sub-district could be an increasing lack of access to surface water for irrigation. With the closure of the Khabur Dam in 2001 (Figure 1a & 8), the natural flow of the lower part of the Khabur River started to be absent and water supply was dependent on the Euphrates (Hole & Zaitchik, 2006). As a result, this led to dry stretches of the river in summer, which in the last decade repeatedly had been observed. Dry stretches in summer would have led to an overall reduced water availability during the winter and the initial sowing period of winter cropt. This would have made the farmers even more reliant on groundwater wells since existing irrigation canals may not have received any more water.

Climate change and a more frequent recurrence of droughts put additional pressure on vegetation and the available freshwater resources. Gleick (2014) and Kelley et al, (2015) suggest that the rise in temperature and the reduction in precipitation over the years were a significant driver for the observed failures in harvest as well as the reduction of water availability. The vegetation health is dependent on the access to water and is as well bound to certain temperature ranges. The reported average increase in temperature of 1 degree Celsius would have added additional pressure on the existing vegetation, especially in the already arid rangelands. Thus, the average increase in temperature, particularly in southern Al-Hassakeh additionally may have reduced freshwater availability and contributed to the observed reduction of vegetation health.

The decline in vegetation health at certain areas is in line with the general yield decline as previously found by Jaafar & Ahmad, 2015. This is also in further agreement with official statistics, published by MOAAR. In the case of wheat, which accounts for at least 50 % of total crop (Wattenbach, 2006), the yield from non-irrigated fields decreased considerably after the years of drought from above 1000 kg/ha to below 500 kg/ha reaching a minimum of 311 kg/ha in 2011 in AHG (Appendix 8.1). Both Hole (2009) and Selby (2019) have also mentioned the reduction in crop yield in those areas for wheat, barley and cotton being three of the strategic crops.

5.2 Land Cover Change Analysis

Overall, I found that the aerial extent corresponding to Single Crop did not change noticeably for AHG as a whole over the whole study period but varying among the sub-districts. However, the gradual decline of Multi Crop suggests that water resources are no longer sufficient during the summer periods, preventing bi-annual cultivation. This may be due to the fact that fuel subsidies were removed in May 2008 in addition to the subsidies for fertiliser in 2009, which made it more expensive to irrigate and cultivate (Selby, 2019). Kelley et al., (2015) additionally suggest that temperatures have gradually increased, particularly in the summer months. These unfavourable conditions and the increase in oil prices could be a possible explanation for the overall decrease in Multi Crop.

The reduction of Single Crop in Quamishli and Al-Malikeyyeh is most likely due to a combination of the drought as well as the removal in fuel subsidies. These two sub-districts are dependent on both rainfed agriculture as well as irrigated (Wattenbach, 2006). Due to the lack of precipitation in particularly 2008, the rainfed fields could not sufficiently be irrigated, which led to a complete crop failure. Statistics released by MOAAR confirm this result (Appendix 8.1). However, also the irrigated fields significantly dropped in 2008. I argue that the subsidy removal had a big effect on these two sub-districts since in 2011, another year of drought, the extent of Single Crop did not drop as significantly as it did in 2008 (Figure 12).

The reduction in Multi Crop and Other Vegetation in these sub-districts is possibly explained by a number of reasons. Firstly, with the onset of the war, Quamishli and Al-Malikeyyeh were often scenes of fights and incidents (Khaddour & Mazur, 2017), ruining the local and national economy. The FAO also reported in a special report that the usual seed supply was reduced to a tenth of its usual distribution (Dost et al., 2015). Hence, it is suggested that farmers focused on growing the essential goods for survival instead of investing into goods like cotton, tobacco and beet. As Selby (2019) showed, the production of cotton has also decreased since 2008.

In Ras-Al-Ain, the pattern of land cover change differs from the other districts. The sub-district was similarly affected by the drought but recovered noticeably faster than the other two sub-districts particularly when looking at the numbers for Multi Crop in the following years. It is likely that due to the direct access to the Khabur River, Multi Crop cultivation could successfully be carried out in the years of 2009/2010. With the onset of the war, however, the area corresponding to Multi Crop also declined, which is possibly due to the switch to essential goods as pointed out above. Eklund, et. al (2017) observed the same development throughout the whole Fertile Crescent.

The observed aerial shift in Single Crop (Figure 11) is most dominant in the Al-Hassakeh sub-district which is most likely due to the already previously mentioned factors namely groundwater depletion and climatic changes in addition to unsuitable soil conditions. I have already mentioned the increasing average temperature in addition to the falling precipitation rates, for some areas more than others (Kelley et al., 2015), which both are important factors for agricultural activities. Being located in the arid climatic zone (Csa) (Koeppen, 1936), corresponding to Farming System Nr 6, it is likely that the continuous decline in rainfall, in addition to the increase in temperature has led to unbearable living conditions and making cultivation of the land profitable impossible.

An additional factor for the observed aerial shift of Single Crop to the northern part could be the unsuitable soil conditions in Al-Hassakeh sub-district. Based on Wattenbach's in-depth summary of the Farming System in Syria, Al-Hassakeh sub-district falls under the Farming Systems number three and six three (Figure 2) (Wattenbach, 2006). It is particularly, the areas corresponding to number six that show the disappearance in Single Crop. Farming System nr. six is not suitable for permanent cultivation as outlined by Wattenbach (2006). Hence, given the soil conditions in Al-Hassakeh sub-district, permanent cultivation was never suitable in the first place and fields may have suffered from salinization, further decreasing crop yields as suggested by Hole (2009).

Also, to keep in mind for southern Al-Hassakeh is the relative location. The available water for irrigation was largely supplied by wells and the Euphrates River (Hole & Zaitchik, 2006) as I mentioned in section 5.1 already. It is likely that particularly the former would have been overused over time. The construction of dams upstream on both the Khabur and the Euphrates rivers (Figure 1a) put additional pressure on the water availability and could have reduced the overall flow providing even less fresh-water resources to the mentioned area. Hence, it may be possible that generally areas further downstream received less water for irrigation, leading to the observed aerial shift of Single Crop north of the Khabur Dam and the corresponding decrease in vegetation health.

Finally, a possible reason for the shift of Single Crop to the areas more proximate to ephemeral water-bodies and the northern part of Al-Hassakeh sub-district could be due to a variety of policy changes. Under the 5 year plan endorsed in 2001, the government decided that summer irrigation was no longer allowed in the steppe area (Hole, 2009) and Selby mentions the removal of fuel-subsidies in 2008. Official numbers from MOAAR (2020), which report a drop of irrigated wheat from 3064 km^2 in 2007 to 1025 km^2 in 2015 (Appendix 8.1) show a decrease in irrigated fields since 2008, implying that fields further away from freshwater resources could no longer be cultivated. Selby (2019) mentions the same trend is observed for barley, which is more common to be grown in these areas as fodder for the livestock (Chatty, 2010). Looking at Figure 10 and Figure 15, this trend can also be observed in southern AHG.

I only found land abandonment in the lower part of southern Al-Hassakeh sub-district, which is why I have decided to closely look at this area using a timeline of Landsat images with a spatial resolution of 30 meters. I put focus on the area around Al-Shaddadi. The images time series confirms the general reduction in 'healthy cropland', which are characterised through the typical square and rectangle shapes.

5.3 Land Abandonment and Out-migration Analysis

Although I observed a decline in vegetation health and thereby agricultural yield in Ras-Al-Ain, I could not attribute this to the abandonment of land. There are several reasons why this could be the case. Firstly, Ras-Al-Ain is located in a different climatic zone than the Al-Hassakeh sub-district and generally richer in freshwater supply making it more suitable for rainfed cultivation. Secondly, as reported by Hole & Zaitchik (2006), the FAO found "an enormous fresh-water aquifer" in Ras-Al-Ain in the 60's, which allows the usage of wells in addition to the already abundant irrigation canals. Finally, the continuous growth of population in northern Al-Hassakeh on top of the official decree that prohibits permanent cultivation in the rangelands all suggest that due to an increased demand for land the abandonment is less likely in the northern sub-districts (Chatty, 2010; Wattenbach, 2006; El Laithy & Abu-Ismail, 2005). It could be hypothesized that in the case of Ras-Al-Ain no long-term out-migration has taken place throughout the study period.

In the case of the Al-Hassakeh sub-district, the situation is more complex. As stated previously, the Farming System of Al-Hassakeh is generally not suitable for cultivation of any of the strategic crops unless access to an irrigation source is ensured. The assessment of the FAO in the 60's reported a shallow rain-fed aquifer south of the Abd al-Aziz Mountain (Figure 15) in addition to a shallow gravel deposit which was temporarily a good source for irrigation from shallow wells. Additionally, the Lower Khabur River was supplied with freshwater from the Euphrates instead of the Khabur River itself since the dams in Marqada and Martyr Basel al-Assad (Hole & Zaitchik, 2006) had been closed in 2001. The pattern of fields observed from Landsat images throughout the years with scattered fields in the countryside confirm the usage of wells for irrigation (Hole & Zaitchik, 2006).

My results suggest further that a larger fraction of the 'abandoned' sample points (89/149) was classified as such before the drought in 2008. The areas of abandonment correspond to the Farming System Nr 6, which is more commonly used by tribal herders keeping livestock (Chatty, 2010; Dukhan, 2014). This land was strategically allocated to the tribes which were favoured by the government (Section 1.4). Despite the decree prohibiting the permanent cultivation due to a degradation of the land in the 90's, these tribes continued cultivation when conditions were suitable. I suggest that due to policy changes, the increasingly unfavourable soil and water conditions which I have mentioned already, permanent cultivation had to be reduced or completely halted already prior to the drought in 2008 resulting in long-term out-migration to land areas with more favourable conditions. Furthermore, keeping the idea of trapped populations in mind, generally these farmers would not have had the ability to migrate long distances (Section 2.1). This could be an explanation for why the extent of Single Crop does not decrease but rather shows the already discussed northward aerial shift of Single Crop in particularly southern Al-Hassakeh sub-district (Figure 12).

The above does not explain the sudden increase in abandonment in 2008 around Al-Shadaddi, south of the Khabur Dam (Figure 15), which automatically could be attributed to the drought. However, as Selby mentions if the excessive drought would have been the cause for additional out-migration, this would only become visible in 2009 (Selby, 2019). The Human Rights Council reported in 2011 that approximately 150 contracts were signed by the agricultural association of Al-Malikeyyeh, the far northeeastern sub-district, in 2007. Selected Arab families from the Al-Shadaddi region were granted a large area of fertile land in Al-Malikeyyeh sub-district (OHCHR, 2011) and were resettled. From Figure 9 and 15, it can be seen that in 2008 an increase in land abandonment was observed particularly in Al-Shadaddi, the southern part of Al-Hassakeh sub-district. It can be hypothesized that the resettlement of people living in southern Al-Hassakeh as a response to political decisions led to increasing long-term out-migration already in 2007, which only became visible in 2008.

In the end, however, it remains questionable whether the increase in observed land abandonment in 2008 was due to the severe drought, the removal of fuel subsidies or due to the specific resettlement of the mentioned 150 families (OHCHR, 2011). It is unlikely that the continuous ground water depletion and the degrading soil conditions, which I have discussed are the driving factors because the latter are continuous and abandonment has already occurred before the drought and continues to do so after. After her interviews, with Syrian migrants in Jordan, Fröhlich (2016) comes to a similar conclusion, pointing out that migration had already taken place before. Based on my results, long-term out-migration took place to a larger extent before the drought which is in agreement with the findings in literature (De Châtel, 2014; Selby, 2019). I suggest that the "additional out-migration" observed in 2008 is not a result from long-term climatic changes and the drought as argued by other scholars (Kelley et al., 2015; Gleick, 2014). Instead, I argue that the observed increase in abandonment in 2008 is predominantly a result of policy changes, the resettlement of people and to a less extent due to the drought.

5.4 Limitation

Land abandonment has widely been used as a proxy indicator for long-term out-migration (> 2 years) (Yin, et al., 2018; Goga, et al., 2019; Kraemer, et al., 2015). However, to my knowledge the method I used in this study has not been applied elsewhere. It is essential to keep in mind the different types of migration and displacement since my study period only covered 15 years and observed land abandonment does not necessarily confirm that migration or displacement actually occurred. As mentioned in the background sections 2.1 and 2.2, the poorest families often are unable to migrate due to a lack of resources. Seasonal migration is a common strategy to find casual employment in the agricultural sector elsewhere. This may result in one or two years, where the farmland was in-active and was classified as Bare Soil. This is why I decided to look at continuous land cover changes for more than 2 years and only focused on the assessment of long-term out-migration.

My results are promising and should be further elaborated on in a larger study. However, the spatial resolution of the RS products that I have used is too coarse to be applied on a farm-scale. Since land abandonment is defined as the *agricultural land that has not been used for two to five years*" (Yin et al., 2018) it would be more precise if the same methodology would be applied using higher resolution images that are able to differentiate between the individual agricultural fields. Underlaying the sample points with Landsat images from multiple years with a spatial resolution of 30 meters show a more detailed overview of land cover change. While it is undeniable that land abandonment has occurred in southern Al-Hassakeh, the assessed points were not always correctly classified. Regardless, given the time constraint, this method has shown to be successful as the obtained results align well with other studies (Hole J. , 2009; De Châtel, 2014; Selby, 2019). Unfortunately, the method I used cannot provide definite numbers of people who have migrated or been displaced over time.

Another factor for consideration when using this methodology is the initial stratified sampling approach and the selection of sample points. I selected the sample points based on the extent of cropland in 2001 when the cropland extent was largest. In general, I chose the LCDS dataset as reference because the verification method mentioned that was used by Eklund et al., (2017b) showed high accuracy. After the visual assessment of numerous sample points using Landsat images I found the dataset to be sufficient and appropriate for this study. Other alternative approaches to differentiate cropland from the remaining classes would have been to use threshold values for EVI, which has been done elsewhere (Jaafar & Ahmad, 2015).

Another limitation is the usage of the Mann-Kendall test on data of such a short time period, being cautiously aware of the big outlier (the year 2008). Regardless, this method has been applied as it has successfully been used elsewhere, including that year and also in the Fertile Crescent (Eklund et al., 2017b). Finally, I conducted the Mann-Kendall test on the mean EVI value of the spring season for each year (March-May) when winter crops are at the peak of their growing period (Figure 4). The study period was constrained to 2000-2015, meaning that the comparison is not done against a long-term average taking 2000 as the baseline. This means that if I had used a longer time series, I could have observed a different trend. However, as suggested by literature (Hole & Zaitchik, 2006; Sadiddin, 2009; Wattenbach, 2006), degradation of the land had already begun before 2000 meaning that the trend I observed in this study would not change. I also chose this study period as my interest lay in the identification of areas showing a relative decline or increase in vegetation health for the period of the current government, which has been ruled by Bashar Assad since 2000. I decided to use the Mann-Kendall test since it looks at the overall decline or increase in values and compares every year with the previous years. Of course, using this method, I am unable to directly infer that the found decrease in vegetation health can be attributed to one specific factor.

5.5 Future Research

The analysis I undertook in this study resulted in promising outputs. However, there are several immediate research steps which could be taken to further elaborate and confirm the findings.

Firstly, the Mann-Kendall test should be applied on the whole of AHG using the original EVI raster files. Secondly, the same analysis method should also be repeated on higher spatial resolution images, such as the Landsat series that is shown in Figure 9. The focus should be set upon southern Al-Hassakeh because based on my results particularly in the southern part, land abandonment was observed. it would be of interest to see whether the areas in close proximity to the sample points show a similar trend. The advantage of using Landsat would be that data are available going beyond 2000. The status of the vegetation seems to be directly bound to the agricultural policy decisions and this could be explored further undertaking such a historical analysis. The observed aerial shift in Single Crop towards the ephemeral waterbodies should also be further investigated in more detail in another study. Furthermore, it would be of interest to conduct a similar study applying the Mann-Kendall test on data that do not go beyond 2008. It would provide more details on whether the environmental changes have already caused significant degradation prior to the drought or not.

Finally, another study which could be of interest is the focus on summer crops like cotton and certain vegetable types to investigate the development of irrigation in AHG. With the reduction of freshwater resources and stricter regulations, the number of irrigated fields should have declined. One possibility would be to undertake the same analysis method on EVI images from the months July and August, which is when the summer crops are at the peak of extent.

6. Conclusion

After successful application of the Mann-Kendall Test on EVI images, I found that a decrease in vegetation health was predominantly observed in Ras-Al-Ain and Al-Hassakeh sub-districts. In Ras-Al-Ain, the sample points that showed the negative trend in vegetation health were located in close proximity to a waterbody. On the other hand, in Al-Hassakeh sub-district the majority of sample points were located in the southern part below the Khabur Dam further away from the Khabur and Euphrates Rivers. Based on my findings and my results I suggest that the observed decline in vegetation health can be attributed to a combination of factors varying from environmental changes and groundwater depletion, policy changes, unsustainable farming methods and population growth. Finally, I argue that the importance of the mentioned factors is likely to vary between the two sub-districts.

For AHG as a whole I found a gradual but continuous decrease in Multi Crop over the whole study period. Similar to the arguments for the observed decrease in vegetation health, I argue that the observed is due to a number of reasons. It may be likely that the removal of fuel and fertiliser subsidies have made summer irrigation unfeasible on top of the groundwater depletion. Although the area of Single Crop did not change as a whole, there was a spatial shift leaving southern Al-Hassekeh sub-district almost Single Crop free from 2008 onwards. Based on literature and my findings, the initial unsuitable soil conditions in the rangeland, the increasing lack of access to freshwater due to the constructions of dams on top of climatic changes led to unsuitable conditions for permanent cultivation and the observed northward shift in Single Crop.

The analysis of land abandonment that I carried out shows that only in Al-Hassakeh sub-district long-term out-migration could be observed but more frequently before the drought in 2008 and thereby also the war which only started in 2011. I argue that the combination of specific agricultural policy changes which were targeted towards the rangelands in the early 2000's as well as the decreasing access to freshwater and the already mentioned groundwater depletion have led to the observed long-term out-migration. Finally, the observed increase in land abandonment in 2008, I hypothesize that this may be due to the resettlement of the mentioned 150 Arab families, as well as the removal of fuel subsidies and to a lesser extent the drought.

For the future, I would recommend further studies using a similar approach but applied on higher resolution satellite images in AHG in order to assess the abandonment and transition of the land in more detail. This is of particular interest given that also most oil resources, as well as a majority of influential tribal communities are located in this governorate. The interconnectedness of all factors requires detailed research to untangle the Syrian conflict and get a better understanding of the human movement within the country and beyond the borders. As I showed in this study, RS and earth observation are useful to assess land cover changes and identify areas where possible out-migration has taken place using land abandonment as a proxy indicator. The actual reasons for land abandonment remain, however, unconfirmed and other methods as well as groundwork are necessary to support the findings of this study.

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8. Appendices

8.1 Development of Total Wheat in Al-Hassakeh Governorate

The three graphs below display the trend of the wheat distribution and gain over time.

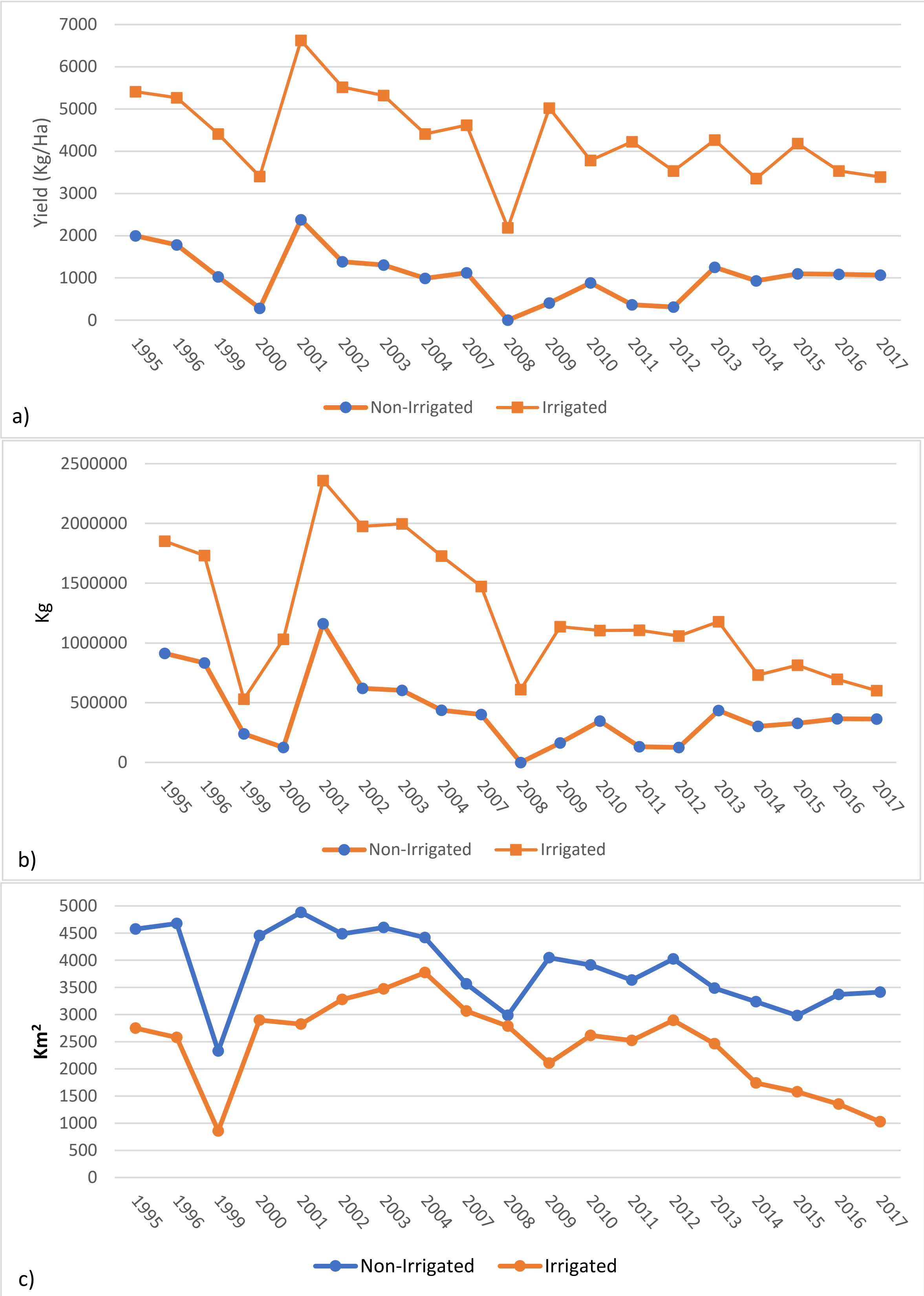

Figure 8.1.1: Statistics of Total Wheat Development: a) Yield (kg/ha) b) Production (kg) c) Area (km^2) (MOAAR, 2020)

8.2 Aerial Land Cover Development from 2000-2015

Classes	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Bare Soil	1191.08	72.27	551.58	228.86	351.37	453.66	305.27	187.52	2334	739.32	146.2	793.51	759.41	221.29	175.13	266.13
Single Crop	1133.97	2321.85	1814.49	2183.43	1975.92	1987.64	2190.18	2355.74	188.54	1840.33	2399.97	1746.56	1784.14	2373.13	2404.98	2335.44
Multi Crop	14.56	157.59	40.92	34.76	71.24	40.51	24.52	41.96	5.21	17.96	65.14	20.28	8.52	9.74	14.17	9.52
Other Vegetation	295.07	83.88	227.94	185.56	235.15	152.44	114.66	50.01	106.79	38.14	24.44	75.36	83.58	31.25	40.99	24.54

Al-Malikeyyeh

Classes	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Bare Soil	2796.60	207.18	1317.57	412.96	831.73	944.15	817.14	749.63	3543.13	2410.88	787.89	2503.38	1778.42	1071.9	658.05	1290.21
Single Crop	814.99	3479.10	2450.61	3402.96	2847.85	2848.81	3028.25	3114.88	286.1	1484.6	3088.37	1301.28	2028	2910.55	3329.8	2702.98
Multi Crop	5.39	220.34	18.49	49.03	97.54	50.64	29.87	76.45	5.96	24.7	109.33	25.12	11.92	5.31	6.52	3.11
Other Vegetation	409.57	120.00	239.94	161.86	249.48	182.97	151.2	85.61	191.42	106.45	41.03	196.82	208.27	38.8	32.24	30.31

Quamishli

Classes	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Bare Soil	2307.88	1344.50	1344.50	1678.66	1727.40	1784.00	1749.56	1708.88	2394.86	2107.56	1467.68	2109.15	1927.52	1716.32	2026.35	1676.45
Single Crop	792.67	1479.53	1479.53	1450.80	1115.87	1163.90	1273.22	1315.61	544.93	1014.85	1564.84	824.82	1269.47	1900.97	1529.91	1991.59
Multi Crop	66.36	835.10	835.10	453.20	573.00	351.67	500.54	618.43	97.56	434.68	711.01	462.41	171.94	109.16	79.63	85.13
Other Vegetation	644.97	152.75	152.75	229.21	395.60	512.30	288.47	168.82	774.51	254.79	68.35	415.69	442.94	85.41	175.98	58.7

Ras-Al-Ain

Classes	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Bare Soil	11866.67	8205.00	11013.58	9650.76	9871.62	10400.06	10612.63	10767.49	12174.53	11989.71	10624.33	11989.65	11732.17	11263.95	11200.10	11066.14
Single Crop	328.52	4046.21	1201.46	2579.82	2177.37	1704.26	1573.48	1427.45	199.23	399.40	1724.01	299.35	594.61	1273.23	1348.53	1508.06
Multi Crop	2.28	226.80	16.05	107.50	167.43	74.12	79.68	87.37	3.65	34.12	122.30	25.91	11.11	3.47	3.24	1.14
Other Vegetation	423.61	123.76	379.56	251.18	363.15	409.16	322.33	309.08	242.64	198.27	148.78	307.02	281.03	61.71	64.58	48.22

Al-Hassakeh

Table 8.3.1. Overview of the land cover class distribution over the study period in each sub-district

The table above shows the separate land cover change over time for each sub-district.

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