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Linking conflict events and cropland development in Afghanistan, 2001 to 2011, using MODIS land cover data and Uppsala Conflict Data Programme

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Masters thesis, 30 credits, in Geographical Information Sciences

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I. Abstract

This thesis describes changes in land cover between 2001 and 2011 in Afghanistan, and analyzes the influence of conflict events on cropland development. The main research questions are how fighting intensity affected cropland areas in Afghanistan within the study period, if the cropland areas decreased or increased, and if there were regional differences in cropland development. So far research has been done on the influence of conflict events on cropland development, but not for Afghanistan.

Yearly MODIS (Moderate Resolution Imaging Spectroradiometer) land cover data have been used in this thesis work to assess cropland changes. Cropland area has increased from 8,188 km² in 2001 to 13,304 km² in 2011. Regional patterns are that the area of cropland decreased in more mountainous regions, and increased in the plains north and south of the Hindu Kush, the mountain range dominating Afghanistan.

Two datasets on conflict events, the Uppsala Conflict Data Programme (UCDP) and the WikiLeaks Afghan War Diaries have been compared. The UCDP data seemed more fit to the analysis due to higher quality standards due to auditing of the data and a more precise definition of conflict events. The number of UCDP entries in a specific area has been used as a measure of conflict intensity.

In areas with higher conflict intensities, cropland area increased slower than in areas without conflict events. While cropland area increased by 85 % from 2001 to 2011 in conflict free regions, it only increased by 37 % in conflict regions. In areas with very high conflict intensities, there is still a 10 % increase in cropland area.

These results fit well into the current state of research: The Soviet invasion in the nineteen-eighties had long lasting negative impact on cropland area, leaving room for increases in cropland area. Research has shown negative effects of war on agricultural development, which fits the findings that higher conflict areas result in decelerated cropland growth. What remains unclear at this point is if there is a causal relationship between conflict intensities and reduced cropland growth, and how things would behave if another measure for conflict intensity was used instead of the number of conflict events. Regarding the overall positive cropland development in Afghanistan, the question arises what part of this growth is due to the influence of poppy cultivation/ heroin production, which would shift the assessment of the growth both from a moral and a food security standpoint.

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III. List of abbreviations

MODIS	- Moderate Resolution Imaging Spectroradiometer
MOD12Q1	- MODIS Land Cover Type product
NDVI	- Normalized Difference Vegetation Index
UCDP	- Uppsala Conflict Data Program
GED	- Georeferenced Event Dataset
UNAMA	- United Nations Assistance Mission in Afghanistan
OCHA	- United Nations Office for the Coordination of Humanitarian Affairs
IGBP	- International Geosphere-Biosphere Programme
ASTER	- Advanced Spaceborne Thermal Emission and Reflection Radiometer
GDEM	- Global digital elevation map
DSI	- MODIS drought severity index
JOC	- Joint Operational Command
GLS	- Global Land Survey

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1. Introduction

The impact of conflict events on land cover has been a research topic for quite some time. Modern GIS techniques enable researchers to do time-series analysis on large study areas, which was not possible before those techniques existed. While research has been done on the impact of warfare on land cover in Iraq (Eklund et al. 2016, Eklund et al. 2017, Gibson et al. 2015), and the Caucasus (Baumann et al. 2014), there is no research on land cover and especially cropland development in Afghanistan. After the 9/11 attacks in 2001, coalition forces invaded Afghanistan to topple the Taliban, who controlled large territories of the country. The coalition forces quickly succeeded with their goal, but ever since the number of conflict events in Afghanistan increased and there is no peace in sight.

1.1. Objectives and general approach

The general aim is to show the land cover composition of Afghanistan between 2001 and 2011, the cropland area development, and the influence of conflict events on cropland development. Is the change in land cover area significant, especially for cropland, and how is it influenced by conflict events? Intuitively, one would assume that a (civil) war lasting as long as the study period has a negative impact on cropland development, but we can see a strong increase in cropland area for Afghanistan between 2001 and 2011. How this compares to the number of events and how events impact this development will be examined in this thesis.

The development of cropland will be assessed by looking at the annual extents of cropland areas in Afghanistan for the timeframe, and also by comparing their spatial distribution. This will be done using MODIS land cover datasets (NASA LP DAAC 2014). The use of MODIS data for purposes such as the ones in this project has been shown by Eklund et al. (2016) and Gibson et al. (2015). The latter have further shown that it is not necessary to derive cropland-data from NDVI values like done by Eklund et al. (2017) for this kind of analysis. Instead they assessed the land cover classification accuracy of MODIS land cover Products, which were satisfying according to Gibson et al. (2015), who assessed the classification accuracy for their study area in Iraq, which is also a arid/semi-arid region, like the study area of this thesis. Eklund et al. (2017) addressed qualitative changes in cropland, which made an analysis of NDVI necessary, but this is not the goal here.

There are different datasets on military events, for example the Uppsala Conflict Data Program which has been employed for research by both Eklund et al. (2016) and Baumann and Kuemmerle (2016). In addition, an excerpt of the Joint Operational Command Logs, published by WikiLeaks will be used. This data involves a much higher number of events, and has also already been used for scientific studies (O'Loughlin 2010b), but it is not a data source that is redacted by researchers, which one has to keep in mind when working with the data.

1.2. Research Gap

The goal of the thesis is to understand the role of conflict events on cropland development in Afghanistan since the beginning of the international involvement in the war in 2001. The civil war in Afghanistan started in 1978 is still going on today (2018), spanning more than 40 years, and at the moment there is no end in sight (Ruttig 2017). A conflict continuing this long is bound to have impacts on almost any aspect of life in the affected country and beyond. We already know that armed conflicts impact land systems world wide, as shown by Baumann and Kuemmerle (2016). We also know that agricultural intensity and productivity decreased inside the land seized by the so called Islamic State,

while the overall cropland area slightly increased (Eklund et al. 2017). Such results are missing for Afghanistan as of now. This lack of a nation wide assessment of land-use (especially cropland) change in Afghanistan is the first research gap this thesis wants to address.
Baumann and Kuemmerle (2016) state that there are surprisingly few studies that empirically link armed conflict and land-system change. Out of the few studies that exist on the topic, most of them revolve about Iraq and states of the former Soviet Union (Baumann et al. 2014; Baumann and Kuemmerle 2016). So there is both a lack of nation-wide assessment of land-use change in Afghanistan, as well as a lack of studies empirically linking armed conflict events to land cover change overall. This thesis will directly contribute new scientific knowledge to the field by trying to address these two issues.

While most of the studies cited are concerning Iraq and other countries, and not Afghanistan, it is still possible to compare study aims: This study will build on the aims of Gibson et al. (2015), who described changes in land cover in Iraq without linking them to events, and Baumann and Kuemmerle (2016), who were able to show that there is a link between armed conflict and changes in cropland use, but did not specify how they are relating to each other, since their study had a worldwide study area and therefore was not able to address specific developments.

1.3. Research Questions

The research questions revolve about the question if and how agricultural development in Afghanistan is linked to war. Question 1 concentrates on the effects of different fighting intensities on agricultural development. Has cropland developed differently in regions with higher fighting intensities? Fighting intensity is determined by the number of events per area. The second question is focused more on the overall development of cropland areas in Afghanistan between 2001 and 2011. How did the area develop, and are there regional differences in cropland growth?

Research Question 1

How did fighting intensity (i.e., the frequency of violent incidents) affect cropland areas in Afghanistan between 2001 and 2011?

Research Question 2

How did cropland areas in Afghanistan develop during the military missions “Operation Enduring Freedom - Afghanistan” (OEF-A) and “International Security Assistance Force” (ISAF), both starting in October 2001? Did the area of cropland decrease or increase? Are there regional differences? The changes in cropland area will be described relative to the situation in 2001, since the military missions began in the fall/winter of 2001, after the end of the growing season in Afghanistan.

1.4. Study Area: Afghanistan

Afghanistan is a landlocked country in Southern Asia, positioned east of Iran and west and north of Pakistan, which can be seen in Figure 1. Its center is at 33°00 N, 65°00 E. Afghanistan has a total area of 652,230 km², which is about one and a half times the size of Sweden, or slightly smaller than Texas.

Figure 1: Locating Afghanistan on the globe and in Asia. Afghanistan is a landlocked country in South Asia and borders Iran, Turkmenistan, Uzbekistan, Tajikistan, China and Pakistan.

1.4.1. A brief history of Afghanistan

Afghanistan as we know it was founded in 1747, when Ahmad Shah Durrani achieved a unification of Pashtun tribes. The name Afghanistan - Land of the Afghans - originates from the persian word for Pashtun: Afghan. After being on the fringe of both the British and the Russian Empire, Afghanistan won independence from those Empires in 1919. In 1978 there was a communist coup in Afghanistan, and the Soviet Union invaded the country in 1979 to support the struggling communist government. Since this invasion began, Afghanistan has been in a constant state of civil war. The Soviet Union withdrew its troops in 1989, facing resistance of internationally supported mujahideen rebels. After the Soviet withdrawal, civil war raged on, and some of the former internationally supported mujahideens, along with returning refugees from Pakistan and others, formed the Taliban. In 1996 Kabul fell to the Taliban. They gained territorial control over large parts of the country. After the 9/11 attacks in 2001, an international coalition and the Afghan Northern Alliance toppled the Taliban. A UN-sponsored democratic government was established in 2004/05. In 2017, this government was in territorial control of about 63% of Afghanistan (SIGAR - Quarterly Report, 2017). The Taliban still consider themselves the rightful government of Afghanistan, and try to force the departure of foreign military forces and the abolition of the democratic government by waging a guerilla war. The events caused by this US lead invasion and the following Taliban insurgency will be the conflict events analyzed in this research project.

1.4.2. The geography of Afghanistan

Most of the terrain is rugged mountain areas, but there are plains in the North and Southwest. The Hindu Kush mountain range divides the country in a northern and a southern part. The highest point is the Noshak, which summit is roughly 7,500 m high. The mean elevation is above 1,800 m. Figure 2 visualizes the elevation of Afghanistan.

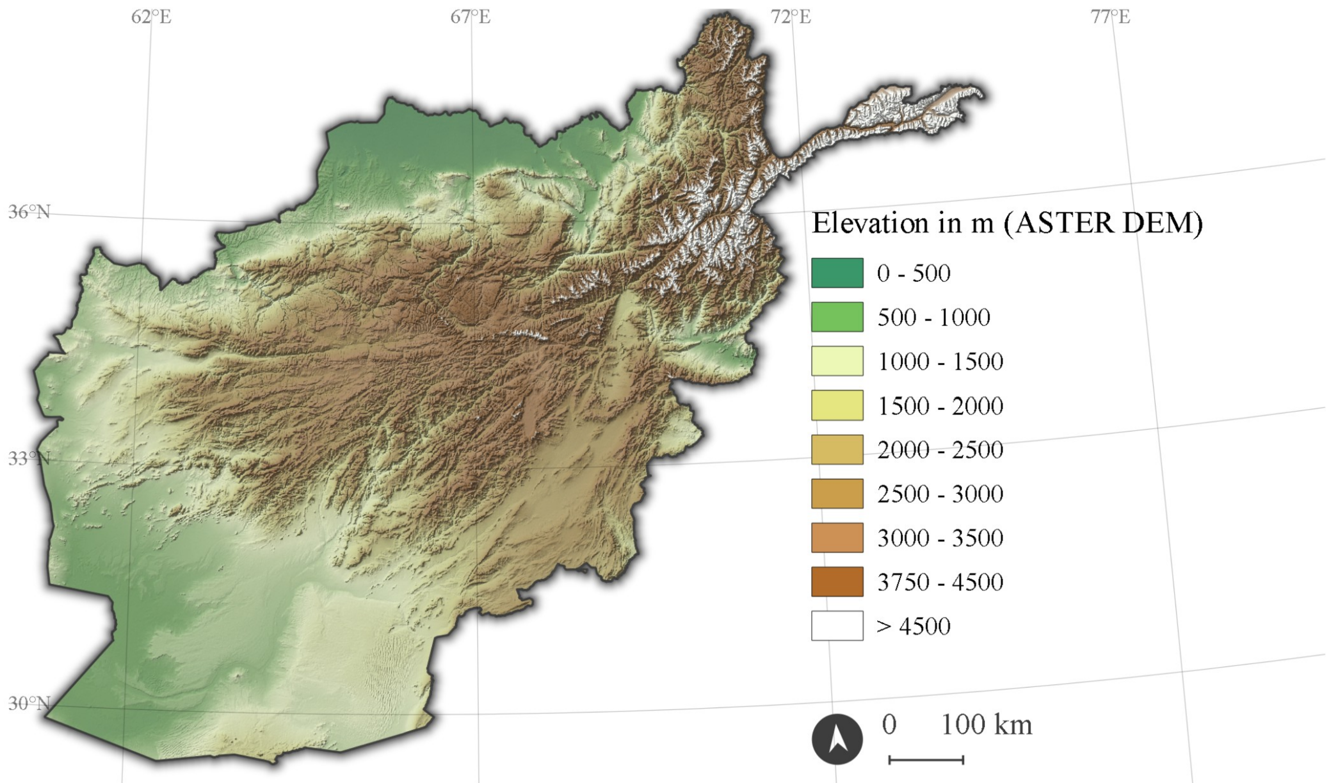


Figure 2: Visualization of the ASTER DEM for Afghanistan. The Hindu Kush mountain range dominates the country, the mean elevation is above 1800 m.

The climate in general is semi-arid and continental, the winters are cold and the summers are hot. Figure 3 shows the Köppen Climate Classification for Afghanistan. The Southwest is dominated by desert climates while the plains in the North are warm and semi-arid. The mountain ranges are humid continental in the center and hot summer Mediterranean at the fringes.

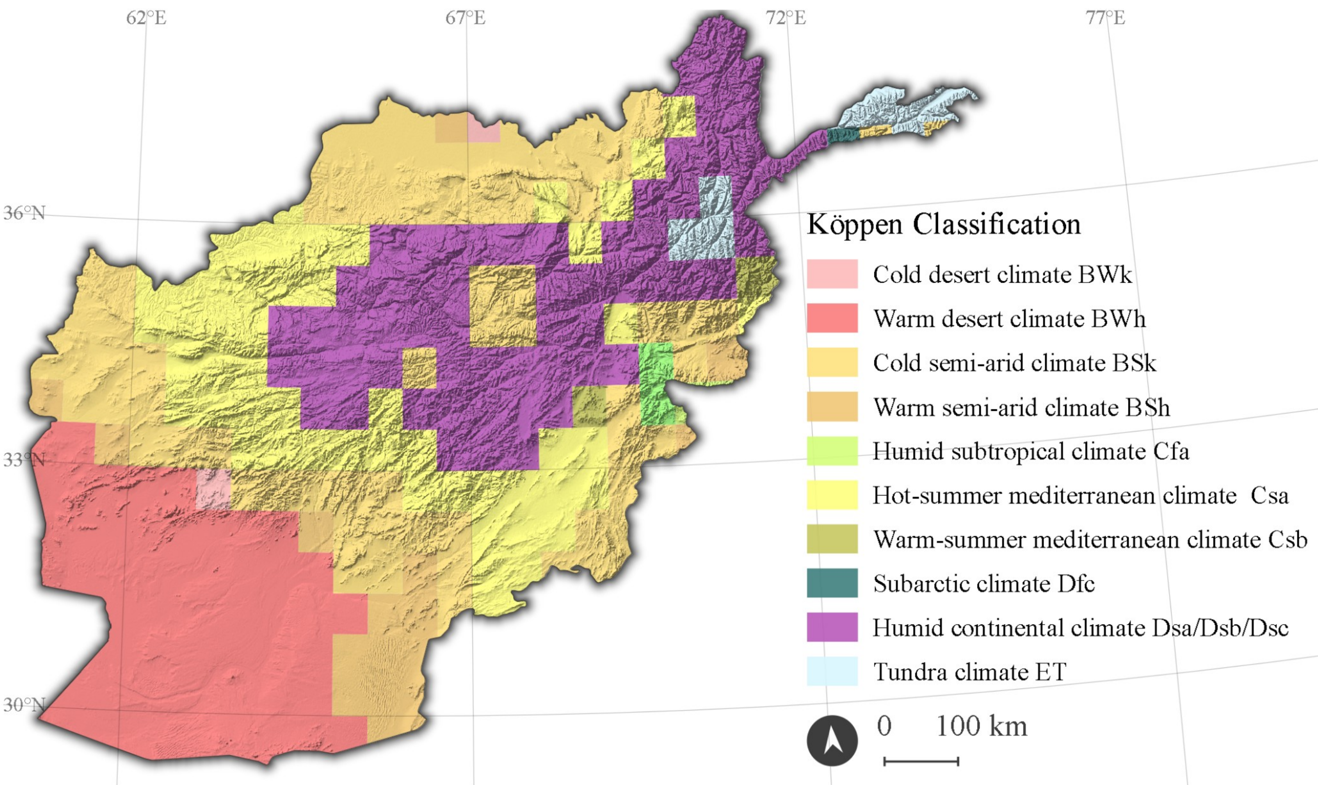


Figure 3: Köppen climate classification of Afghanistan. The southwest is classified mostly desert climate, the mountain ranges as humid continental climate.

The CIA Factbook (Central Intelligence Agency - World Factbook, 2017) describes the land use as 58,1 % agricultural, of which 11,9 % are arable land, 0,2 % are permanent crops and 46 % are permanent pasture in 2011. Since the focus of this thesis is on land cover in Afghanistan, these numbers have to be compared to the findings made here. However, the CIA Factbook uses the category agricultural land, which includes both cropland and pastures. Since pastures are a land use hard to detect using remote sensing, it is not possible to directly compare this percentage of agricultural land to the MODIS data. The MODIS data indicate that the land cover of Afghanistan in 2013 was mostly made up of barren land (39,9 %), Grasslands (36,37 %) and Open Shrublands (20,24 %). Cropland is the fourth most dominant land cover class, with about 1,7 % of the total area. If we compare this to the number on permanent crops in the CIA Factbook, it is about 10 times bigger. If we compare it to the number of arable land, it is about 10 times smaller. Other classes combined make up less than 3 % of the land area.

The population is an estimated 34,125,000 (Central Intelligence Agency - World Factbook, 2017). Most of the population lives in the foothills of the Hindu Kush mountains. Many of the valleys within the mountain range are also populated by smaller groups. The Southwest consists of mostly desert and is only sparsely populated. In Table 1 we can see population densities for different provinces. In the Southwest, Farah, Nimroz, Hilmand and Kandahar have very low population densities of 4-20 inhabitants per km². In the Kabul region, populations densities go up to 220 inhabitants/km² in Kapisa, and even 820 inhabitants/km² in Kabul, but this province is mostly made up of urban fabric. Overall, there is a lack of reliable data on population numbers and distributions because no central government was able to collect all data needed for over 40 years. There are population statistics provided by the government on a regional and district level for the years 2004 to 2013, but sadly none before 2004 or after 2013. These data are available online (Central Statistics Organisation - Islamic Republic of Afghanistan, 2017)

There is a variety of different ethnic groups, the largest being the Pashtun, Tajik, Hazara and Uzbek groups. Official languages are Afghan Persian and Pashto. Afghanistan is divided into 34 provinces and 399 districts, which are displayed in Figure 4. Apart from these administrative divisions, it is also divided into 8 regions, a division created by the United Nations Assistance Mission in Afghanistan (UNAMA). This remark is for clarification purposes, since the UNAMA regions are often referred to as administrative regions in Afghanistan and are widely used by military and humanitarian aid organizations.

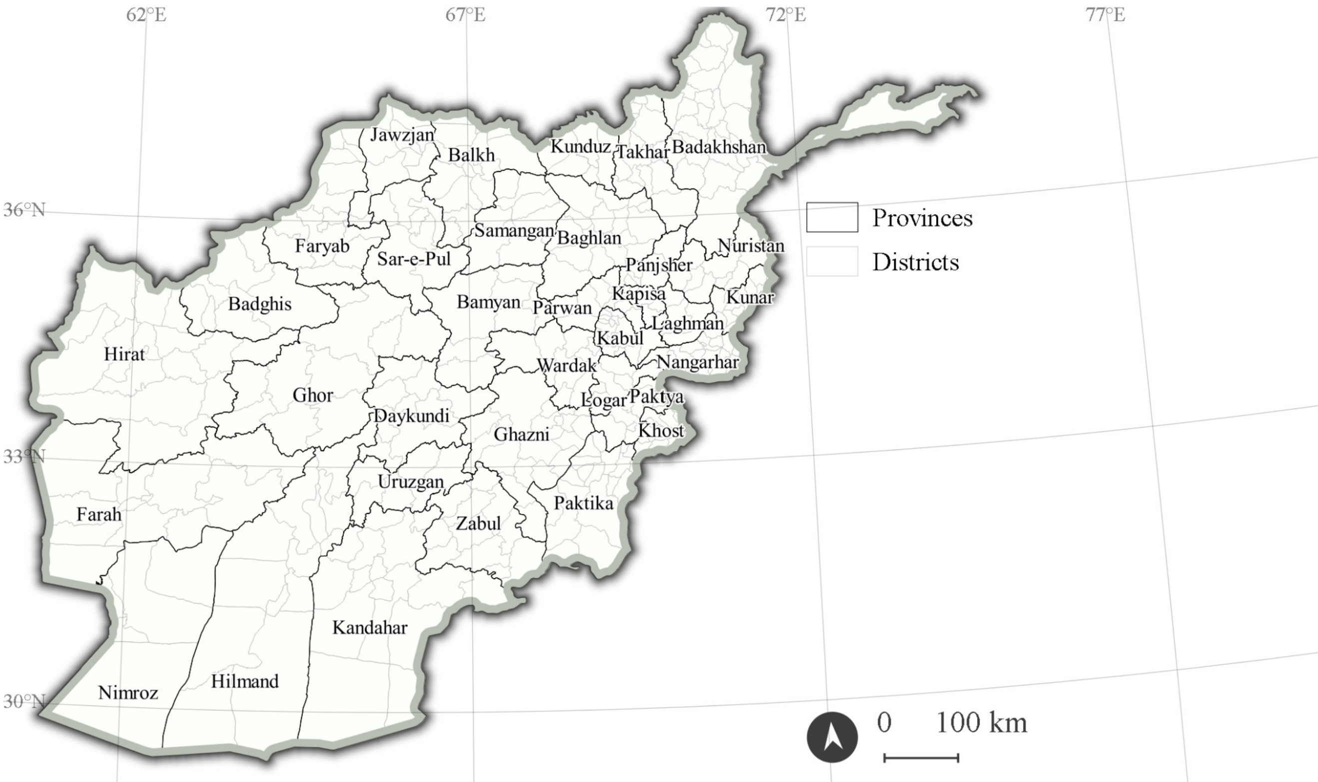


Figure 4: The administrative regions of Afghanistan. There are 34 provinces and 388 districts.

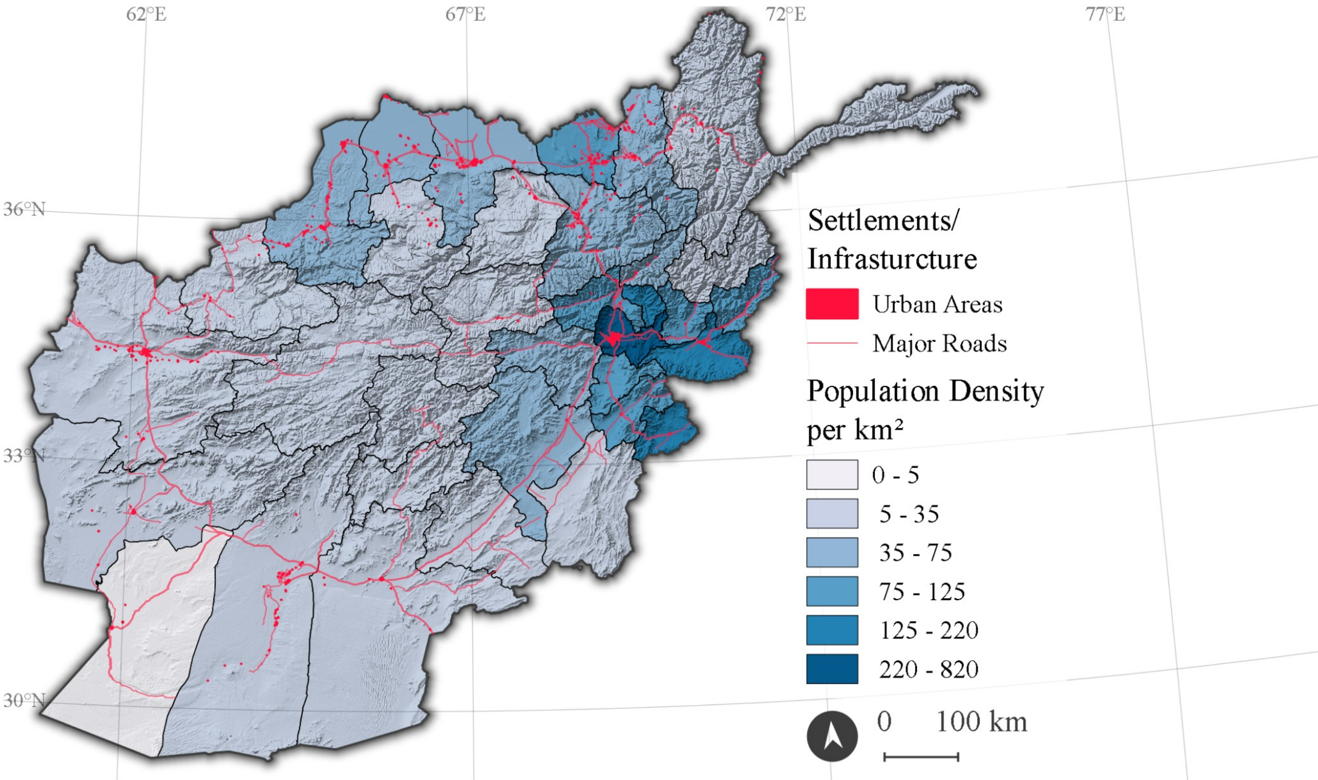


Figure 5: The population of Afghanistan. Most of the population is located in the East around Kabul.

Figure 5 represents the population distribution in 2011. Most people live around Kabul in the East and in the northern plains. The south and southwest are sparsely populated.

Table 01: The population per province in Afghanistan in 2011.

Province	Population 2011	Population/ km²
Badakhshan	889,700	20.47
Badghis	464,100	22.41
Baghlan	848,500	47.66
Balkh	1,219,200	72.7
Bamyan	418,500	23.39
Daykundi	431,300	27.33
Farah	474,300	9.56
Faryab	931,800	44.97
Ghazni	1,149,400	53.05
Ghor	646,300	17.41
Hilmand	864,600	14.41
Hirat	1,744,700	31.76
Jawzjan	503,100	45.24
Kabul	3,818,700	820.29
Kandahar	1,127,000	20.81
Kapisa	413,000	219.5
Khost	537,800	125.53

Province	Population 2011	Population/ km²
Kunar	421,700	86.98
Kunduz	935,600	118.38
Laghman	417,200	108.77
Logar	367,000	83.5
Nangarhar	1,409,600	190.56
Nimroz	153,900	3.75
Nuristan	138,600	15.42
Paktika	407,100	21.35
Paktya	516,300	97.88
Panjsher	143,700	38.53
Parwan	620,900	111.08
Samangan	362,500	28.07
Sar-e-Pul	522,900	34.25
Takhar	917,700	74.49
Uruzgan	328,000	30.2
Wardak	558,400	52.78
Zabul	284,600	16.4

2. Literature research

The following chapter sums up seven published papers and one book relevant for this thesis. Baumann and Kuemmerle (2016) point out that there are surprisingly few studies which empirically link armed conflict and land system change. This lack will be addressed for Afghanistan in this work. Most of the studies described below are concerning Iraq and other countries, not Afghanistan. Gibson et al. (2015) did an analysis of changes in land cover in Iraq using MODIS land cover data, which will be done in this thesis to answer parts of research question two: How did cropland develop in Afghanistan between 2001 and 2011? De Beurs and Henebry (2007) analyzed the land cover of Afghanistan between 1984 and 2005, and concluded that the destructive effects of the Soviet invasion had long lasting negative effects on agriculture in Afghanistan. This leads to the assumption that there will be few cropland areas in the beginning of the study period and potentially an increase over time. The most influential papers were:

- Baumann, M., and T. Kuemmerle. 2016. The impacts of warfare and armed conflict on land systems. Journal of Land Use Science 11:672-688.

This paper looks at land use changes in conflict areas on a worldwide scale. It is very influential for this thesis because it is the number one reference that justifies further research on the topic. Their use of the Georeferenced Event Dataset from the Uppsala Conflict Data Program (UCDP GED) demonstrates that it is an appropriate means for the research questions posed in this thesis. The methodology laid out by Baumann et al. suggests splitting up the target area on some kind of administrative level and summing up changes in land use and conflict events on a regional/municipal basis. It has a much broader focus than the thesis, which is one of the reasons why it is an important source to keep the greater research questions in the field of land use science in mind. Also Baumann et al. did a systematic literature review on case studies assessing land use changes in areas affected by armed conflict. Their meta-study on 38 research projects on this topic gives a good overview of the current state of research. They highlight a number of research needs in the field, most importantly a surprising lack of studies empirically linking armed conflict and land system change.

- Eklund, L., A. Persson, and P. Pilesjö. 2016. Cropland changes in times of conflict, reconstruction, and economic development in Iraqi Kurdistan. Ambio 45:78-88.

This study looks at the Duhok governorate in Iraqi Kurdistan. This region has been attacked by the Iraqi armed forces during the late 1980ies. These attacks are now known as Anfal. Eklund et al. did look at the pre-Anfal, the post-Anfal, the reconstruction and the present period. This is relevant for this thesis as a pre- and post-intervention situation is compared; the same will be done in Chapter 3.4.2 “Development of different land cover classes over time”. What differentiates this paper from the other papers in this overview is the fact that they also concentrate on a so called reconstruction period. This thesis research will try to link the coalition invasion in Afghanistan with changes in land cover, so this added aspect of reconstruction is very important. In the paper by Eklund et al., other conflict related factors on population have been provided to support the qualitative research on cropland changes. They use NDVI data in spring and right after harvest time to determine wheat and barley croplands. They used different sources of satellite imagery for this analysis. While this method is not relevant for this thesis, because a MODIS land cover product shall be used, the analysis on the changes in cropland

area are highly relevant for these studies. They state that some contextual knowledge of agriculture and political circumstances in the study area are necessary to interpret the NDVI values in a meaningful way, which indicates that working with MODIS land cover data might be preferable.
The results indicate that cropland areas had strongly decreased after the Anfal attacks and increased in the reconstruction period. However, the cropland areas did not fully recover until the present period. The spatial distribution of the cropland areas changed over time. Remote areas have been reduced the most after the attacks, while areas which had not been used in the pre-Anfal situation recently have been cultivated. To find out about similar patterns in Afghanistan is one of the goals of the thesis.

- Gibson, G. R., J. B. Campbell, and C. E. Zipper. 2015. Sociopolitical influences on cropland area change in Iraq, 2001-2012. Applied Geography 62:339-346.

The authors analyzed land use changes in Iraq between 2001 and 2012. The temporal extent of this research is very similar to the one planned in this thesis. They tested the suitability of the MODIS LCP data and deemed it suitable for their work, which gives an indication on the aptitude of this dataset for the thesis. They further evaluate the different classification models available for MODIS LCP data, and their work will certainly help choosing classification models/data sources for the thesis work. They explain their workflow in detail, which starts with polygonizing raster land use data, clipping them to political and natural boundaries and performing regression analysis with cropland areas within the clipped boundaries. Regression analysis was used because it is possible to incorporate additional explanatory factors and interactions like droughts. Also the relatively short time-series of about 12 years (with a temporal resolution of one year) is well depicted using regression analysis.

- Rashid, A. 2010. Taliban: The Power of Militant Islam in Afghanistan and Beyond, 2nd ed., I.B.Tauris.

This book is considered the standard reference concerning the rise of the Taliban in Afghanistan. The first edition of the book was published before the 9/11 attacks, when there was less international focus on Afghan politics, but is has been updated in 2010. The author, Ahmed Rashid, has been the Pakistan, Afghanistan and Central Asia Correspondent for the Daily Telegraph for more than 20 years. The book's contents are split into 3 parts: First the history of the Taliban movement is explained, including their origins, their struggle for power, and their crimes committed along the way. This chapter helps in the understanding of the fights that carried on after the invasion, since different regions of Afghanistan reacted differently on the rise of the Taliban, some regions fighting them until the invasion began. These regions of course experienced different conflicts during the invasion than the Taliban strongholds. This could also have an impact on potential differences between land cover changes.
The second part of the book concentrated on the relationship between the Taliban and Islam. It also sheds some light on the role of heroin production in Afghanistan for the Taliban economy, which might be relevant to the study of cropland development.
The third part focuses more on the geopolitical implications of the Taliban regime. Most relevant for this thesis work will be a chapter about the Taliban resurgents between 2000 and 2009. Even though this book is not a scientific source, it has proven a reliable source on the history of the Taliban and Afghanistan.

- Eklund, L., Pilesjö, P., and Brandt, M. 2017. How conflict affects land use: agricultural activity in areas seized by the Islamic State. Environmental Research Letters 12 (2017) 054004

This paper was published in April of 2017. It covers a very similar topic like this thesis covers, and it has been written by Lina Eklund, Martin Brandt and Petter Pilesjö, who supervises this thesis work. In this paper, Eklund et al. have a look at land use and especially agricultural development in areas seized by the so called Islamic State in Syria and Iraq. To do so, they analyzed a time series of NDVI with MODIS satellite imagery. The seasonal changes in NDVI helped them to determine cropland. After this classification, an accuracy assessment has been done and it has been decided that the classification was sufficient for the tasks. So the extent of cropland in Syria and Iraq for the period 2000 to 2015 has been mapped at an annual scale. After this major changes in land use in Iraq and Syria have been determined. Then they analyzed and discussed land use changes in the areas under influence by the so called Islamic State. They analyzed the cropland dynamics in relation to precipitation to normalize them and minimize the influence precipitation has on the results. They found that 34 % of Syria's cropland and 15 % of Iraq's total cropland have been inside IS controlled territory. The biggest change in cropland inside the IS territory was that 25 % of all cropland with two harvest periods have been changed to single cropped in 2015. There was an overall slight increase in cropland, but the intensity (single harvest vs double harvest) has been largely reduced.
This work can be compared to the thesis work, but there are some differences. The method Eklund et al. employed to determine cropland areas will not be used in this thesis. Their approach allows some qualitative statements about cropland development, while in this thesis MODIS land cover data is analyzed, with the goal of a quantitative analysis. Because they differentiated between single harvest and double harvest, Eklund et al. used a less coarse temporal resolution, while in this thesis yearly land cover data will be employed. Also Eklund et al. are not relating land cover changes to single events (points or small regions).

- De Beurs, K.M., Henebry, G.M., 2007. War, drought, and phenology: changes in the land surface phenology of Afghanistan since 1982.

For their research de Beurs and Henebry used AVHRR NDVI data as well as MODIS NDVI data to understand the development of the Afghan land surface between 1984 and 2005. They look at both war and drought trying to figure out how both conditions affect the land surface phenology. They then focus more closely on significant changes in the Kandahar region, and compare the phenology of 2001 (a drought year) with 2003 (a year with sufficient precipitation). They find that the destructive effects of the Soviet invasion destroyed the agricultural sector until this day, which was dependent on orchards (almonds, pistachios). They show that war has similar effects on agriculture as long-term drought events: De-vegetation and reduction in the spatial variation of the land surface phenology.
This paper is especially relevant for this thesis because of the study area and the methodology: While most papers on land cover change use linear regression models, they use the Fligner-Policello test. This decision is backed up by the fact that the data they used is non-normally distributed, has unequal period lengths and unequal variation between groups. In case this applies for the data used in this thesis, the methodology of this paper might give important hints on how to handle the data.
De Beurs et al. divide the temporal extent of their study into different steps (Soviet Involvement, Afghan Independence, Taliban Rule and US Involvement) and try to see different trends within these steps. To check the influence of droughts, the used Palmer Drought Severity Index.

- O’Loughlin, J., Witmer, F.D.W., Linke, A.M. and Thorwardson, N. 2010. Peering into the Fog of War: The Geography of the WikiLeaks Afghanistan War Logs, 2004–2009. Eurasian Geography and Economics, 2010, 51, No. 4, pp. 472–495.

While the Uppsala Conflict Data Program might be the most well known source for Geodata on conflict events, it might also be interesting to use the WikiLeaks Afghanistan War Logs. O’Loughlin et al. show all entries of the Joint Operation Command, most of them with a geo-coordinate. This paper should serve as a guideline on how to work with the WikiLeaks data. They look at the spatial distribution of conflict events, but also on the different categories of entries from the Joint Operational Command. They also compare the logs with media reports and identify cluster of violence in Afghanistan, which could help determine zones of special interest for this thesis .

- Buhaug, Halvard and Gates, Scott, 2002. The Geography of Civil War. Journal of Peace Research, 2002, vol. 39, no 4, pp. 417-433.

This study is trying to establish connections between geographical factors and the spatial distribution of civil wars and their influence on the course of events. The relevance for this work lies in the fact that they found no evidence that population was related to the geography of civil war. Population density, total population, and dispersion of the population all proved to be insignificant with respect to both scope and location.

3. Data, Methodology and Results

In this section the different data sources are listed and described. The methodology is structured according to different data types, in each section the processing of the respective data type needed to answer the research question will be explained. Before addressing the data types and the data processing, a short paragraph will present the spatial reference systems used.

3.1. Spatial Reference

Two different spatial references have been used in this thesis project:
Since the research focuses on changes in area development, all geodata has been reprojected to NSIDC EASE-Grid Global 2.0 (EPSG:6933). This projection was chosen because it is an equal area cylindrical projection and uses meters as base unit (Brodzik et al. 2012). It is well suited for displaying Afghanistan without too much distortion because the standard parallel is at 33° N, which runs through Afghanistan. All calculations and statistics have been done using NSIDC EASE-Grid Global 2.0.
For mapping purposes however, a custom spatial reference system has been created. The goal was to be consistent in visualising Afghanistan through all maps presented in this thesis. This custom spatial reference system is well suited for showing the location of Afghanistan on a globe as well as showing Afghanistan close up. This reference has been used for all maps presented in this thesis. The system is an azimuth orthographic projection centered on 35°N and 66°E. The definition is:
+proj=ortho +lat_0=35 +lon_0=66 +x_0=0 +y_0=0 +a=6371000 +b=6371000 +units=m +no_defs.
Proj stands for the projections name, in this case an orthographic projection. Lat_0 determines the latitude of origin, in this case 35°N, lon_0 is the longitude of origin, 66°E. x_0 and y_0 are False easting and false northing, which have not been used in this reference system. A and b are the radii of the ellipsoid axes, and units are set to meters.
The benefits of using this custom projection are visible when comparing Figures 1 and 2: We can see Afghanistan at three different scales and three different map extents, all using the same spatial reference system.

3.2. Data sources

3.2.1. Administrative Regions

Administrative Regions Levels 0 (Country), 1 (Province), 2 (District) and UNAMA regions (which are not official but used by the UN and NATO) have been downloaded as vector polygons from the Humanitarian Data Exchange (The Humanitarian Data Exchange, 2012). The original source for the dataset is the United Nations Office for the Coordination of Humanitarian Affairs (OCHA). These datasets will be used to aggregate, for mapping purposes, and to join them with statistical information like population time series.

3.2.2. Land Cover Data

MODIS MCD12Q1 v051 has been downloaded for all years available (2001 - 2011) for all tiles overlapping with Afghanistan in hdf4 file format at the NASA Earthdata Portal (https://earthdata.nasa.gov/). They have been merged and converted to geotiff with HEG Tools (NASA LP DAAC 2014), and then reprojected to NSIDC EASE-Grid Global 2.0 (EPSG:6933). The dataset has been established and described in Friedl et al. (2010). The International Geosphere-Biosphere Programme (IGBP) classification will be used for the calculations. It divides the land cover into 17 categories (Loveland and Belward 1997). The classification scheme is presented in Appendix Table 1.

3.2.3. Elevation Data

273 ASTER GDEM tiles with a ground resolution of 30 m have been downloaded, merged and reprojected for the study area. This dataset will be used for mapping purposes and for determining mountainous areas. These data are distributed by the Land Processes Distributed Active Archive Center (LP DAAC), located at the U.S. Geological Survey (USGS) Center for Earth Resources Observation and Science (EROS).

3.2.4. Drought Severity Index

The MODIS drought severity index is a global drought severity index (DSI), which is based on MODIS (Moderate Resolution Imaging Spectroradiometer) satellite measurements. It is covering a continuous period of 12 years, from 2000 to 2011, with a yearly temporal resolution. Both the timespan and the fact that this dataset is created using data from the same satellite as the land cover data make it a good fit for the thesis.
Drought severity might be useful because some variability in cropland can presumably be attributed to drought/precipitation. Not regarding this could lead to false conclusions on the correlation of conflict events and land cover change. According to Zhang (2014, p.2), the MODIS DSI has been developed using evapotranspiration/potential evapotranspiration and NDVI data. It monitors global terrestrial droughts between 2001 and 2011. According to Mu et al. (2013), major droughts that occured within the time period have been detected using this dataset.

3.2.5. Conflict Data

There are two main conflict datasets that will be used in this thesis. The Uppsala Conflict Data Program (UCDP) Georeferenced Event Dataset (GED) and the Joint Operational Command Logs published on WikiLeaks under the name Afghan War Diaries. Both datasets contain georeferenced conflict events as points with a timestamp. The UCDP GED is redacted by scientists and widely used in the scientific community (Baumann and Kuemmerle 2016, Sundberg and Melander 2013) and has mainly been used for analysis in this thesis. Some testing and visualisation has however be done both with the UCDP and the WikiLeaks data to see how they compare.
For the UCDP GED data the Global Version 17.6 is used, which can be downloaded as ESRI shapefiles at http://ucdp.uu.se/. This shapefile contains point data, one point per conflict event. Every point has a date, the factions involved and a casualty count as attribute data. These points have been split up into different datasets by year, and have been aggregated at different administrative levels and in rasters with different resolutions. This dataset dates back well beyond the scope of this research. A selection of events placed in Afghanistan resulted in 22.726 events, 13.967 of which within the years of 2001 to 2011. Events are defined by at least one casualty.
Wikileaks Joint Operational Command Logs: This dataset has been leaked from the US Military. It includes the log of the joint operational command for Afghanistan and Iraq. Since most of the log entries include a coordinate, this dataset can draw a 'map' of the war. There are different classes of events which appear in the log. This dataset covers the time from 2004 to 2009. There are roughly

77.000 points for Afghanistan within this period, not all of them are necessarily conflict events, but all of them indicate military activity. This dataset will be referred to as 'WikiLeaks data' further on. In 3.3.1 the WikiLeaks data will be compared with the UCDP GED. The number of relevant features in the WikiLeaks data is 3-4 times higher than in the UCDP GED.

3.2.6. Population Data

The Afghan Central Statistics Organization provides a population time series (Central Statistics Organisation - Islamic Republic of Afghanistan, 2017). They published one excel file per year including the population of the provinces and the districts, split up in male, female as well as urban and rural. After cleaning up and unifying the data it was possible to join them with the Administrative Borders Level 1, Provinces. The data are available for the years 2004 to 2013. As this thesis is looking at developments from 2001 to 2011, and there are no data available from 2001 to 2004, population data will not be used for the analysis. They will however be used to show the general population distribution, as can be seen on Figure 5. Different publications (O'Loughlin et al. (2010a); De Beurs and Henebry (2007); Buhaug and Gates (2002)) indicate that it is justifiable not to use population data for the analysis. The main reason for this being the absence of reliable local area or even regional data.

3.2.7. Temporal Coverage

Due to the fact, that the different datasets were available for different temporal coverages, Table 2 gives and overview.

Table 2: Used Datasets and their temporal coverage

MODIS MCD12Q1 v051, Land Cover data	2001-2011
MODIS DSI, Drought Severity Index	2001-2011
UCDP GED, Conflict Data	1989-2016
WikiLeaks Afghan War Diaries, Conflict Data	2004-2009
Population Data, Afghan Central Statistics Organization	2004-2013

3.3. Analysis of conflict events

The first step in working with the event datasets was to split them up annually to enable a comparison of the number of events over time. A correlation analysis for the number of events per year shows that the datasets are highly correlated for the timespan in which both are present, this can be seen in Figure 6 and Table 3. The spatial and annual distribution for conflict events in the Uppsala Conflict Data Programme Georeferenced Event Dataset is shown in a series of maps in Figure 9. Furthermore Figures 7 and 8 show the annual event numbers, which indicates how the conflict developed over time. The conflict datasets are aggregated in rasters to enable analysis of cropland development within conflict areas.

3.3.1. Comparing the UCDP and WikiLeaks datasets

While the UCDP GED relies mostly on press releases and official statistics, the Afghan War Diaries dataset is created using the Joint Operational Command Logs of the US-led coalition forces in Afghanistan. The number of entries is about 10 to 20 times higher than in the UCDP GED, since every form of action is recorded, including actions without casualties. The annual number of events in each dataset has been printed as a scatter plot in Figure 6. This plot suggests a relatively strong linear relationship between the number of events in the two datasets. and testing the annual number of events of both datasets for Pearson's Correlation, it can be shown that the two datasets are highly correlated for the timespan in which both are present, with a Pearson's r of 0.96. N equals the number of years in which both datasets are present, in this case 2004-2009, so n=6.

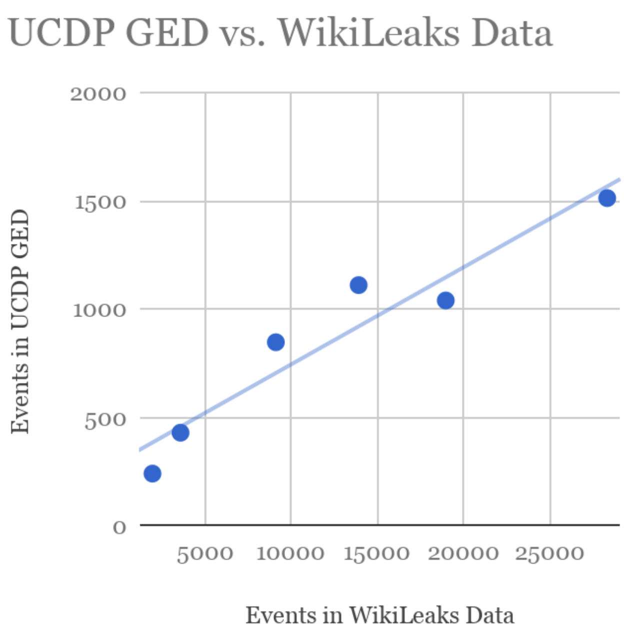


Figure 6: A scatterplot showing the annual event numbers of UCDP GED and the WikiLeaks dataset.

3.3.2. Spatial and temporal distribution of conflict events

To be able to assess the impact of conflict events on land cover, it is crucial to understand how the number of yearly events and the distribution of conflict events change over time within the study area. The yearly number of conflict events for both conflict datasets can be seen in Figures 7 and 8.

In 2001 the invasion of coalition forces in Afghanistan started. In this year 263 conflict events occurred according to the UCDP GED, whereas in the next year there have only been 94 events. Looking further ahead, it becomes visible that the years 2002 to 2004 had the least number of conflict events in the timespan between 1989 and 2016. This fits to the narrative that the initial invasion was successful in toppling the Taliban and bringing relative peace to the region. The amount of conflict events in the following years increased, until in 2005 a higher count than in the initial invasion year has been reached. From 2004 onwards, there has been a strong increase, which reaches its peak in 2011 with 2198 events (UCDP GED), the last year of the timeframe. So within 10 years of the initial invasion, the event count increased 10-fold compared to the first years of international involvement.

Looking at the WikiLeaks data, we can see 1958 events in 2001, while in 2009 the number rose to about 28,400. This dataset contains events without casualties and is not scientifically redacted, which explains the very high event count

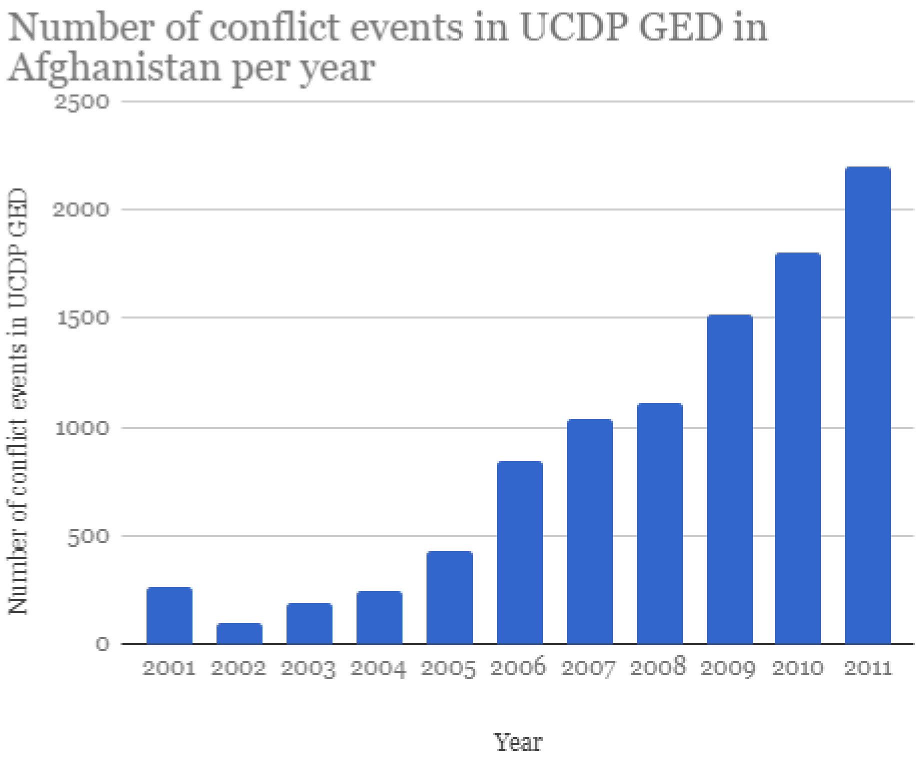


Figure 7: The yearly number of conflict events in the UCDP GED between 2001 and 2011 for Afghanistan.

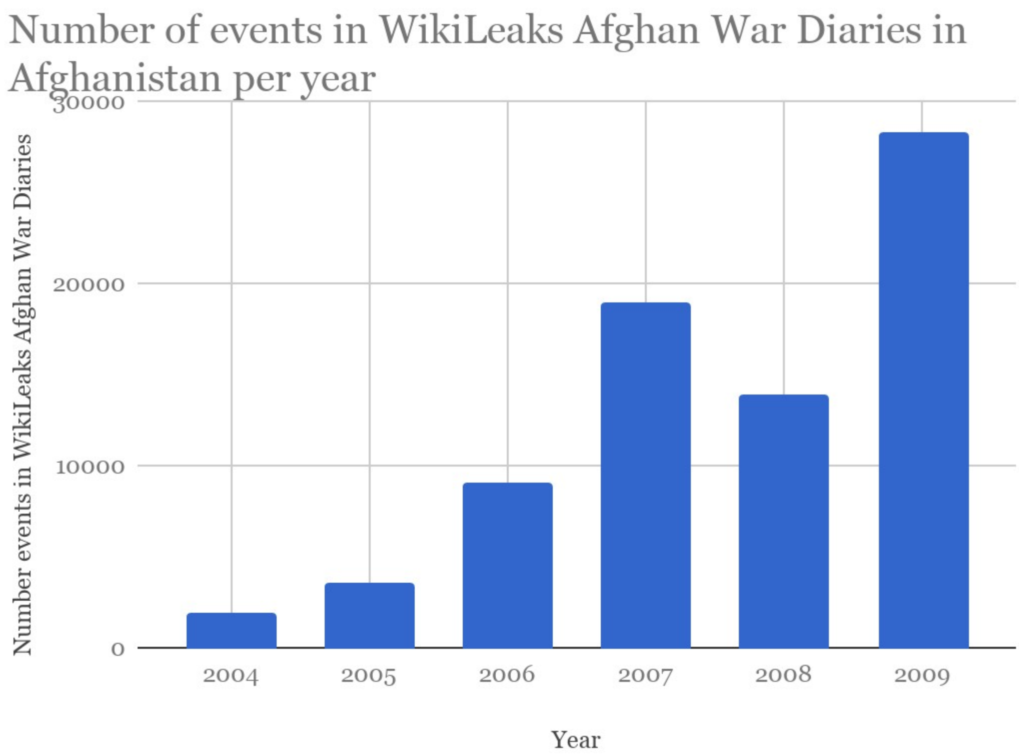
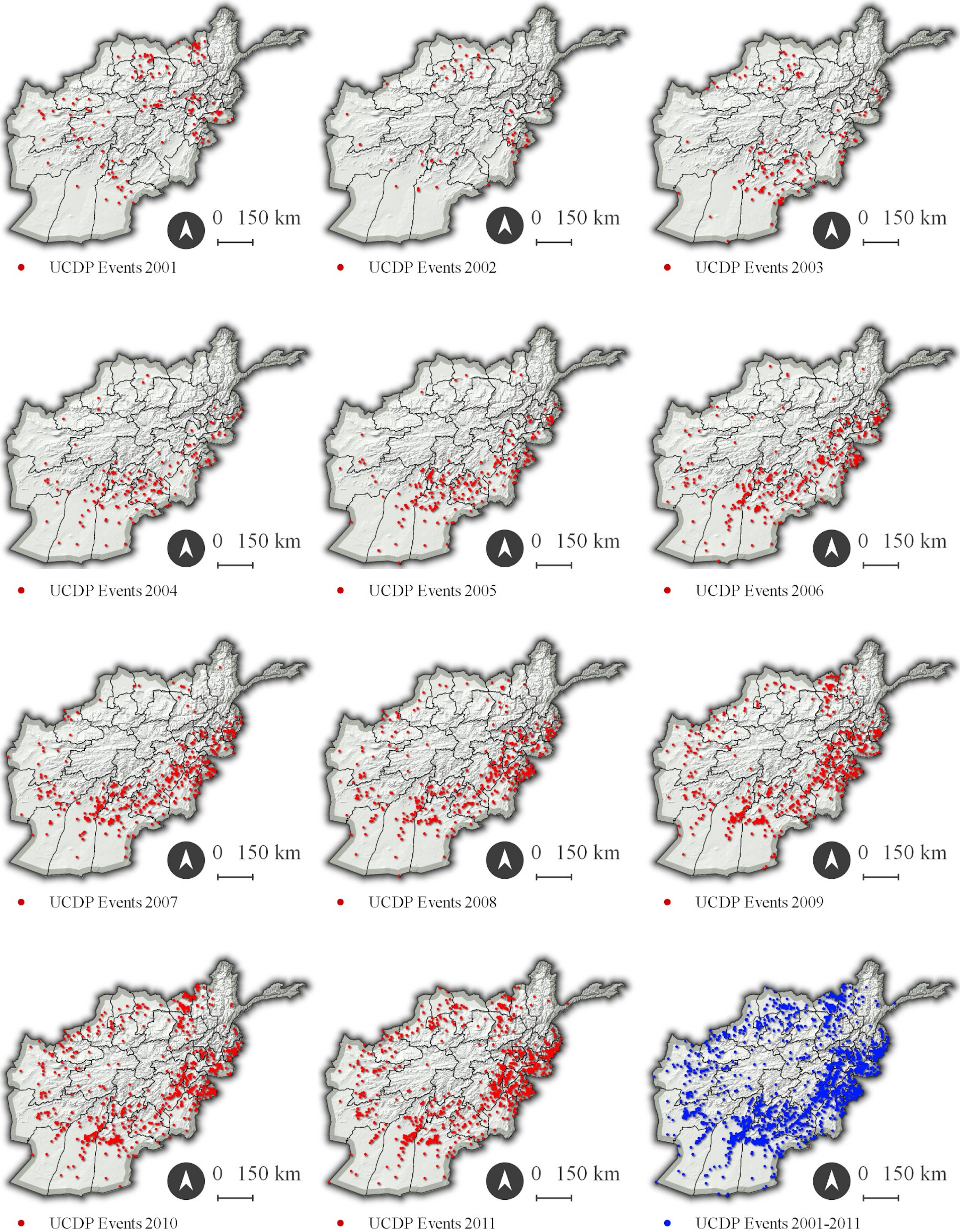


Figure 8: The yearly number of conflict events in the WikiLeaks data between 2004 and 2009.

Figure 9 illustrates the spatial distribution of conflict events per year. While in 2001 the conflict events have been evenly distributed over the (populated) country, in the following years the North is rather calm. An increase in conflict activity in the South happens from 2004 to 2006, especially in the southeast region around Kabul. From 2007 to 2011, conflicts emerge in the North again, until reaching the highest level in 2011, surpassing the activity of the initial year of invasion and are distributed over the whole country. The central highlands and the southern desert show very few conflict events, most likely due to accessibility and very sparse population (see Figure 5 for an approximate population distribution).


0 150 km
UCDP Events 2001
UCDP Events 2002
UCDP Events 2003
UCDP Events 2004
UCDP Events 2005
UCDP Events 2006
UCDP Events 2007
UCDP Events 2008
UCDP Events 2009
UCDP Events 2010
UCDP Events 2011
UCDP Events 2001-2011

Previous Page: Figure 9: Yearly maps of the UCDP events in Afghanistan 2001-2011. The last map (bottom right) shows the sum for all years.

3.3.3. Converting points to raster

To assess the impact of conflict events on cropland development, zones of different conflict intensities have been compared in their cropland development. Does cropland behave differently over time when looking at these different conflict classes? To be able to answer this question, the conflict events have to be translated from points to some kind of area, and the resulting areas have to be classified into different conflict intensities.

O'Loughlin et al. (2010a) have shown that aggregating the number of conflict events in raster cells is a suitable way to estimate fighting intensity. Using both the UCDP and the WikiLeaks conflict events data, rasters have been generated containing the number of conflict events per cell. The process of creating a raster turns a point into an area, so the question arises which resolution would be suitable, because the resolution directly translates into an area affected by one point (in this case conflict event). While O'Loughlin et al. (2010a) aggregated conflict events on a grid with a resolution of 20 km, they only used this grid for visualization purposes. It is to be expected that the effects of conflict events on land cover happen at a smaller scale than 20 km grids. Several rasters have been created to assess the suitability of different resolutions: The finest resolution chosen was the resolution of the MODIS data, which is 413 m (in this case an equal area projection is used, resulting in this exact resolution, varying from the 500 m generally assumed as spatial resolution of MODIS data). For aggregation of conflict events coarser resolutions were created using multiples of the land cover resolution to ease geodata processing. The aggregations tested are: 826 m (2 land cover grid cells), 1652 m (4 land cover grid cells) and 4129 m (10 land cover grid cells). After comparing how these different resolution compare and what the sample sizes for different conflict intensities are, one of the resolutions is chosen for further testing. This selection will be explained in 3.3.4..

Figure 10 illustrates the percentage of land with at least 1 conflict event per year at different resolutions.. The coarsest resolution of 4129 m has about 2 % conflict cells in 2011, while the finer resolutions range from 0.02 to 0.3. The different aggregation resolutions result in different percentages. As expected, when the grid gets coarser, the aggregation effects result in larger areas, because an event affects a larger grid cell. We can see that while overall the percentage of cells with conflict cells increases, there is no increase between 2007 and 2008 at the 4129.24 m resolution, and a dent in the smaller resolutions. Looking at the total number of events in the GED dataset, there has still been an increase between 2007 and 2008. This suggests that a spatial concentration must have happened in those years with the affected cells decreasing and the number of events slightly increasing. At this point, it becomes evident that the number of conflict events sharply increased since 2002.

Figure 12 visualizes the number of cells with at least one conflict event over time The data source of the conflict events in this case is UCDP GED. Figure 11 visualizes the same with WikiLeaks data as data source. Since the cells overlap the administrative border of Afghanistan, the total area of the rasters is slightly larger than the actual area of Afghanistan, and the sizes vary slightly at different resolutions.

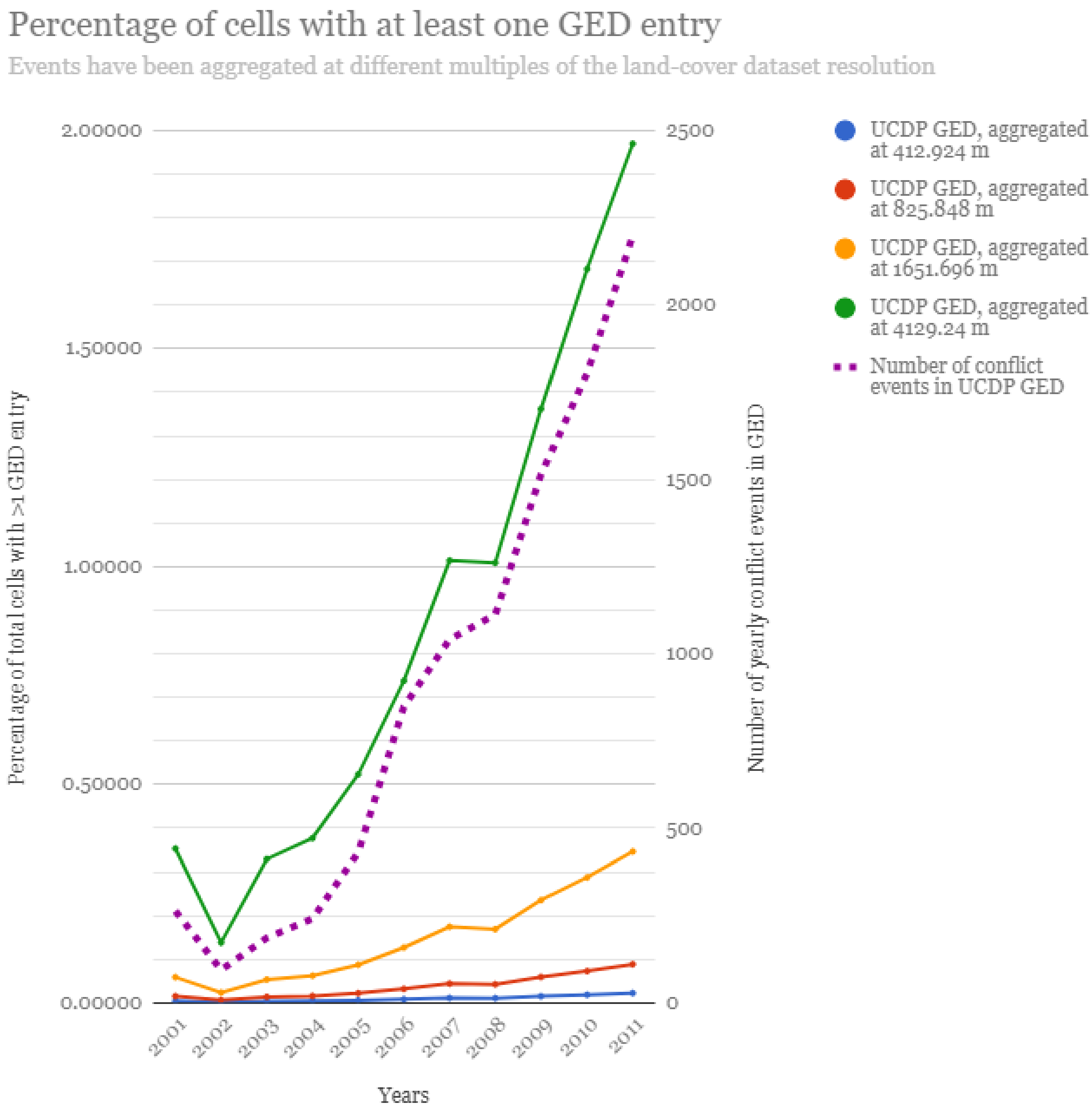


Figure 10: A comparison between the number of conflict events in UCDP GED and the percentage of cells containing at least one conflict event.

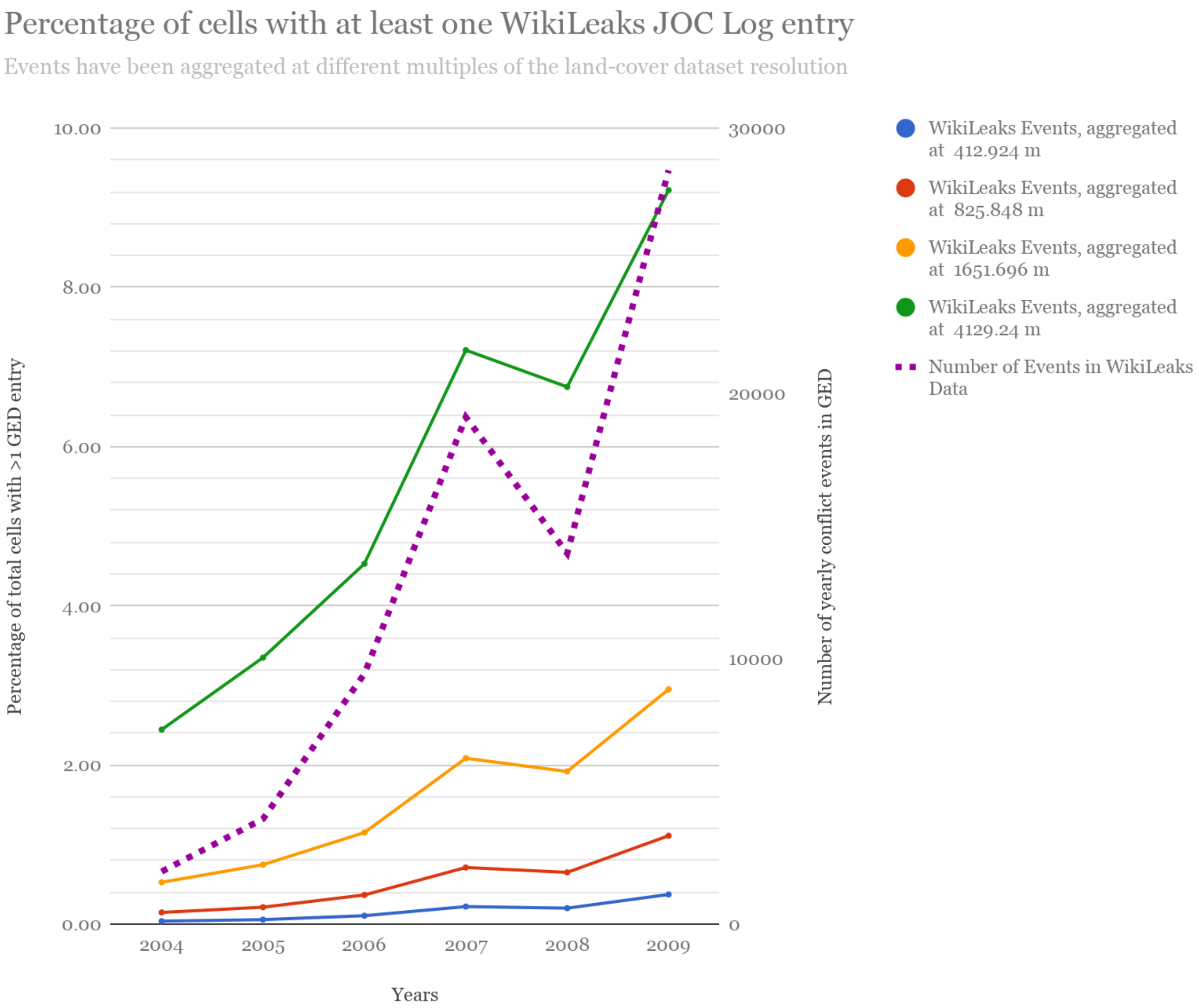


Figure 11: A comparison between the number of conflict events in the WikiLeaks data and the percentage of cells containing at least one conflict event.

3.3.4. Determining conflict event resolution and conflict intensities

In the following chapters, the UCDP GED was mainly used, as it is available for the complete study period. If the WikiLeaks data are used additionally, it will always be mentioned separately.
Looking at the raster containing all cells affected by GED conflict events between 2001 and 2011, we can see that using the finest resolution (412.924 m), 0.094 % of all cells contain at least one conflict event. Using the coarsest resolution (4129.24 m), equal to 100 MODIS land cover cells, 6,94 % of all cells contain at least one conflict event. Tables 4, 5 and 6 show, among other information explained below, the different percentages at different resolutions. Looking at the 0.094 % to 6.94 % of cells which are classified as conflict cells, there are qualitative differences, which can be seen in Table 05: with the coarsest resolution tested, 53.8 % of all conflict cells contain only one conflict event in the study period while with the finest resolution tested, 63.2 % of all conflict cells do. The the coarsest resolution shows the most aggregation and highest event counts per cell.

The measure used for conflict intensity is conflict events per cell, where all conflict events over the study period are added up. Several classes of conflict intensities have been created to be able to compare cropland development at different intensities. The first class contains conflict free cells. At coarsest resolution, 4129.24 m, these make up about 93.05 % of all cells, at finest resolution 99.9 %. The second class contains cells with at least 1 conflict event. These account for 6.94 % at coarsest, and 0.094 % at finest resolution. The third class contains cells with more than 5 events per cell, accounting for 1.9% at coarsest resolution, 0.02 % at finest respectively . From then on, the classes go up in steps of 5 percents per cell until reaching more than 50 events per cell. Using 4219 m resolution, only 0.2 % of all cells contain more than 50 events. This translates to between 83 (4129 m resolution) to 78 (413 m resolution) cells with intensities that high. Table 6 shows the sample area of different conflict intensities at different resolutions. Since the goal should be to show if different conflict intensities have different impacts on cropland area development, it is important to have a sample size for high conflict events which is still big enough to see trends. Using the finest resolution, the sample area of the highest conflict intensity class would be merely 1.3 km². With the other resolutions the sample area for this class would be 5.3, 21.3 and 141.5 km².

A factor to take into consideration when choosing which resolution is appropriate is the size of an agricultural unit. 413 by 413 m is a relatively small area, while 4.12 by 4.12 km seems a more appropriate size. Since it is to be expected that fighting affects a whole agricultural unit, and not just some small portion of it, choosing a resolution that is more coarse may be better suited to study the effects of fighting on agriculture.

Given these reasons, the analysis will be done with the coarsest resolution of 4129.24 m. The sample area for this resolution will from now on be referred to as conflict areas.

Table 3: Percentage of cells with different conflict classes (conflict events per cell).

UCDP	413 m resolution	826 m resolution	1652 m resolution	4129 m resolution
Conflict Classes	% of cells	% of cells	% of cells	% of cells
0	99.9062	99.6291	98.5894	93.0583
> 1	0.0938	0.3709	1.4106	6.9417
> 5	0.0167	0.0671	0.2804	1.9060
> 10	0.0089	0.0355	0.1436	0.9822
> 15	0.0064	0.0257	0.1037	0.6955
> 20	0.0050	0.0202	0.0807	0.5283
> 25	0.0041	0.0165	0.0663	0.4327
> 30	0.0033	0.0133	0.0531	0.3637
> 35	0.0029	0.0116	0.0463	0.3079
> 40	0.0027	0.0108	0.0433	0.2734
> 45	0.0025	0.0099	0.0399	0.2522
> 50	0.0021	0.0083	0.0331	0.2203

Table 4: Percentage of conflict cells with different conflict classes.

	413 m resolution	826 m resolution	1652 m resolution	4129 m resolution
Conflict Classes	% of conflict cells	% of conflict cells	% of conflict cells	% of conflict cells
> 1	63.21	62.89	61.30	53.80
> 5	11.26	11.39	12.19	14.77
> 10	5.98	6.02	6.24	7.61
> 15	4.32	4.36	4.51	5.39
> 20	3.38	3.42	3.51	4.09
> 25	2.78	2.79	2.88	3.35
> 30	2.24	2.25	2.31	2.82
> 35	1.95	1.96	2.01	2.39
> 40	1.83	1.84	1.88	2.12
> 45	1.67	1.68	1.74	1.95
> 50	1.40	1.41	1.44	1.71

Table 5: Area covered by cells with different minimum event counts. With 413 m resolutions, only 1.3 km² are covered, with 4129 m resolution 140 km² are covered.

UCDP	413 m resolution	826 m resolution	1652 m resolution	4129 m resolution
Conflict Classes	Sample Area (ha)	Sample Area (ha)	Sample Area (ha)	Sample Area (ha)
0	64137043.67	63961592.76	63301460.84	59772663.91
> 1	60188.70	238094.90	905729.09	4458737.91
> 5	10724.84	43103.97	180054.58	1224234.73
> 10	5694.91	22779.63	92209.77	630873.05
> 15	4109.20	16505.00	66565.63	446726.32
> 20	3222.57	12958.47	51833.89	339307.40
> 25	2642.85	10571.39	42558.35	277925.15
> 30	2131.33	8525.31	34101.25	233593.53
> 35	1858.52	7434.07	29736.29	197787.23
> 40	1739.16	6956.65	27826.62	175621.42
> 45	1585.71	6342.83	25644.14	161980.92
> 50	1329.95	5319.79	21279.18	141520.17

The maps in Figure 12 give an impression of the spatial distribution of conflict events in Afghanistan, and how different conflict intensity classes compare. The maps have been created using a raster resolution of 4129 m. The maps show the total number of conflict events for all years. An annual breakdown of conflict events can be seen in Figure 9.

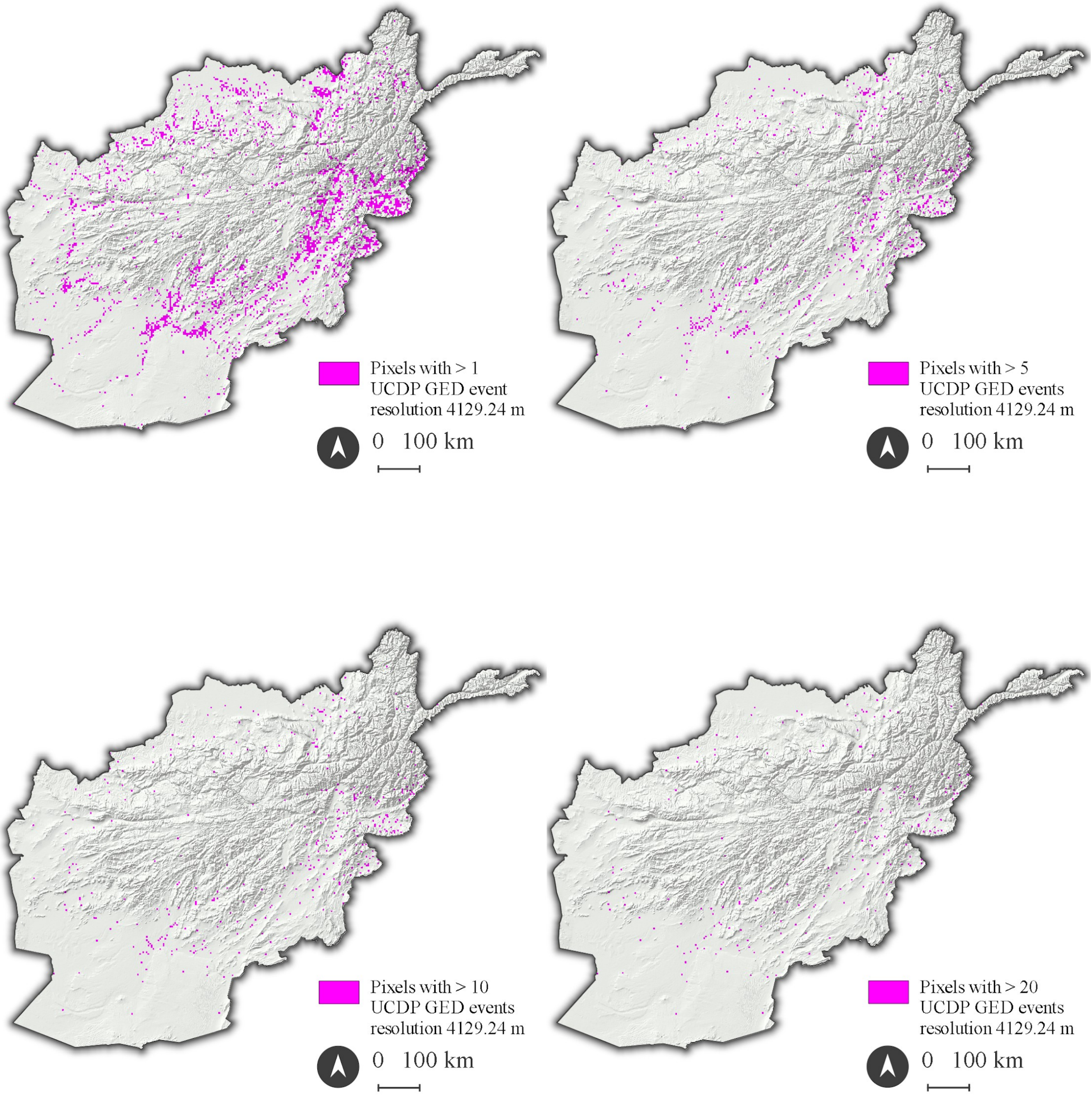


Figure 12: Visualizing 4 different conflict intensities. The conflict intensity is given in events per cell. Areas with >20 events per cell are hardly visible at this scale and make up a very small portion of Afghanistan.

3.3.5. Defining conflict areas and conflict intensity

From now on, all raster cells with at least one conflict event at 4129 m resolution will be referred to as conflict areas. If not declared otherwise, the source of conflict data is the UCDP GED. Conflict area defined by WikiLeaks data will be named accordingly. Conflict intensity is defined by the number of events per raster cell. Figure 13 visualizes the conflict areas.

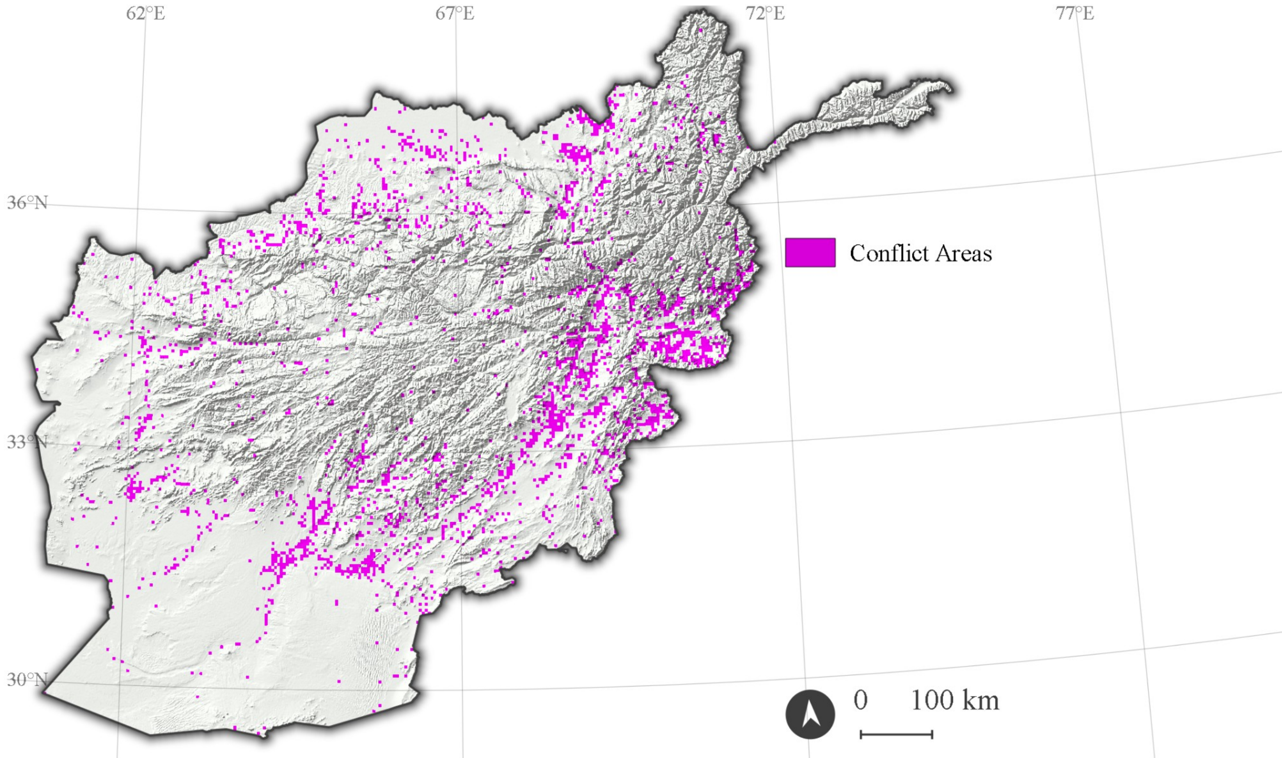


Figure 13: Visualizing conflict areas. Every cell containing at least one conflict event is classified as conflict area. The source for conflict events is the UCDP GED.

3.4. MODIS land cover data

3.4.1. Accuracy Assessment

When working with automatically generated land cover data like the MODIS MOD12Q1 dataset, it is important to assess the accuracy of the dataset to see if it is suitable for further analysis in the study area. Accuracy assessment is usually done using the dataset that is to be assessed and a so called ground truth dataset. In many countries, Germany for example, there are official datasets on land cover and land use created and maintained by federal agencies, which can be used as ground truth. In Afghanistan however, there has not been any stable government with complete territorial control over the last 40 years, and no official datasets exist. To address the lack of a ground truth dataset, high resolution satellite imagery has to be compared manually to the (moderate resolution) MOD12Q1 dataset. The accuracy assessment has been done for a sample of three years, 2001, 2005 and 2010. User's accuracy, producer's accuracy and Kappa have been calculated. User’s accuracy tests for false positives, meaning a cell has been classified as cropland, but should in fact be something else. Producer's accuracy tests for false negatives, meaning a pixel was not classified a scropland even though it should have been. The kappa index of agreement gives an overall assessment of the accuracy of the classification for all classes. According to Fitzgerald et al (1994) the Kappa index of agreement is an appropriate tool for evaluating interclassifier problems. It reflects the difference between actual agreement and the agreement expected by chance. A Kappa value of 0.55 means that the classification accuracy is 55 % better then by chance alone.

The results have been relatively consistent, which suggests that sampling three years out of 10 is sufficient to get a first indication of the data accuracy. The imagery used for comparison was the Global Land Survey (GLS) 2000, GLS 2005 and GLS 2010 datasets. These datasets have a resolution of 30 m. The year in the name of the datasets does however not indicate the exact year in which the data has been collected, for example GLS 2000 data has been collected between 1999 and 2003. GLS datasets were created using Landsat Thematic Mapper and Landsat Enhanced Thematic Mapper Plus by NASA and the U.S. Geological Survey. They were created to allow access to a consistent, terrain-corrected collection of data for different times.

Gibson et al. (2015) also use GLS imagery in their 5 year temporal resolution, which suggests that using GLS from the preceding year is both tolerable and best practice. To validate the land cover data, 100 random points for the cropland land cover class have been created for each year. An additional 160 sampling points for all other land cover classes combined have been created. For the 260 sampling points per year the MOD12Q1 land cover class as well as the visually inspected land cover class was collected and a confusion matrix has been created. The results of the confusion matrix can be seen in Table 07.

The Kappa values show the overall accuracy of the land cover classification, 1 means the map is completely accurate, 0 completely inaccurate. The Kappa values (0.557 to 0.629) determined here not very high, but good enough to continue working with the data. The User’s Accuracy is quite low.

As an example, the distribution of sampling points and their assessment for the year 2001 can be seen on Figure 14.

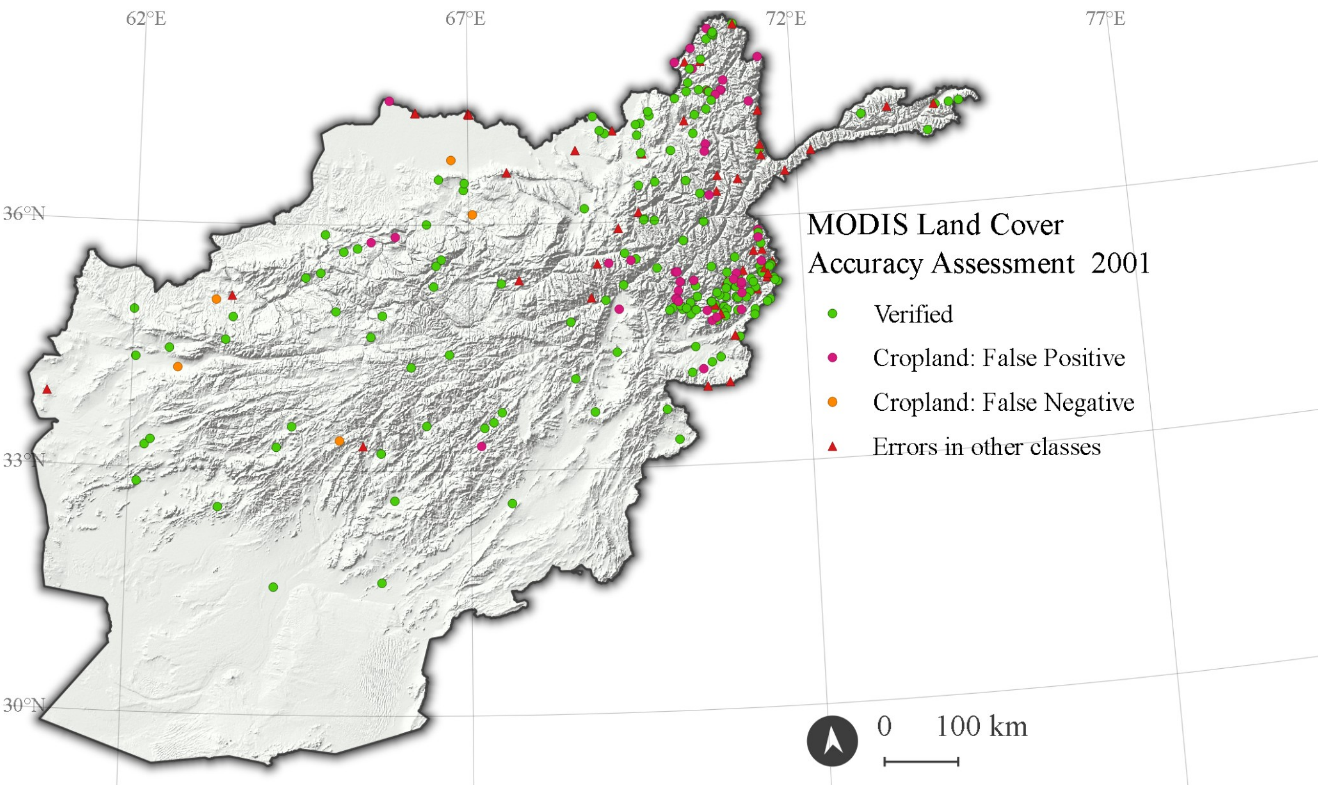


Figure 14: Cropland Accuracy Assessment for 2001. MODIS Land Cover data has been tested for accuracy using high resolution satellite imagery (GLS).

Table 6: Accuracy values for the three years tested. MODIS Land Cover data has been tested for accuracy using high resolution satellite imagery (GLS).

Year	Producer's Accuracy Cropland	User's Accuracy Cropland	Kappa (includes all land cover classes)
2001	0.921	0.580	0.557
2005	0.895	0.680	0.629
2010	0.934	0.7100	0.628

3.4.2. Development of different land cover classes over time

This section will describe the land cover in Afghanistan in 2001 and 2011, and compare it to the land cover in areas with at least one conflict event (for how these areas were determined, see 3.3.4. Determining conflict event resolution and conflict intensities). Further, changes in land cover between 2001 and 2011 will be visualized. In an additional step, a special emphasis will be put on cropland development.

Land cover in 2001

The land cover of Afghanistan in 2001 was mostly made up of barren land (46.4 %), grasslands (22.1 %) and open shrublands (20.2 %). Cropland is the fourth most dominant land cover class, with about 1.3 % of the total area. Other classes combined make up less than 1.5 % of land cover.
Figure 15 visualizes the land cover composition in maps for 2001 and 2011. Pie charts illustrate the percentages of different land cover classes for 2001 and 2011. The data is split up into two pie charts,

as the 4 major land cover classes make up about 99 % of land cover, and changes in the smaller land cover classes would not be visible. The four most dominant land cover classes make up more than 97 % of the total area. The other land cover classes each make up less than 1 % and are shown in smaller pie charts. Also the land cover composition in conflict areas is shown in pie charts.

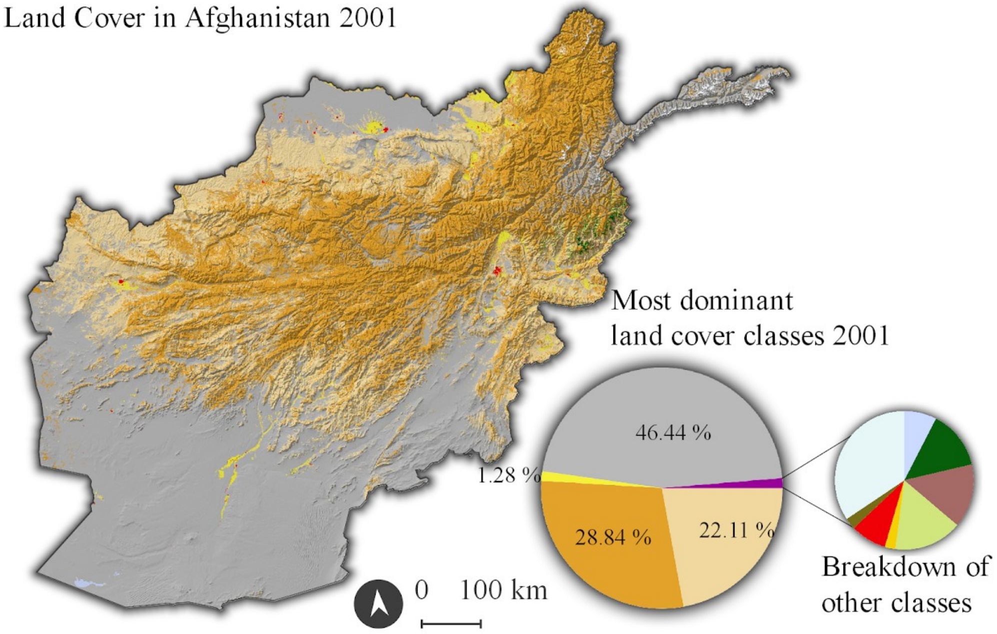
Most croplands are located north of the Hindu Kush mountain range around Kunduz, Masar-e Sharif and Herat. Another region with cropland activity is located north of Kabul. The patterns suggest that the cropland area is distributed within the southern valleys of the Hindukush. Another hotspot of cropland activity seems to be in the Southwest along Hilmand River near Kandahar and Lashkar Gah. Other than that, there is very little cropland activity, which is not surprising since the rest of the country mostly consists of the high Hindu Kush mountain ranges and the southern desert.

Land cover in 2011

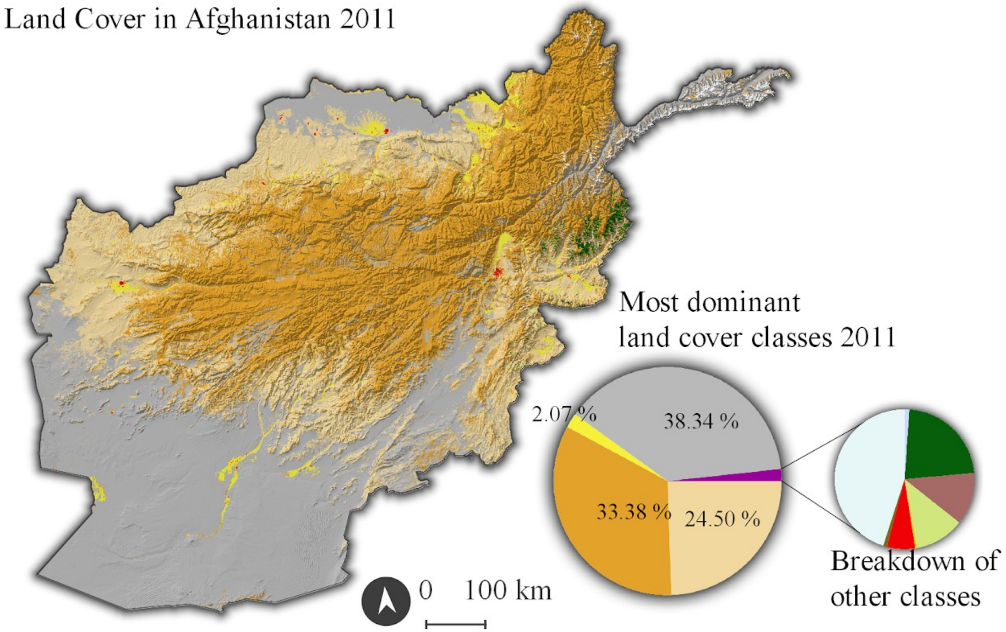
In 2011, Barren Land accounts for 38.3 %, a decrease of 8.1 percentage points. Grasslands now take up 33.4 %, an increase of 11.3 percentage points and open shrublands account for 24.5 %, an increase of 4.3 percentage points. So there seems to be an overall greening effect in Afghanistan, with barren land declining from 2001 to 2011. The distribution of cropland activity is about the same as in 2001, but it seems the growth in cropland area has mostly affected the regions north and south of the Hindu Kush.

Figure 15 visualizes the situation in 2001 and 2011. Both the land cover in 2001 and 2011 are displayed as a map. The percentages of different land cover classes for 2001 and 2011 are shown in a table and visualized as pie charts to make them comparable. Also the percentages of different land cover classes within conflict areas are shown, as they differ from the country wide values. This is not surprising, since armed conflict usually takes place in inhabited areas, as Baumann and Kuemmerle (2016) have shown. Different classes for forests are aggregated to reduce the number of classes and to ease comprehension.

Land Cover in Afghanistan 2001

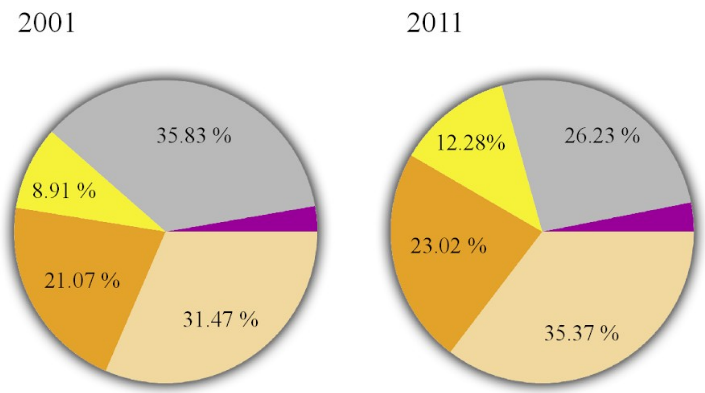


Land Cover in Afghanistan 2011



MOD12Q1 Land Cover Classes	% 2001	% 2011
0: Water	0.1002	0.0191
1 - 5: Forests	0.1827	0.3843
6: Closed shrublands	0.1972	0.2068
7: Open shrublands	22.1148	24.5021
8: Woody savannas	0.2104	0.1963
9: Savannas	0.0328	0.0069
10: Grasslands	28.8438	33.3777
11: Permanent wetlands	0.0002	0.0006
12: Croplands	1.2764	2.0738
13: Urban and built-up lands	0.1115	0.1115
14: Cropland/natural vegetation mosaics	0.0352	0.015
15: Snow and ice	0.4569	0.771
16: Barren	46.4379	38.3351

Most dominant land cover classes in areas with >1 conflict event



Previous Page: Figure 15: Comparing the land cover situation in 2001 and 2011.

As Figure 15 shows, the land cover composition for conflict areas is different from the overall land cover composition of Afghanistan. While in 2011 about 2.1 % of Afghanistan is cropland, 12.8 % of conflict areas is. Barren takes up 38 % of the country, but only 26.3 % of the conflict areas. The percentages for the 5 most prominent land cover classes in 2011 are listed in Table 7 and visualized in Figure 16. This shows that the land cover within conflict areas does not represent the average composition of the whole country. Cropland and urban areas are more prominent in conflict areas than in overall Afghanistan. Grasslands and barren lands are less prominent in conflict areas. In areas with higher conflict intensities, there are higher percentages of cropland and urban areas. One reason for this is that conflict events usually take place in inhabited areas. (Baumann and Kuemmerle 2016)
The effect of different conflict intensities on cropland areas will be analyzed in further depth, but first the development of the land cover over time will be addressed.

Table 7: A comparison of 5 land cover classes in 2011 with their respective aerial percentages at different conflict intensities.

	Open shrublands	Grasslands	Croplands	Barren	Urban/ built-up	Other
Afghanistan	24.29	33.46	2.09	38.47	0.09	1.59
Areas with > 1 conflict events	35.37	23.02	12.28	26.23	0.73	2.37
Areas with > 10 conflict events	37.03	19.46	14.59	24.59	1.89	2.43

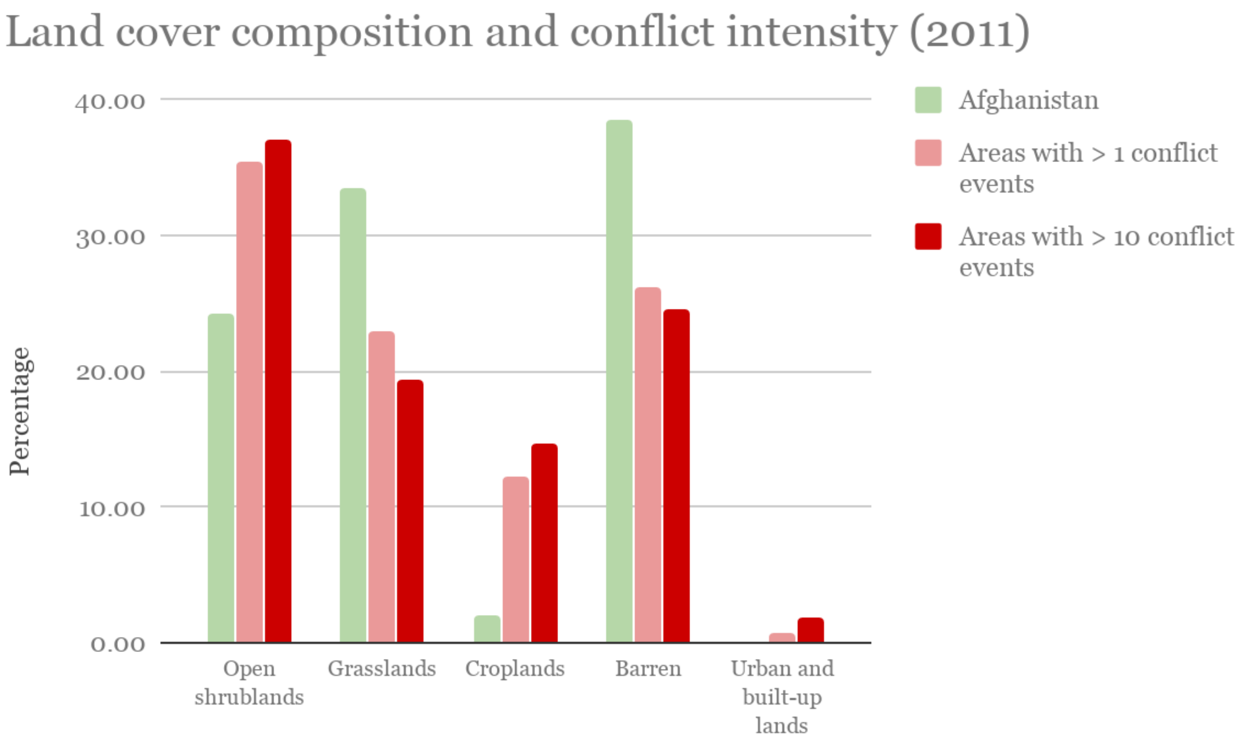


Figure 16: A visualisation of land cover composition in 2011 at different conflict intensities. Cropland and urban areas are more prominent in conflict areas than in overall Afghanistan. Grasslands and barren lands are less prominent in conflict areas.

Development of different land cover classes over time

After focussing on a comparison of the situation at the beginning and the end of the study period, the focus will now be the development of the different land cover classes over time. Figure 17 shows the 4 most dominant land cover classes and their yearly percentages of total area, while Figure 18 shows the less dominant land cover classes. Looking at the most dominant types we can see a rather steady increase in cropland development, which will be analysed further in the following chapter 3.4.3 Cropland Development. Barren land declines strongly over time, but has a small increase in 2008-2009. This analysis is based on the regression slopes in Figure 17. Barren land has a negative slope, while the other three land cover classes show a positive regression slope. Table 8 gives the exact percentages year by year which have been visualized in Figure 17. It also states the regression slopes for each of the 4 major land cover classes. Figure 18 shows all land cover classes that account for less than one percent of the total area of Afghanistan. Evergreen needleleaf forests strongly incline over time, and water has a clear negative trend. Snow and ice increased, but shows a rather random development over the study period. Table 09 shows the annual development of all land cover classes in the study period.

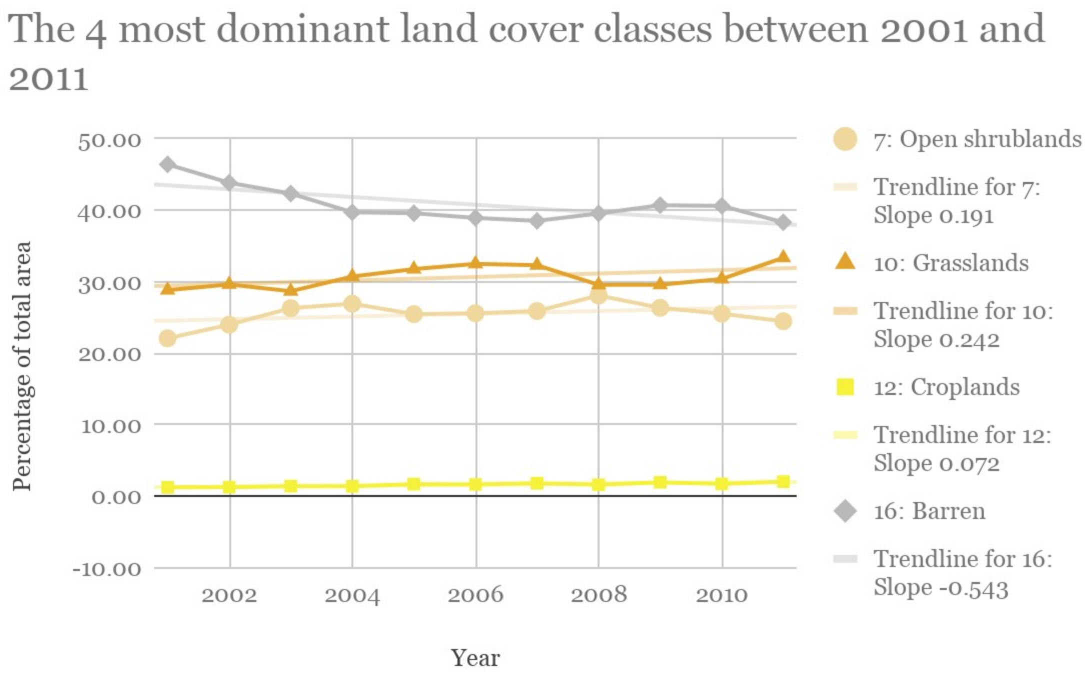


Figure 17: The development of the most dominant land cover classes between 2001 and 2011. Cropland has a near linear increase, while the 3 big classes open shrublands, grasslands and barren show a more chaotic development. There is a decrease in barren lands, an increase in grasslands.

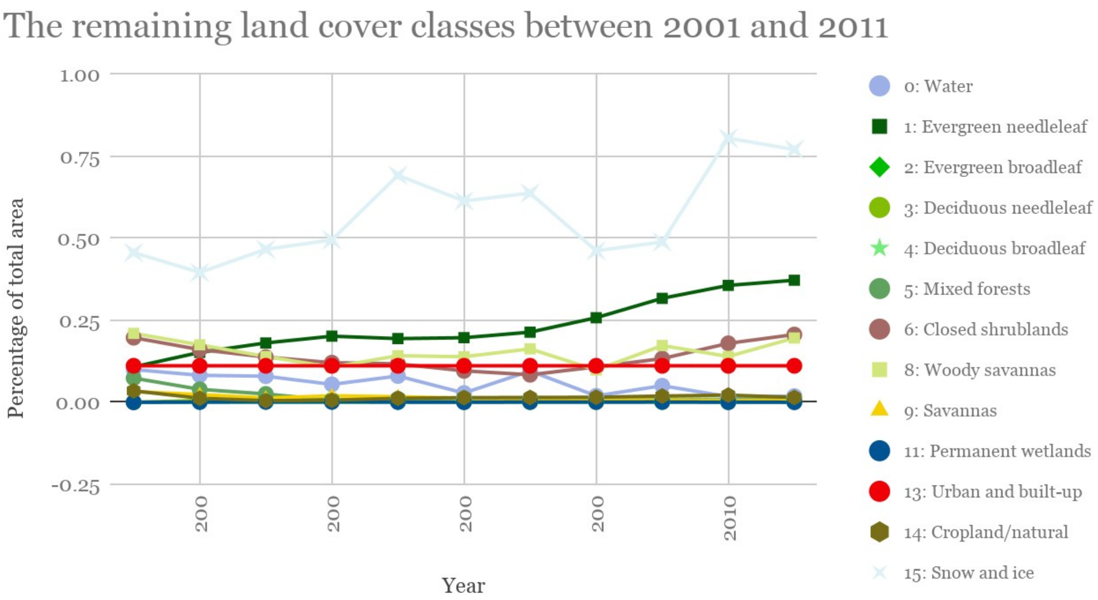


Figure 18: The development of the less dominant land cover classes between 2001 and 2011. Each class within this figure accounts for less than 1 % of the area of Afghanistan. There are increases with forest land cover classes, also snow and ice increased, but shows high fluctuations.

Table 8: Development of the four major land cover classes over time. For every year the percentage of the overall area of Afghanistan for the four major land cover classes is given. The last line indicates the regression slope from 2001 to 2011.

Year	7: Open shrublands	10: Grasslands	12: Croplands	16: Barren
2001	22.11	28.84	1.28	46.44
2002	24.02	29.65	1.30	43.87
2003	26.33	28.70	1.44	42.36
2004	26.95	30.75	1.42	39.74
2005	25.50	31.79	1.72	39.61
2006	25.62	32.53	1.68	38.95
2007	25.93	32.33	1.85	38.54
2008	28.10	29.59	1.64	39.57
2009	26.38	29.60	1.98	40.72
2010	25.56	30.41	1.75	40.63
2011	24.50	33.38	2.07	38.34
Regression slope	0.191	0.242	0.072	-0.543

Table 9: Development of the 13 less prominent major land cover classes over time. For every year the percentage of the overall area of Afghanistan for the four major land cover classes is given. The last line indicates the regression slope from 2001 to 2011.

Year	0: Water	1: Evergreen needleleaf forests	2: Evergreen broadleaf forests	3: Deciduous needleleaf forests	4: Deciduous broadleaf forests	5: Mixed forests	6: Closed shrublands	8: Woody savannas	9: Savannas	11: Permanent wetlands	13: Urban and built-up lands	14: Cropland /natural vegetation mosaics	15: Snow and ice
2001	0.10	0.11	0.00	0.00	0.00	0.07	0.20	0.21	0.03	0.00	0.11	0.04	0.46
2002	0.08	0.15	0.00	0.01	0.00	0.04	0.16	0.18	0.02	0.00	0.11	0.01	0.40
2003	0.08	0.18	0.00	0.01	0.00	0.03	0.14	0.14	0.01	0.00	0.11	0.01	0.47
2004	0.05	0.20	0.00	0.01	0.00	0.01	0.12	0.11	0.02	0.00	0.11	0.01	0.50
2005	0.08	0.19	0.00	0.00	0.00	0.01	0.12	0.14	0.02	0.00	0.11	0.01	0.69
2006	0.03	0.20	0.00	0.00	0.00	0.01	0.10	0.14	0.01	0.00	0.11	0.01	0.61
2007	0.10	0.21	0.00	0.00	0.00	0.01	0.08	0.16	0.01	0.00	0.11	0.01	0.64
2008	0.02	0.26	0.00	0.00	0.00	0.01	0.11	0.10	0.01	0.00	0.11	0.02	0.46
2009	0.05	0.32	0.00	0.00	0.00	0.01	0.13	0.17	0.01	0.00	0.11	0.02	0.49
2010	0.02	0.36	0.00	0.00	0.00	0.01	0.18	0.14	0.01	0.00	0.11	0.02	0.81
2011	0.02	0.37	0.00	0.00	0.00	0.01	0.21	0.20	0.01	0.00	0.11	0.01	0.77
Regression Slope	-0.007	0.024	0.000	0.000	0.000	-0.004	0.000	-0.001	-0.002	0.000	0.000	0.000	0.029

3.4.3. Cropland Development

The overall cropland area in Afghanistan increased by 62.5 % between 2001 and 2011. Figure 19 shows the total cropland area per year as well as a regression trend line. As mentioned in the above section, there is a strong linear relationship between cropland area and time, with an r^2 of 0.823 and a slope of 46495 ha/a. There are however years (2004, 2006, 2008 and 2010) where the cropland area decreased compared to the preceding year. The biggest cropland area occurred in 2011, the smallest cropland area in 2001. Figure 20 shows where cropland areas have been lost and gained in a direct comparison between 2001 and 2011.

Most larger cropland areas that already existed in 2001 expanded until 2011. No large cropland area vanished, and in the northern fringes of the Hindu Kush a new cluster of relatively small cropland areas emerged.

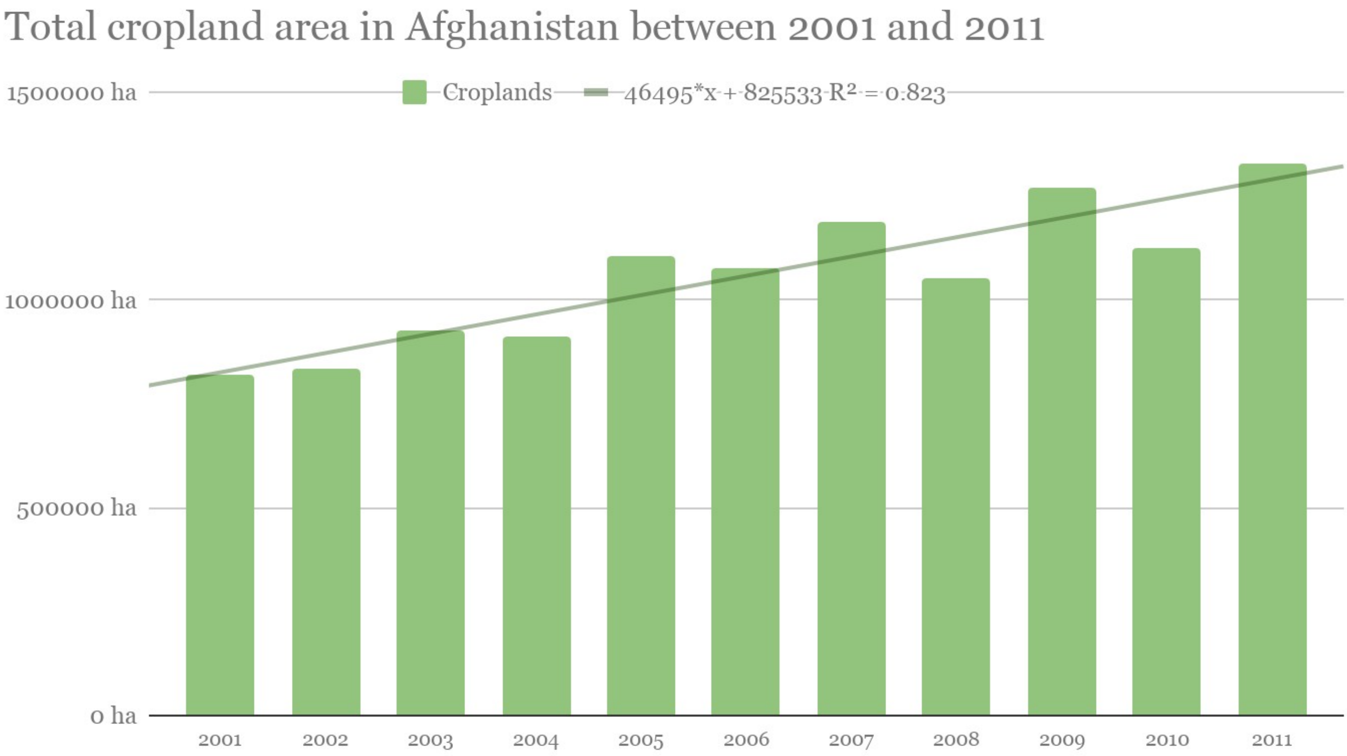
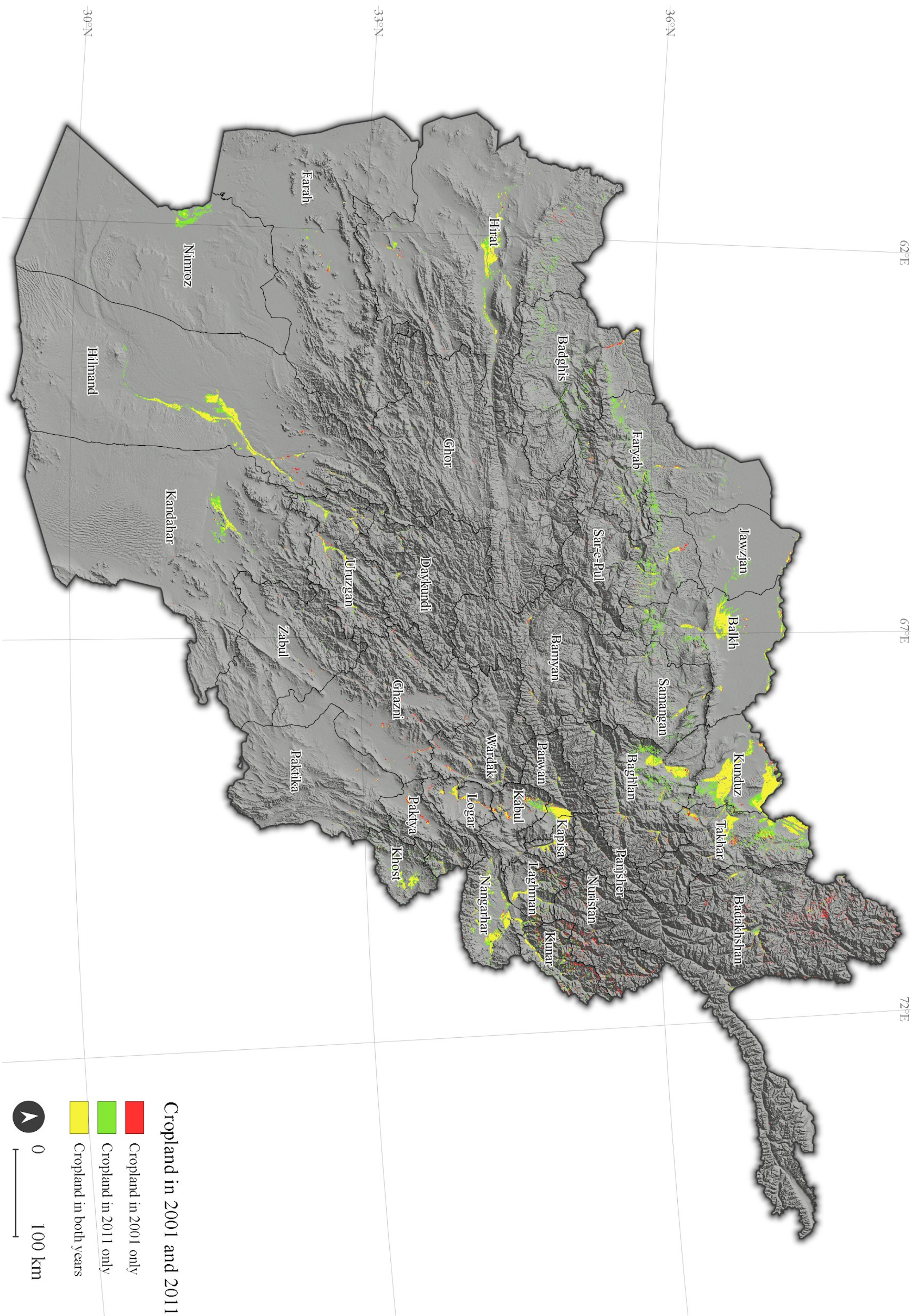


Figure 19: Cropland area per year. The slope coefficient is 46495 ha/year. R^2 is relatively high with 0.823. There is a linear relationship between cropland area and time.



30°N
33°N
36°N
62°E
67°E
72°E
Farah
Nimroz
Hirat
Hilmand
Badghis
Ghor
Faryab
Kandahar
Sar-e-Pul
Jawzjan
Uruzgan
Daykundi
Balkh
Zabul
Bamyan
Samangan
Ghazni
Wardak
Parwan
Baghlan
Kunduz
Paktika
Paktya
Logar
Kabul
Kapisa
Takhar
Khost
Nangarhar
Laghman
Nuristan
Panjsher
Badakhshan
Kunar
Cropland in 2001 and 2011
Cropland in 2001 only
Cropland in 2011 only
Cropland in both years
0
100 km

Previous page: Figure 20: Differences in cropland area from 2001 to 2011. Most cropland area losses occur in the mountain range, most increases in the plains in the North and Southwest.

3.4.4. Significance of cropland area changes

The above chapter visualized the development of all land cover classes over the study period. This chapter will put a special focus on cropland development, since the research question 2 mostly focuses on cropland development. The overall assumption of this is, that there has been a change or some kind of development in cropland area within the study period. To check this assumption statistical testing has been done. Did the cropland area change significantly between 2001 and 2011?
This was answered by doing a multiple regression with years and drought severity index (DSI) as independent variables, and cropland area as dependent variable. This analysis has been done in PSPP, an open source statistics software. The result has shown that there is a highly significant relationship between time and cropland area, while the influence of the drought severity index on cropland area does not seem significant. Pearson's correlation coefficient has been calculated to confirm this, also showing no significant correlation between cropland area and DSI. This leads to the conclusion that the cropland area indeed changed over time significantly, and that changes in cropland are not a function of changing DSI. Gibson et al. (2015) came to similar results when testing for correlation between cropland area and DSI..

Table 10: Summary of the multiple regression analysis

R	R^2	Corrected R^2
0.93	0.87	0.83

Table 11: Correlation Coefficients for Cropland Area

Coefficients Cropland Area			
	Standardized Coefficient Beta	t	Sig.
Time (Years)	0.91	7,04	0.000
Mean DSI per Year	0.21	1,61	0.146

Table 12: Pearson's correlation for cropland area, year and DSI

Pearson's Correlation				
		Cropland area	Year	Mean DSI
Cropland area	Pearson Correlation	1.00	0.91	0.19
	Sig. (1-sided)		0.000	0.284
	N	11	11	11
Year	Pearson Correlation	0.91	1.00	-0.02
	Sig. (1-sided)	0.000		0.481
	N	11	11	11
Mean DSI	Pearson Correlation	0.19	-0.02	1.00
	Sig. (1-sided)	0.284	0.481	
	N	11	11	11

3.4.5. Provincial differences in cropland development

While the overall cropland area increased within our study period, there are regional differences. All changes are relative to the cropland area in 2001.

In 9 of the 34 provinces the cropland area decreased, the strongest decrease happened in Ghazni province with about 73 % of cropland lost between 2001 and 2011, as can be seen on Figure 21. In Nuristan and Badakhshan there is a decrease of about 68 and 62 %. In the other 25 provinces however, the cropland area increased. The highest change happened in Nimroz Province with about 1800 %, so almost a twenty fold increase, however, in 2001 there have been only about 18 km² of cropland in Nimroz, a province with a total area of about 40,000 km². There are 9 provinces with increases larger than 100 % of the 2001 cropland area, so they at least doubled their cropland area. While all provinces in the northern and southern plains gained cropland area, some of them more than doubling their cropland area, some provinces in the mountain ranges have lost cropland area. Figure 21 and Table 14 and visualize the provincial changes and the changes in % of the 2001 cropland area for all provinces. Appendix Table 2 lists all provinces with their yearly cropland area and changes.

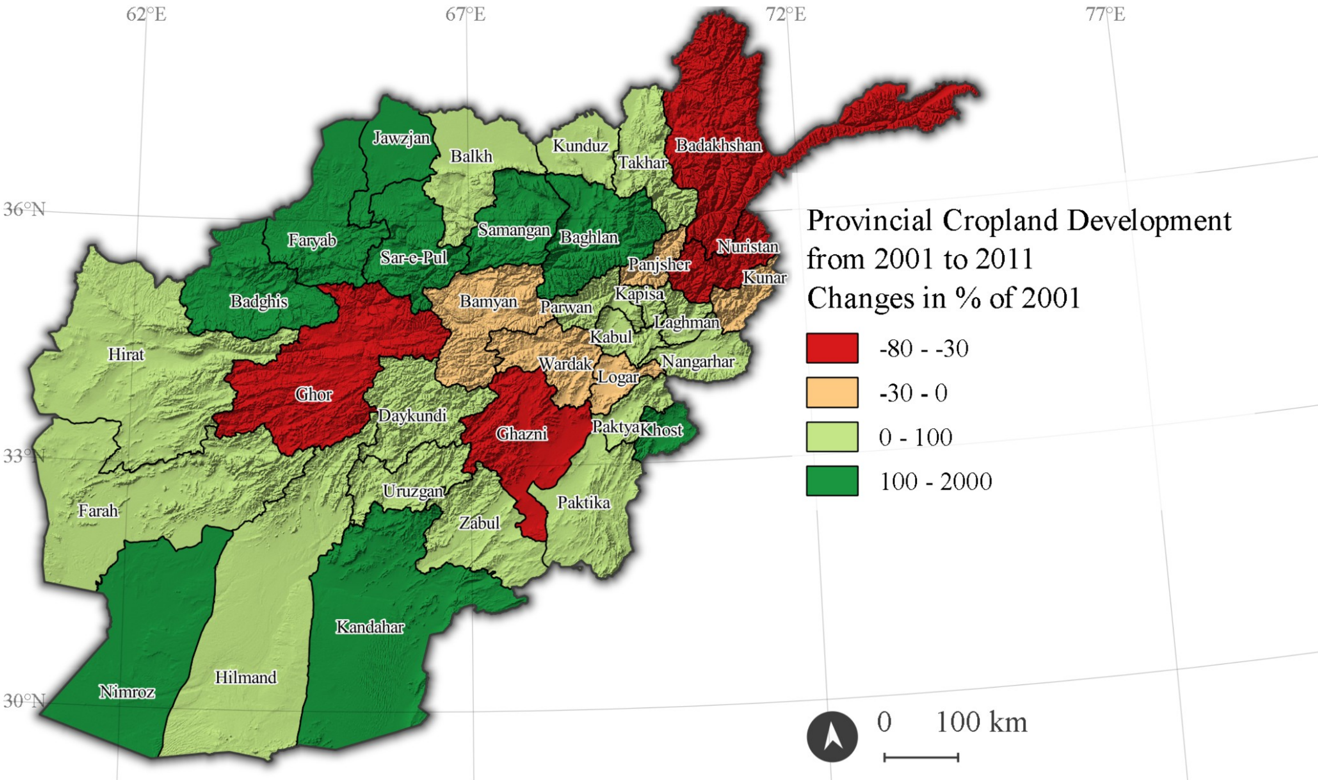


Figure 21: Provincial cropland development from 2001 to 2011. There are strong provincial differences in cropland development.

Table 13: Changes in cropland area per province, 2001 to 2011. All provinces marked red show decreases, all provinces marked in green show increases in cropland area. Darker tones indicate changes below -50 and above 100 %.

Province	Change in % 2001-2011
Ghor	-57.1
Hilmand	46.3
Uruzgan	34.9
Nimroz	1875.0
Baghlan	113.9
Ghazni	-73.3
Kunar	-5.9
Zabul	25.0
Badakhshan	-62.2
Khost	121.1
Kabul	22.8
Faryab	369.4
Parwan	18.0
Hirat	87.8
Logar	-12.0
Takhar	81.2
Laghman	16.3

Province	Change in % 2001-2011
Balkh	99.3
Sar-e-Pul	201.8
Daykundi	48.7
Kandahar	166.7
Panjsher	-29.5
Bamyan	-23.3
Paktya	6.7
Nuristan	-68.2
Paktika	38.6
Jawzjan	495.3
Kapisa	4.9
Badghis	437.0
Wardak	-16.6
Farah	44.6
Nangarhar	57.5
Kunduz	41.7
Samangan	252.2

3.4.6. Spatial patterns in cropland development on a regional scale

On a broader scale, Figures 21 and Figure 22 indicate that most gains in cropland area have happened north and south of the Hindu Kush mountain range, while the mountainous regions had less of a positive, in some regions even a negative, trend between 2001 and 2011.
To check if this impression is true, three regions have been roughly defined along the edges of the Hindu Kush. The first region consists of five provinces north of the mountains: Faryab, Jawzjan, Balkh, Kunduz and Takhar. The provinces Sar-e-Pul and Baghlan have not been selected. while these include areas north of the mountain range, for the most part they are still within the mountainous areas. The second region consists of three provinces south of the Hindu Kush, Nimroz Hilmand and Kandahar. The third region is made up of the remaining regions, most of them mountainous in nature. Figure 22 shows the regions described above.

In the first, the northern region, the increase in cropland between 2001 and 2011 is about 83 %, in the second, the southern region, the increase is about 99 % and in the third, the mountainous region, the increase is only about 10 %. The overall increase for the whole country is 63 %. A noticeable spatial pattern thus seems to be that the mountainous regions have a less positive and in some provinces negative cropland development, while the regions north and south of the Hindu Kush show a stronger increase in cropland than the rest of the country.

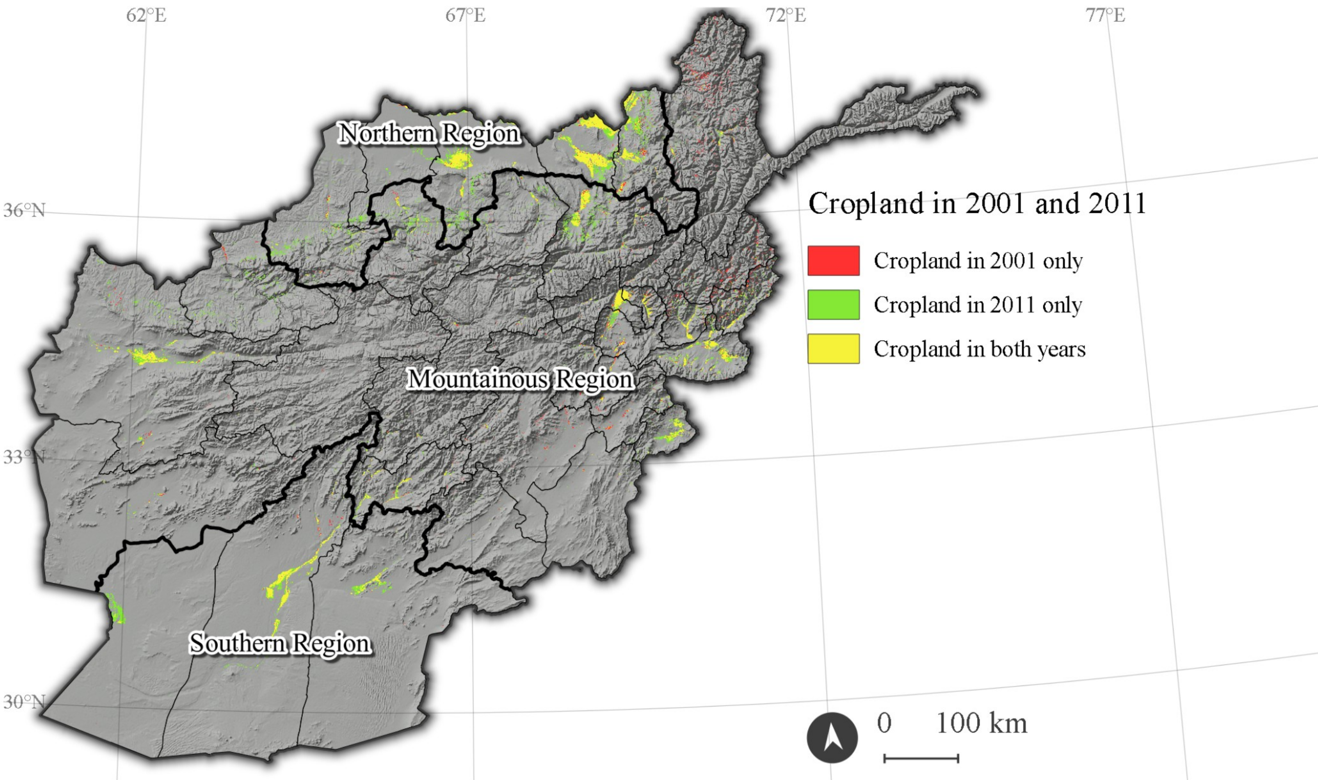


Figure 22: Dividing mountainous regions and plains to detect spatial patterns in cropland development.

3.4.7. Impact of conflict events on cropland development

While in the preceding section development of cropland areas in Afghanistan and regional/provincial differences are described, this sections aims at linking conflict events to cropland development, to determine if there is a correlation between conflict events and the development of cropland areas. The first two methods will explore the regional and provincial differences determined in the previous section, the third method will employ statistical testing for areas influenced by conflict events in Afghanistan.

Are differences in provincial development linked to the number of conflict events in the province?

As listed in Table 13, different provinces show different cropland growth rates between 2001 and 2011. To see if the number of conflict events per province is linked to cropland growth, scatterplots are shown. To make the provinces comparable, the changes in cropland are determined in % of the 2001 value (for WikiLeaks data 2004). The number of events are given in total values and in events per km². This is done both for the UCDP and the WikiLeaks datasets (for the WikiLeaks data, the study period is 2004-2009). Nimroz province has been discarded for the scatterplots, as it is a very strong outlier and makes plotting this on one graph difficult to read.

Figures 23 to 26 show that there is no linear correlation between either the amount of conflict events or the density of conflict events in a province and its cropland area development. However, the provinces with the highest event count do not show high cropland growth, and the provinces with very high cropland growth show a low number of conflict events, as seen in Figures 23 and 25. This behaviour becomes a bit more evident when looking at events/km², as shown in Figures 24 and 26. This indicates the presence of a weak logarithmic correlation, and in fact using a logarithmic trendline there is a coefficient of determination of 0.25 for UCDP Events per km² vs changes in cropland area in % of the province area. However this does not hold up for the WikiLeaks dataset.

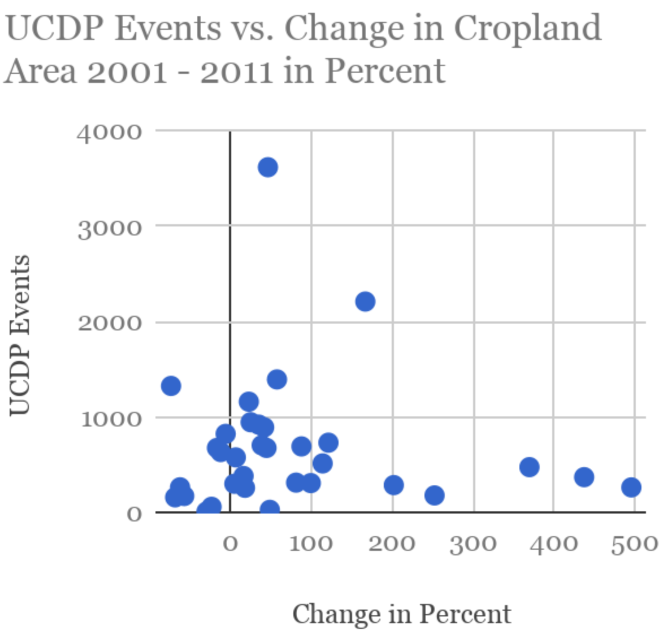


Figure 23: Scatterplot showing UCDP events and cropland area change on a provincial level.

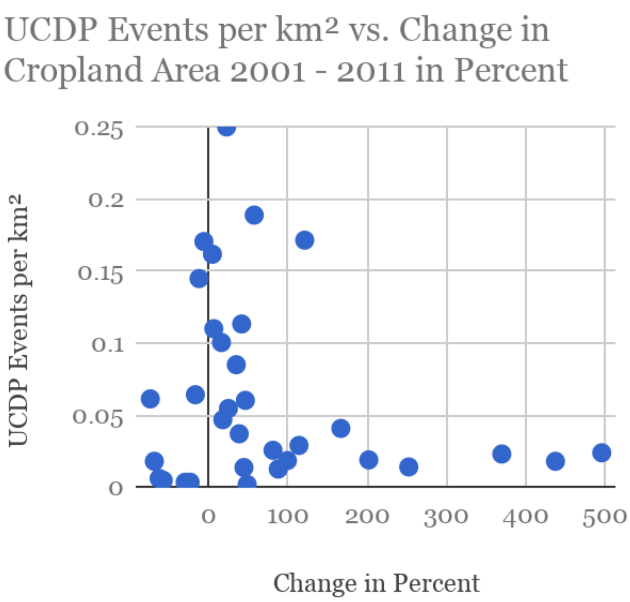


Figure 24: Scatterplot showing UCDP events/km² and cropland area change on a provincial level.

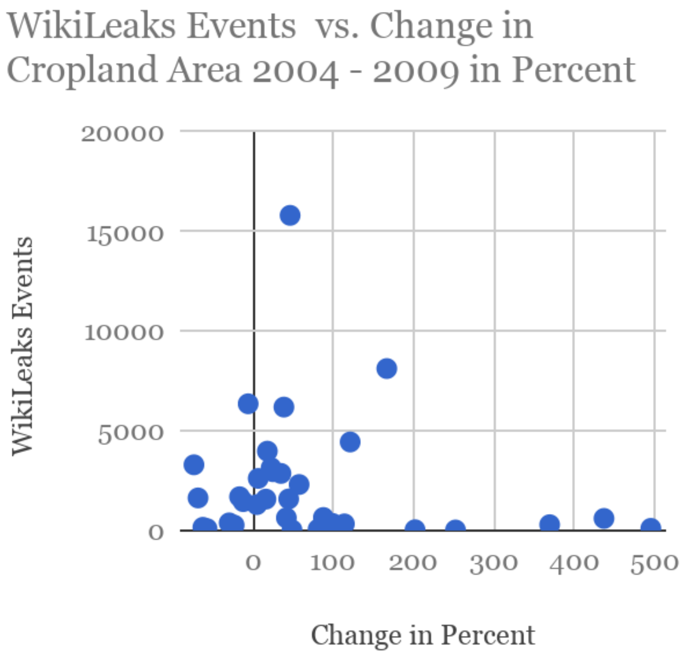


Figure 25: Scatterplot showing UCDP events and cropland area change on a provincial level.

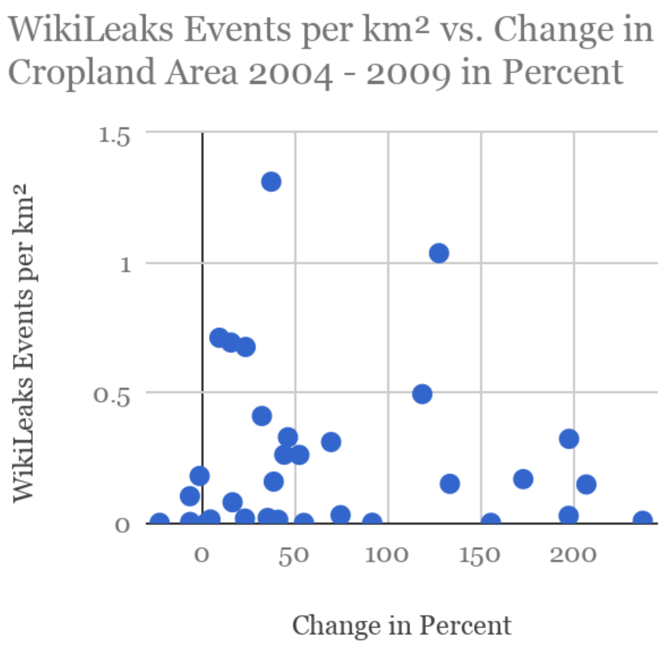


Figure 26: Scatterplot showing WikiLeaks events/km² and cropland area change on a provincial level.

Can conflict intensity be linked to cropland growth rates?

To answer the question how conflict events and conflict intensity influence cropland development, the following analysis has been done. The conflict events are rasterized at a resolution of 4129 m (which represents 10x10 MODIS land cover cells). Every raster cell contains the number of conflict events in the study period for the respective cell. This has been done for both the UCDP and the WikiLeaks data. Subsets of the MODIS land cover datasets from 2001 to 2011 (and 2004 to 2009 for the WikiLeaks data) are created using these values: The first subset contains all areas in Afghanistan not affected by conflict events according to the different resolutions. The second subset contains all areas in Afghanistan affected by at least one conflict event. Several more subsets have been created representing different numbers of conflict events per cell for comparison. The aim is to show how cropland development within these subsets compares to the overall development for Afghanistan, and how strong the linear relationship between year and cropland area is per subset.

Cropland development within the different subsets

As discussed before, there generally is a positive trend for cropland area development between 2001 and 2011. A growth factor (Cropland Area in 2011 / Cropland Area in 2001) has been calculated for comparison of different conflict intensity subsets. For the total area, the growth factor is 1.63. For conflict free areas, the growth factor is 1.86, and for areas with at least one conflict event the growth factor is 1.34. Figure 27 shows the growth factors for different conflict intensities. We can see that higher conflict intensities generally result in less cropland area increases.

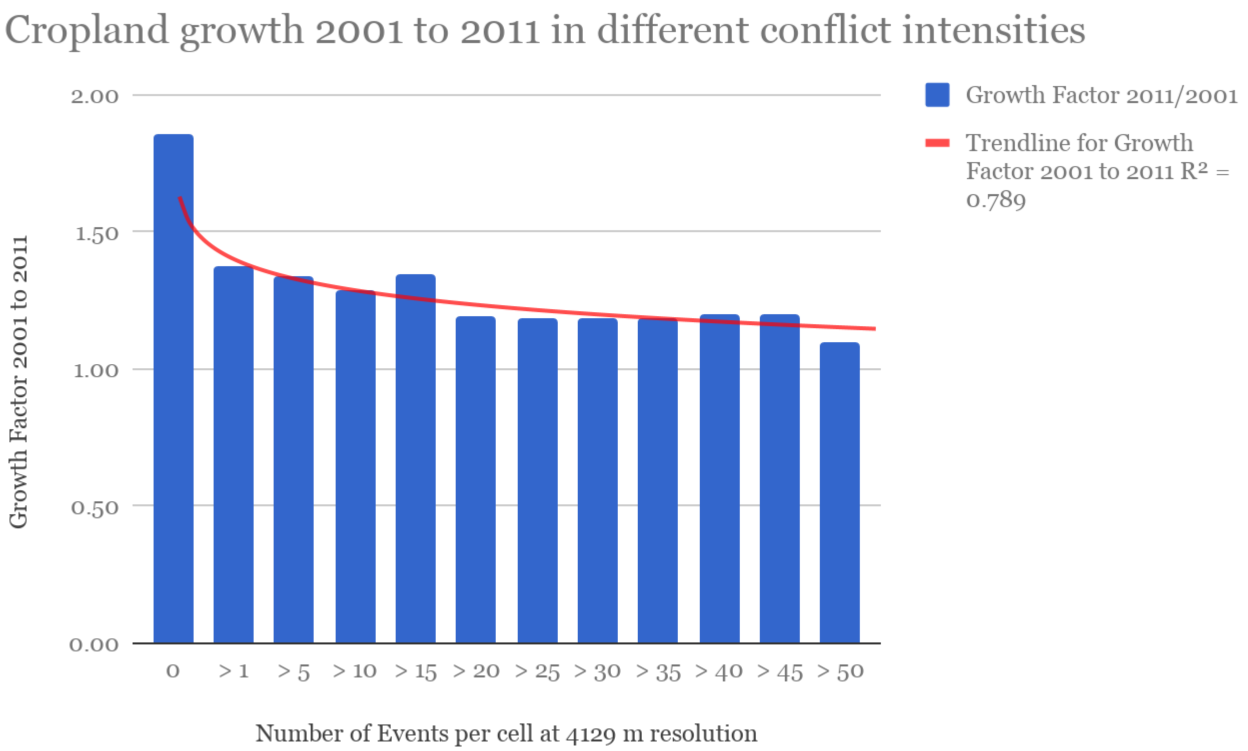


Figure 27: A comparison of cropland growth between 2001 and 2011 in areas of different conflict intensities.

However, this growth factor only compares 2001 to 2011 and does not show the temporal development. To address this, Figures 28 and 29 compare the yearly development of different conflict intensities. While the trend for conflict free areas is clearly positive with a slope of 30025 ha/a and has an r^2 of 0.741, the trend for areas with at least one conflict event is less positive with a slope of 14649 ha/a and has a lower r^2 of 0.694. As shown in Figure 28, the higher the conflict intensity, the less positive is the trend over the timeframe and the smaller r^2: The total cropland areas have the strongest increase, cropland in conflict areas has the slowest increase. Figure 30 shows the development of Pearson's r, r^2 and the slope coefficient with different conflict intensities. Both the growth factor and the time series analysis indicate that the higher the conflict intensity, the slower the cropland area increase in Afghanistan between 2001 and 2011.

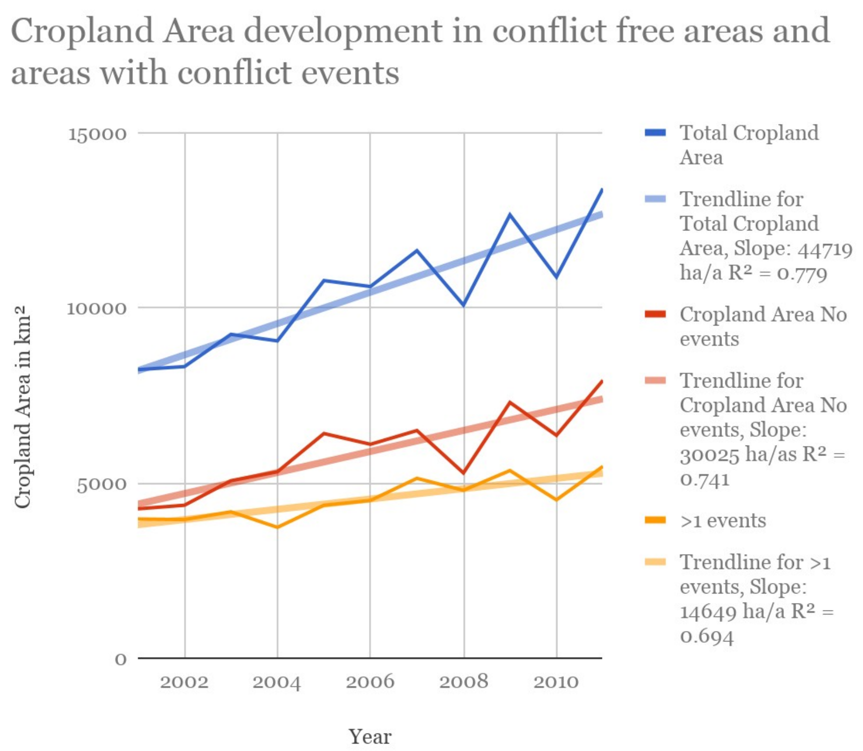


Figure 28: Comparing cropland development in total, in conflict free areas and in conflict areas.

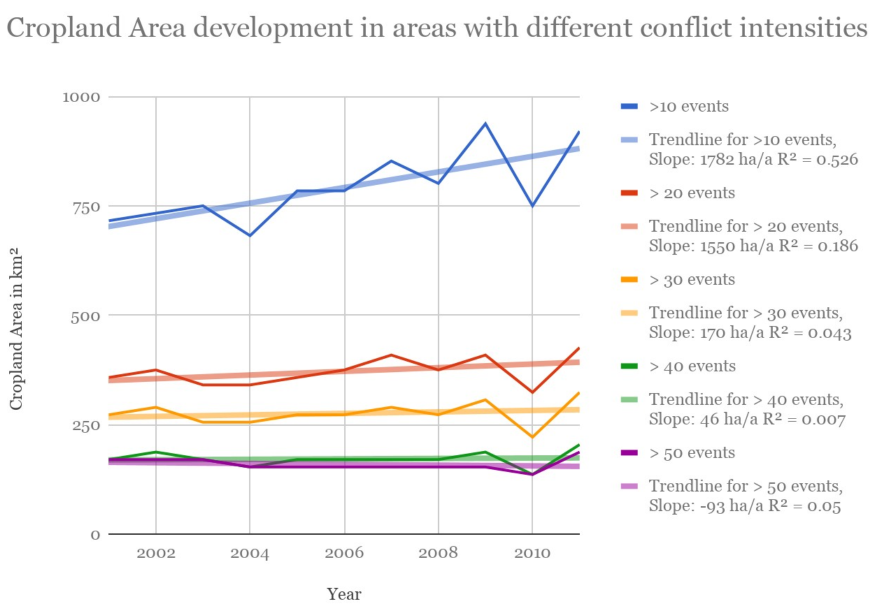


Figure 29: Comparing cropland development in areas of different conflict intensity.

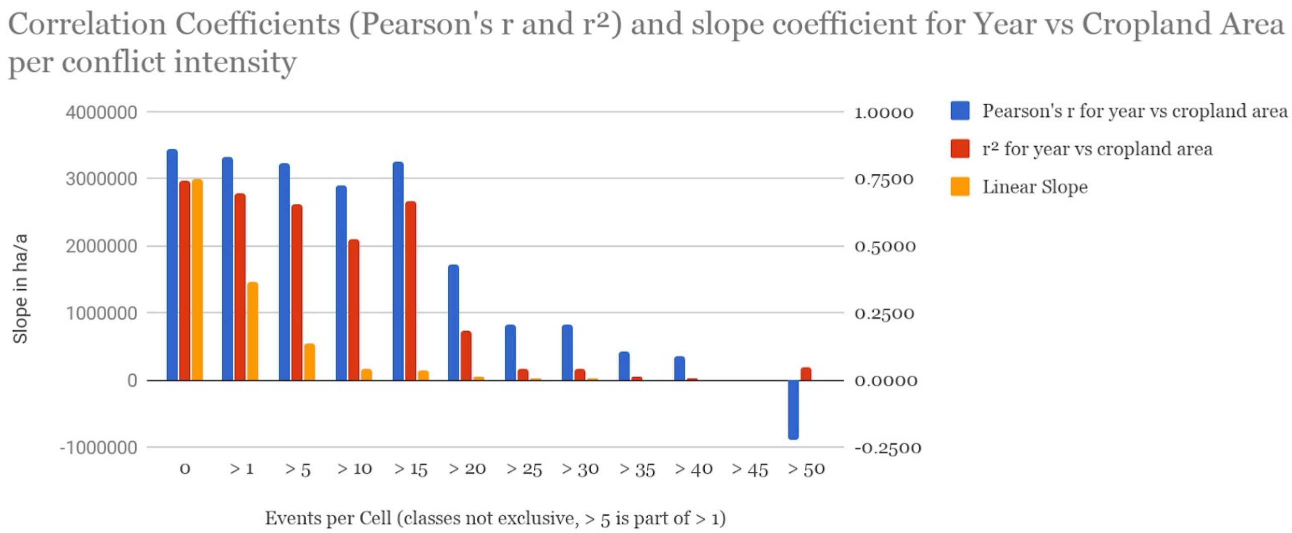


Figure 30: Pearson's correlation coefficient for year and cropland area at different conflict intensities. The higher the conflict intensity gets, the less linear the cropland development. There is a sharp drop at about 20 events per cell.

4. Discussion

4.1. Shortcomings and potential for further research

There are some shortcomings to the methodology and data used in this thesis which could be sources of error and reason for further research in this area.

First of all, while it is possible to show some correlation between cropland development and conflict intensity, this is not enough to indicate a causal relationship. There are a lot of other factors which could play into this, starting by a more in depth analysis of precipitation, availability of seeds and fertilizer and machinery needed among many other social and economical factors. Also there is no qualitative statement about the emerging cropland areas: What are they used for? How big is the impact of puppy cultivation/heroin production? Maybe this particular question could be analyzed with high resolution imagery like landsat ETM+ with 15 m resolution panchromatic.

The accuracy of the MODIS land cover data has been checked for three years due to the scope of the thesis, and the availability of imagery. This methods had its limitations: while it was possible to determine if an area can be considered cropland, it was not possible to tell if an area was actually cultivated in the given year. Also 10 points per land cover class was not enough to assess the accuracy of the given class. This was however not in the scope of this analysis: the goal was merely to identify areas which are in fact cropland, but have been falsely classified as something else.,

The indicator relevant to the question how well cropland has been classified in the MOD12Q1 dataset, are the user's accuracy and the producer's accuracy. The user's accuracy, also referred to as type 1 error, tests for false positives, where a pixel is classified as cropland but should have been classified as another class. The producer's accuracy, also referred to as type 2 error, tests for false negatives, where a pixel is not classified as cropland, even though it actually is cropland. Additionally, the Kappa index of agreement gives an overall assessment of the accuracy of the classification for all classes. While the producer's accuracy for cropland is relatively high (between 0.895 and 0.934), the user's accuracy is relatively low (between 0.58 and 0.71). This means that there are many pixels classified as cropland but are in fact something else, while there are only very few actual cropland pixels that have been falsely classified as something else. The user's accuracy is not very satisfying and has to be kept in mind when considering potential sources of error for this thesis.

The conflict intensity has been aggregated in raster cells by counting all events occuring in the study period. Splitting these data annually would be interesting for correlating conflict intensity and cropland development, because the research questions could be answered for every single of the 10 years, which might result in more meaningful results, but would also multiply the overall workload of the analysis.

The main results are all based on the UCDP GED. The WikiLeaks data might be suitable for determining conflict intensities if filtered and redacted in greater depth. A potential problem here could be fact that the original data source for the WikiLeaks dataset is the US government. There may be a bias to overestimate the number of enemy combatants killed and to underestimate the number of civilians killed in the attribute data of events. Since the scope of this research project was centered on the spatial distribution of conflict events, and not the number of casualties, there is no negative effect to be expected.

Further it would be interesting to do a qualitative assessment of the cropland areas, for example by using monthly NDVI time series data like Eklund et al. (2017) did in their research.
It would be interesting to split the conflict events further into different event categories, such as terrorist attacks, mines and conflicts state versus state. These different types of conflict events might have different effects on cropland and land cover in general.
Also the intensity was purely based on the number of conflict events. Other ways of determining conflict intensity such as casualties per cell or duration of an event might be interesting as well. Does an area with only one conflict event lasting several weeks behave the same as an area with one conflict event which lasts half an hour?
While DSI data has been used to check for a correlation with cropland area development, this analysis was very coarse, only using an annual average DSI for the whole country. Doing a spatial analysis and examining local and regional correlations between cropland area and DSI or precipitation data might show a bigger influence of drought than assumed in this thesis.

5. Conclusions

5.1. Answering the research questions

Research Question 1:

How did fighting intensity (i.e., the frequency of violent incidents) affect cropland areas in Afghanistan between 2001 and 2011?

In conflict areas, there was a slower cropland area growth than in areas without conflict events. This effect increases with higher conflict intensities. (For a definition of the terms conflict area and conflict intensity, see 3.3.5 Defining conflict areas and conflict intensity). While the cropland area development in Afghanistan shows a linear correlation to time, this correlation gets weaker in areas with higher conflict intensities. Nationwide cropland area in Afghanistan increased between 2001 and 2011 by 61 %. In areas with higher conflict intensities, this growth tends to slow down. While in conflict free regions the cropland area increased by 85 % from 2001 to 2011, it only increased by 37 % in conflict areas. With higher conflict intensities the growth further decreases, in areas with at least 50 conflict events per cell (between 2001 and 2011) there is only a 10 % increase in cropland area.

Looking at administrative provinces, the number and density of conflict events in a province can not be used to predict cropland development within the respective province. However, very high cropland increases did not happen in provinces with a very high conflict event count, and provinces with a very high event count do not show very high cropland area growth. The same goes for the number of conflict events per province per km².

Research Question 2:

How did cropland areas in Afghanistan develop during the military missions “Operation Enduring Freedom - Afghanistan” (OEF-A) and “International Security Assistance Force” (ISAF), both starting in October 2001? Did the area of cropland decrease or increase? Are there regional differences? The changes in cropland area will be described relative to the situation in 2001, since the military missions began in the fall/winter of 2001, after the end of the growing season in Afghanistan.

Cropland areas in Afghanistan increased by 61 % between 2001 and 2011 from 8,188 km² in 2001 to 13,304 km² in 2011. A noticeable spatial pattern is that mountainous regions have a less positive (and in some provinces negative) cropland development than the country-wide average, while the plains north and south of the Hindu Kush show a stronger increase in cropland than the country-wide average. To evaluate this the country has been split up into three regions depicted in Figure 22. While in the northern and southern region cropland area increased by about 83 and 99 % respectively, in the mountainous region is only increased by about 10 %.
In 9 of the 34 provinces the cropland area decreased, the strongest decrease happened in Ghazni province where about ¾ of cropland area has been lost between 2001 and 2011. In Nuristan and Badakhshan there is a decrease of about ⅔. In the other 25 provinces however, the cropland area increased. There are 9 provinces which more than doubled their cropland area.

5.2. Putting the results in perspective

These results fit well into the current state of research, as it was to be expected to see very little cropland in the early years of the study period, and big potential for increases in cropland area due to the effects of the Soviet invasion in the nineteen-eighties (De Beurs and Henebry 2007). While the overall cropland area is increasing, there are negative effects in areas with a high number of conflict events, since they show slower cropland growth. This fits to De Beurs and Henebry (2007), who have shown that war has negative effects on agricultural development. They further show that NDVI values have been rising between 2001 and 2004 (the end of their study period), which fits well to the findings made in this thesis, that barren land is decreasing and grasslands and cropland are increasing.

The answer to research question 2, namely that land cover composition in conflict areas is very different from that in conflict free areas, and that the percentage of cropland in conflict areas is much higher than the average fits to the findings of Baumann and Kuemmerle (2016), who stated that cropland and urban areas are highly overrepresented in their analysis of conflict events.

VI. References

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VII. Appendix

Appendix Table 1: The 17 classes of the international geosphere biosphere programme DISCover classification scheme (Belward et. al. 1996).

Value	Class	Description
0/17	Water	Oceans, seas, lakes, reservoirs, and rivers. Can be either fresh or saltwater bodies.
1	Evergreen Needleleaf forest	Lands dominated by needleleaf woody vegetation with a %cover >60% and height exceeding 2 m. Almost all trees remain green all year. Canopy is never without green foliage.
2	Evergreen Broadleaf forest	Lands dominated by broadleaf woody vegetation with a %cover >60% and height exceeding 2 m. Almost all trees and shrubs remain green year round. Canopy is never without green foliage.
3	Deciduous Needleleaf forest	Lands dominated by woody vegetation with a %cover >60% and height exceeding 2 m. Consists of seasonal needleleaf tree communities with an annual cycle of leaf-on and leaf-off periods.
4	Deciduous Broadleaf forest	Lands dominated by woody vegetation with a %cover >60% and height exceeding 2 m. Consists of broadleaf tree communities with an annual cycle of leaf-on and leaf-off periods.
5	Mixed forest	Lands dominated by trees with a %cover >60% and height exceeding 2 m. Consists of tree communities with interspersed mixtures or mosaics of the other four forest types. None of the forest types exceeds 60% of landscape.
6	Closed shrublands	Lands with woody vegetation less than 2 m tall and with shrub canopy cover >60%. The shrub foliage can be either evergreen or deciduous.
7	Open shrublands	Lands with woody vegetation less than 2 m tall and with shrub canopy cover between 10% and 60%. The shrub foliage can be either evergreen or deciduous.
8	Woody savannas	Lands with herbaceous and other understory systems, and with forest canopy cover between 30% and 60%. The forest cover height exceeds 2 m.
9	Savannas	Lands with herbaceous and other understory systems, and with forest canopy cover between 10% and 30%. The forest cover height exceeds 2 m.
10	Grasslands	Lands with herbaceous types of cover. Tree and shrub cover is less than 10%.
11	Permanent wetlands	Lands with a permanent mixture of water and herbaceous or woody vegetation. The vegetation can be present either in salt, brackish, or freshwater.
12	Croplands	Lands covered with temporary crops followed by harvest and a bare soil period (e.g., single and multiple cropping systems). Note that perennial woody crops will be classified as the appropriate forest or shrub land cover type.
13	Urban and built-up	Land covered by buildings and other man-made structures.
14	Cropland/Natural vegetation mosaic	Lands with a mosaic of croplands, forests, shrublands, and grasslands in which no one component comprises more than 60% of the landscape.
15	Snow and ice	Lands under snow/ice cover throughout the year.
16	Barren or sparsely vegetated	Lands with exposed soil, sand, rocks, or snow and never have more than 10% vegetated cover during any time of the year.

Appendix Table 2: The cropland areas per province and year in km².

Province	Cropland											km² 2001 to 2011	Change in % 2001 - 2011
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011		
Ghor	27.8	80.0	23.0	28.0	6.8	16.5	28.8	28.6	21.7	7.8	11.9	-15.9	-57.1
Hilmand	791.7	775.5	856.8	781.3	894.6	1011.6	1165.9	1184.2	1197.0	1107.9	1158.6	366.9	46.3
Uruzgan	203.9	213.0	222.2	167.6	182.1	211.1	232.4	259.2	258.1	224.4	275.2	71.3	34.9
Nimroz	18.4	18.8	23.5	18.2	52.2	65.1	325.7	229.2	370.0	308.1	363.7	345.3	1875.0
Baghlan	432.1	475.2	601.2	699.2	798.5	771.4	658.5	537.6	799.5	763.7	924.3	492.3	113.9
Ghazni	118.8	91.9	61.0	12.8	11.3	31.4	130.4	152.3	171.5	37.7	31.7	-87.1	-73.3
Kunar	256.3	241.4	230.7	216.2	279.1	254.7	332.0	239.4	312.0	230.2	241.3	-15.0	-5.9
Zabul	17.7	15.5	13.3	2.4	3.6	22.2	30.0	40.4	33.1	19.4	22.2	4.4	25.0
Badakhshan	488.8	364.7	232.7	175.5	255.4	411.4	405.8	444.5	188.6	159.1	184.8	-304.0	-62.2
Khost	167.9	158.7	196.9	173.9	319.4	296.3	402.2	307.1	388.4	313.4	371.4	203.4	121.1
Kabul	164.9	148.0	136.2	55.4	68.0	102.0	126.2	144.4	94.3	108.4	202.4	37.5	22.8
Faryab	100.8	253.2	273.3	323.1	377.3	209.9	282.4	149.5	364.5	313.9	473.0	372.2	369.4
Parwan	227.1	224.4	231.2	198.0	212.8	211.8	212.6	224.4	219.4	234.8	268.0	40.9	18.0
Hirat	535.0	581.1	681.5	683.4	701.3	689.2	656.8	739.8	895.3	805.8	1004.6	469.6	87.8
Logar	133.8	121.2	118.3	69.2	83.2	90.5	118.2	129.6	131.3	103.5	117.8	-16.0	-12.0
Takhar	716.1	725.0	950.4	1151.6	1487.8	1377.7	1226.3	887.7	1106.6	1079.3	1297.4	581.3	81.2
Laghman	183.5	165.9	170.7	157.2	205.5	176.1	238.2	166.8	216.5	173.1	213.3	29.8	16.3
Balkh	669.6	725.3	927.7	951.9	1034.3	1050.8	1012.1	1010.6	1189.3	1063.3	1334.6	665.0	99.3
Sar-e-Pul	130.3	170.2	257.0	227.1	309.8	194.4	205.6	145.4	346.6	351.1	393.2	262.9	201.8
Daykundi	32.6	36.3	37.2	30.5	23.4	36.5	48.8	50.6	48.4	39.9	48.4	15.9	48.7
Kandahar	145.3	117.1	119.7	82.2	134.2	249.8	309.3	337.4	383.0	363.2	387.4	242.1	166.7
Panjsher	13.3	13.0	11.8	6.5	7.2	9.7	10.6	12.6	5.6	7.3	9.4	-3.9	-29.5
Bamyan	44.0	42.6	34.8	17.7	22.8	23.2	21.1	23.0	19.8	11.4	33.8	-10.2	-23.3
Paktya	66.5	50.6	50.1	26.6	45.2	50.1	103.2	87.8	105.5	62.6	70.9	4.4	6.7
Nuristan	202.9	151.4	121.6	92.6	113.9	95.8	108.6	89.2	90.2	75.5	64.5	-138.5	-68.2
Paktika	15.0	11.1	9.4	4.4	6.0	10.2	26.4	18.4	34.1	19.6	20.8	5.8	38.6
Jawzjan	43.3	48.6	158.1	121.2	293.4	179.7	200.9	148.7	224.0	178.3	257.8	214.5	495.3
Kapisa	216.4	219.4	216.2	181.2	207.2	209.4	226.6	225.1	215.2	225.6	226.9	10.6	4.9
Badghis	68.7	161.8	189.1	245.9	238.2	160.8	199.3	153.1	381.6	300.3	369.0	300.3	437.0
Wardak	70.9	68.7	57.5	20.5	38.9	50.8	75.7	69.7	47.9	44.2	59.2	-11.8	-16.6
Farah	28.3	21.1	22.7	11.6	11.4	14.0	26.9	26.3	32.7	18.1	40.9	12.6	44.6
Nangarhar	446.6	431.2	436.2	409.6	588.4	542.6	737.1	561.8	720.4	569.7	703.5	257.0	57.5
Kunduz	1351.3	1363.4	1506.1	1702.2	1962.7	1892.1	1947.9	1665.0	1925.9	1770.2	1914.6	563.4	41.7
Samangan	58.8	69.4	67.2	64.5	70.1	60.7	54.6	48.1	156.0	145.1	207.2	148.3	252.2
Afghan-istan (SUM)	**8188.4**	**8354.8**	**9245.2**	**9109.1**	**11045.9**	**10779.6**	**11887.0**	**10537.5**	**12694.2**	**11235.8**	**13303.6**	**5115.2**	**62.5**

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