Effects of Armed Conflicts and other Socio-economic Shocks on Land Use Change in the Caucasus

A dissertation proposal submitted by

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1. Overview

The purpose of this dissertation is to understand the effects of armed conflicts and other socio-economic shocks on land use changes. Human-induced changes stemming from political decisions and socio-economic events can lead to long-lasting modifications of land systems. Armed conflicts and warfare are among the most drastic socio-economic shocks and potentially trigger changes in land use in multiple ways. Yet, existing studies assessing the effects of socio-economic shocks on land use change are scarce and focus at local rather than broad spatial scales, leading to incomplete understanding of how land use is affected.

My goal is to identify the effects of socio-economic shocks such as armed conflicts and the collapse of the Soviet Union on land use change over broad spatial and temporal scales by using advanced remote sensing techniques and statistical methods.

In 'Chapter I' I will focus on land use change detection, in 'Chapter II' I will examine the effects of armed conflicts on land use and in 'Chapter III' I will evaluate the effectiveness of protected areas to prevent forest disturbance (Figure 1-1).

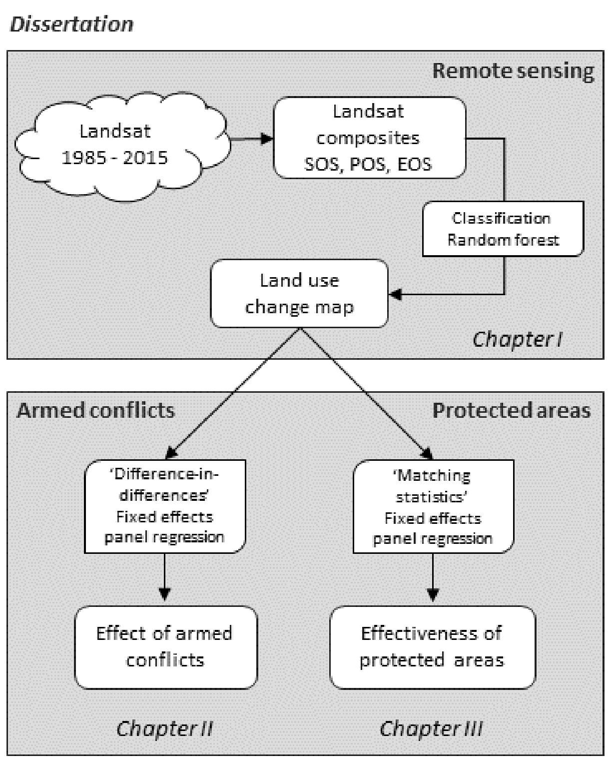


Figure 1-1: Flowchart for my dissertation.

2. Introduction

The complex human-environment interactions associated with regime shifts make predicating land use changes challenging (Dearing et al. 2010; Müller et al. 2014). The challenge is to relate underlying local and global drivers to changes in the land-system (Turner et al. 2007; Dearing et al. 2010). Not only environmental disasters, but economic and political events can cause changes in land-systems and often it is a combination of the three (Müller et al. 2014). The effects of socio-economic shocks on land use can vary greatly and certainly differ based on the prevalent political conditions. In Eastern Europe (Gutman & Radeloff 2016) and the former Soviet Union (Lerman 2001) the collapse of the Soviet Union was a socio-economic shock that caused a transition from a planned economy to a market economy, altered institutions and created new land use management. The changes in land use management led to agricultural abandonment in many Eastern European countries (Prishchepov et al. 2012).

Armed conflicts are among the shocks that can trigger changes in land-systems rapidly and can affect both society and the environment (Baumann & Kuemmerle 2016).The negative effects of armed conflicts on ecosystems and land systems can be direct, such as destruction by bombs and other military activities, but also indirect through the displacement of millions of people (McNeely 2000). However, the outcomes of armed conflicts can be beneficial for the environment under certain circumstances. For example timber harvesting can decrease due to a decrease in investment or the establishment of demilitarized zones, which become a no-man's land (McNeely 2000). On the other hand, armed conflicts can lead to unsustainable forest management, illegal logging and agricultural abandonment (Álvarez 2003; Aide et al. 2013; Ordway 2015; Jaafar et al. 2015).

The effects of armed conflicts can be wide-spread, long-lasting and intense and often affect urban areas, agriculture and forests (Alix-Garcia et al. 2013; Butsic et al. 2015; Baumann et al. 2015). Although the effects can be spatially and temporally heterogeneous and context-dependent, clear cause-effects relationships exist between actors and land use outcome (Baumann & Kuemmerle 2016). It is important to reveal context-dependent land use information to understand future land use change due to socio-economic shocks to plan and manage natural resources, provide ecosystem services for humans and protect biodiversity.

In this proposal I will use ‘land use change’ synonymously to ‘land use/land cover change’. I am aware that forest (observed biophysical cover with trees) is a ‘land cover’ type and not a ‘land use’ type such as agriculture, where humans are actively modifying the land, for instance, for different crop types (Lambin & Geist 2006). However, for simplicity, I will refer to both as ‘land use’ hereafter.

The overarching goal of my research is to advance the understanding of the effect of socio-economic shocks such as armed conflicts and policy shifts on land use on broad spatial and temporal scales in order to improve future land use science and to reveal insights into the role of underlying drivers of land change.

The Caucasus offers unique research opportunities because it has undergone the transition from a planned economy to a market economy after the collapse of the Soviet Union. It has also experienced more armed conflicts than any other post-Soviet region.

Remote sensing is the ideal technology for land change studies as it is spatially explicit and useful for inaccessible war-torn areas and quasi-experimental methods offer great potential to assess treatment effects on observational data.

To address my overarching goal, I will work on three objectives:

In **Chapter I**, I will map land use changes from 1985 to 2015 across the Caucasus region by classifying satellite derived imagery.

I will answer the question of how topographic correction of Landsat imagery improves change detection accuracy, how forest and agriculture have changed since 1985 and what patterns of land use are prevalent in each of the four countries in the Caucasus.

In **Chapter II**, I will evaluate the role of armed conflicts on land use change.

I will assess the observed land use changes in forest and agriculture from Chapter I in relation to socio-economic shocks, namely armed conflicts by employing ‘difference-in-differences’ statistics and fixed effects panel regression .

In **Chapter III**, I will assess the effectiveness of protected areas in preventing forest disturbance related to the collapse of the Soviet Union and armed conflicts.

I will use the change detection maps from Chapter I in order to test whether forest disturbance decreased or increased within and outside protected areas since 1985, whether protected areas established before 1991 were more effective than protected areas established after 1991 and whether higher protection categories (IUCN I&II) were more effective than lower ones (IUCN III-V). I will use ‘matching’ statistics and fixed effects panel regression.

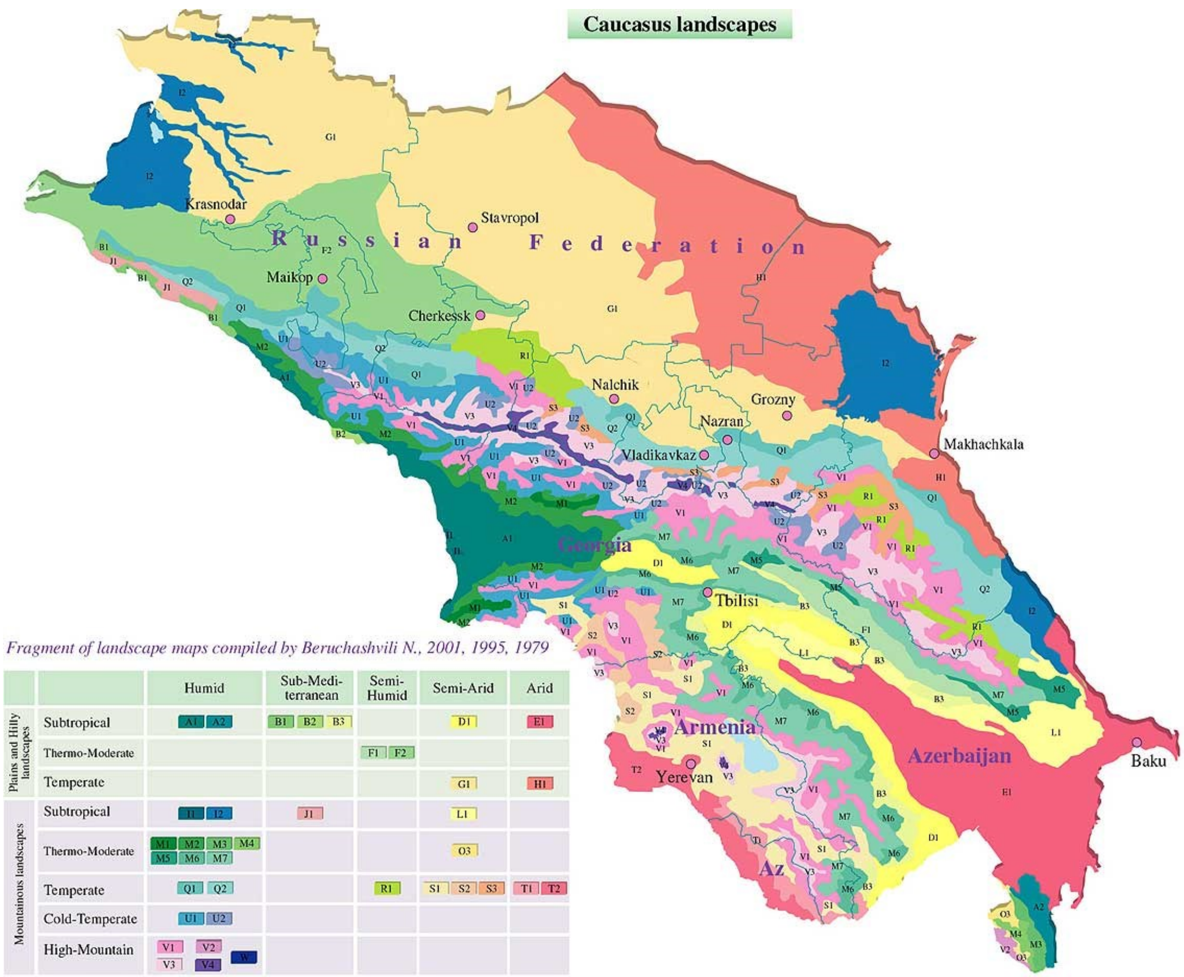
3. Study area

3.1. Geography

I will analyze the area between the Black Sea and the Caspian Sea, within the Caucasus ecoregion, encompassing parts of Russia in the north, and Armenia, Azerbaijan and Georgia in the south (Transcaucasia) (Figure 3-1). The northern part of the Caucasus is related to the continental belt, and the southern part to the subtropical one (Coene 2010). The area is divided by five major topographic features, the North Caucasus Plain, the Greater Caucasus Mountain Range, the South Caucasus Depression, the Lesser Caucasus Mountain Chain and the Dogu Karadeniz Mountains, the Southern Highlands and the Talysh-Western Alborz Mountains. The lowlands of the South Caucasus Depression separate the Greater Caucasus from the Lesser Caucasus (Zazanashvili et al. 2012).

The elevation of the Greater Caucasus ranges from 500-1000 m a.s.l. in the west to 3000 m a.s.l. in the east, with the main ridge containing the tallest mountain Mount Elbrus with 5642 m a.s.l. and permanent snow and ice. High altitude and abundant precipitation is predominant. The Lesser Caucasus ranges from 2000-2800 m a.s.l. in the west and 2500-3000 m a.s.l. in the east. The Greater Caucasus ridge blocks the colder air masses from Russia and leads to an increase in air temperature south of it, especially during winter. The areas close to the Black Sea have highest precipitation values in contrast to the east of the Caucasus with rather arid climate (Figure 3-1) (Volodicheva 2002; Coene 2010).

The Caucasus region can be sub-classified into seven major ecological zones; desert and semi-deserts, steppes, primary forest-steppe, sparse arid woodlands and forests. Steppes occur north of the Greater Caucasus and Transcaucasia, but were modified by humans and widely replaced by agriculture and pasturelands (Zazanashvili et al. 2012). The mountain areas of the Greater Caucasus are mostly forested with deciduous forest. On the north slopes and in higher elevation pinewoods are common (Coene 2010). The southern part of the slopes harbor subtropical forest. In the eastern parts of the Caucasus and Transcaucasia (foothills of the Greater and Lesser Caucasus and Karabakh), sparse arid woodlands connect semi-deserts with woodlands. Semi-deserts are often irrigated and used for cultivation of cotton, cereals and wine. The Armenian highlands are a mix of steppes and meadows and some of it is irrigated and used for agriculture. The slopes of the Talysh Mountains are forested with oak and beech, the lowlands are used for rice and tea cultivation. The Caucasus has a remarkable diversity of forest types and about 17% of the total land area is covered by forest (UNEP-GRID 2002). Natural forest mainly remained in eastern Georgia, Azerbaijan, Karabakh and Hirkan (Volodicheva 2002; Coene 2010).



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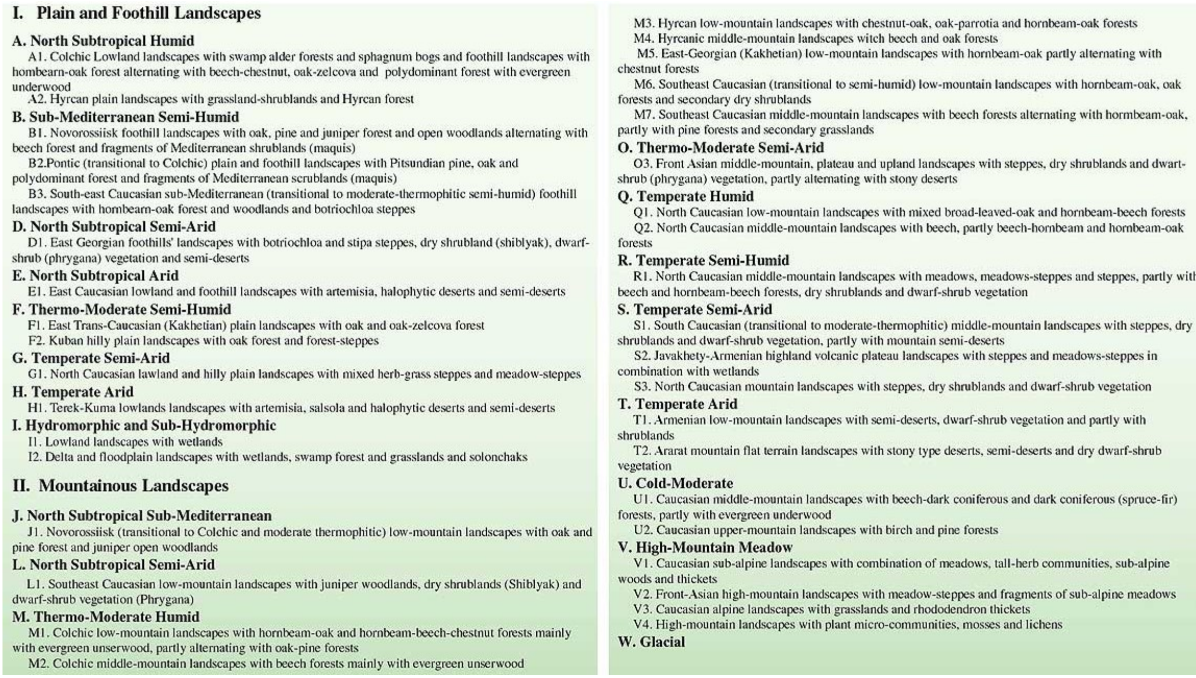

Figure 3-1: Vegetation map of the Caucasus region (source: UNEP GRID-Tbilisi 2002).

3.2. Political situation

3.2.1. Reforms after the collapse of the Soviet Union

During the Soviet Union, the Transcaucasian countries, as well as the North Caucasus, which is part of the Russian Federation, were controlled by the central government of the Soviet Union. The economy of all three Transcaucasian countries was centrally ruled from Moscow. The major industrial sectors were oil and gas, chemicals and machinery, fertilizer, and food production (UNEP-GRID 2002). The two economic regions, Transcaucasia and the North Caucasus, were specialized in different sectors. Armenia, Azerbaijan and Georgia were specialized in the production of fruit, tea, tobacco, cotton and wines. The North Caucasus had its economic based on arable lands and pasture and was economically significantly stronger than Transcaucasia. In 1998 the share of the North Caucasus of the total Caucasus GDP was 77.7% (UNEP-GRID 2002).

After the collapse of the Soviet Union, policymakers in the former Soviet Union (FSU) countries emphasized transition strategies which were based on the Washington Consensus, a guideline for transition countries. The Washington Consensus focuses on liberalization of prices and foreign trade, macroeconomic stabilization, privatization, corporate governance, along with institutional, political and enterprise reforms. It was a challenging time for the ruling politicians to push through economic reforms in order to gain stability and prosperity in the country (Fischer & Gelb 1991). Generally, the performances of the transition countries after 1991 were rather poor compared to their pre-transition period (Svejnar 2002).

Generally, all countries had to fight monetary overhang, the accumulation of money over time, and inflation as inter-regional trade decreased. The countries experienced a great loss in production output between 1990 and 1992 and were in great need to liberalize their prices (The World Bank 1993; Fischer & Sahay 2000). Mostly with the support of the World Bank and the International Monetary Fund (IMF) the countries started pushing reforms and laws. For Armenia, Azerbaijan, Georgia and Russia, the transition started in 1992 and precipitated numerous reforms. By 2000, the countries implemented most of the important laws and reforms, though many of them were not effectively enforced.

Policy reforms can take different shapes in different countries and this greatly affects their transition and hence either directly or indirectly land use. For instance economic policies, property rights, access to land, labor, technology and information is often shaped, but also constrained by policy reforms and institutions (Batterbury & Bebbington 1999). For transition countries there are three major pillars of policy reforms, liberalization, stabilization, and privatization and the four countries dealt differently with them and were not equally successful.

Liberalization is the first pillar of economic policy reforms for transition countries. The membership of the World Trade Organization (WTO) was a major step in liberalization for many FSU countries. Georgia had major reforms and liberalized its interest rates and most prices by 1992. It successfully became a member of the WTO in 2000. Armenia abolished the foreign trade registration in 1992, started to permit land tradability in 1994 and had most prices liberalized by 1995, which positively influenced negotiations to join the WTO by 2000 (EBRD 2000). Although Azerbaijan had liberalized most prices, liberalized trading and adopted a foreign investment law by 1992, WTO negotiations were less successful, because the country was lacking local industry protection. Azerbaijan did not join the WTO until 2003. In Russia the state trading monopoly was abolished in 1992. The liberalization of domestic and external markets was quickly attempted and foreign trade and access to foreign exchange was liberalized by 2000. Russia did not become a member of the WTO for various reasons such as an underdeveloped service sector to foreign countries (EBRD 2000).

A second pillar for transition economies is to achieve stabilization in the fiscal market and therefore to tighten credit policies in order to reduce inflation (Fischer & Gelb 1991). All four countries introduced their own new currency, with a fixed exchange rate to the US dollar to decrease inflation. Georgia introduced corporate profit taxes and personal income taxes in 1991 and introduced its new currency, the lari, in 1995. Armenia introduced its own currency, the dram, in 1993, adopted major tax reforms in 1997 and pursued a tight monetary policy. Azerbaijan enacted a central bank law and introduced its new currency, the manat, in 1992. In 1996, Azerbaijan initiated the treasury bills market, a non-inflationary source for financing the budget deficits (Fischer & Sahay 2000). Russia unified the exchange rate in 1992, introduced its new currency, the rouble, in 1993 and further enacted a new tax code in 1999, which introduced a personal income tax. All countries were supported by the IMF and the World Bank during their transition periods.

A third important step in transition economies is to focus on privatization (Fischer & Gelb 1991). Privatizing and restructuring state-owned properties were essential in order to change land ownership entirely. However, all four countries were facing a lack of skilled personnel to develop strategies and implement economic reforms, and property rights were often not effectively protected. Investment and growth were often hampered when the legal framework to protect property rights was missing in the transition countries (Bhatty 2002). Georgia started small-scale and large-scale privatization in 1993, and initiated voucher privatization, where citizens were given or could cheaply buy shares of a state-owned company, in 1995. Voucher privatization ended a year later. In 1999 the country started to register agricultural land titles. The privatization law allowed the sale of private land. Armenia's privatization policy started in 1991 with land reforms and small-scale privatization and was followed by a privatization law in 1992. In 1994 the voucher privatization was initiated, followed by large-scale privatization in 1995. According to the privatization law, companies which could not be sold after three attempts were liquidated. In 1999 Armenia also adopted a new law on property rights (EBRD 2000). Azerbaijan adopted its first law on privatization and private ownership rights in 1991. The next stage was undertaken in 1993, when the country adopted the small-scale privatization law, followed by large-scale privatization law in 1995. Actual small-scale privatization started one year later in 1996 (EBRD 2000). In 1992, Russia adopted a mass privatization program, but Russia's loans-for-shares approach led to a decline in credibility of reformers and politics in the country. Many large-scale privatization approaches favored politics and insiders, and were therefore less effective. The primary privatization method in Russia was through vouchers or direct sales. Russia was more successful in privatizing small-scale companies than large-scale companies by 2000 (EBRD 2000). Most FSU countries emphasized liberalization and privatization first, before improving their institutional performance (EBRD 2000). All four countries successfully privatized small-scale firms by 2000. However, Georgia realized a rapid liberalization, but failed with the subsequent institutional reforms. This picture also held true for Armenia and Azerbaijan.

The transition to market economies had major implications for institutions when the Iron Curtain fell. Changes in land reforms were part of the policy shift which mostly occurred in the agricultural sector in the form of redistribution. Under Stalin agriculture was controlled by large collective farms, but once the privatization process in 1991 started, major changes in the agriculture sector took place in the FSU (UNEP-GRID 2002). During the Soviet Era, the Caucasus region had strong agricultural sectors and supplied products like corn, grapes, tobacco, fruits and tea throughout the entire Union of Soviet Socialist Republics (USSR). However, the countries were highly specialized and after the collapse, shortage of basic food supply became a major problem (UNEP-GRID 2002). In 1997, the agricultural sectors in Armenia, Azerbaijan and Georgia accounted for 20% of the country's total GDP. This grew to 30% by 2000. Agriculture became very important sector and the restructuring of the entire sector was a huge task. Although, the largest agricultural land area was situated in the lowlands of the North Caucasus in Russia (UNEP-GRID 2002), agriculture was a major sector in Armenia, Azerbaijan and Georgia. For example, in 1999 14% of the population was employed in the agricultural sector in Armenia, and nearly one-third of Azerbaijan's population worked in the agricultural sector (Giovarelli & Bledsoe 2001; UNEP-GRID 2002).

Land reforms also affected the forest sector, which was mostly under Russian control and planned by Moscow for all member countries during the Soviet Union. As a result, forest management was therefore similar in all countries. Forest was either owned by the state (forest of general state importance) or by the collective or state agricultural enterprises (forest of local importance) and part of the land fund, but was not owned by private owners (EBRD 2000). The USSR Forestry Code from 1978 stated that the entire forest was divided in three categories, mainly in protected forest (group I), forest with restricted industrial use (group II) and industrial forest (group III) (Sayadyan & Moreno-Sanchez 2006). Although local communities did not have property rights, they relied on the natural resources provided by the forest. Kolkhozes were lacking a systematic and sustainable forest management system so smaller forest enterprises within the farm were established (Michel 2016).

During the Soviet Union most of the extensive logging took place in Russian temperate forest, where timber was easily accessible (Wendland et al. 2011). Georgia, Armenia, Azerbaijan and the North Caucasus were mostly importing timber from Russia during the time of the Soviet Union. After the collapse, an energy crisis resulted in an increased amount of woodcutting and collection of firewood especially in areas close to settlements (UNEP-GRID 2002). After gaining independence, Armenia, Azerbaijan, Georgia and Russia all passed a forest code. Up until this time, “forest” and “local forest” were terms which were vaguely defined in the different forest codes for each country and definition differed among the countries. This is still the case today. The vague definition of forest made it hard to monitor forests on a consistent basis. In general, over usage and unsustainable management were major problems in the forest sector and missing ownership rights affected governance performance (Michel 2016).

The collapse of the Soviet Union and the political reforms thereafter led to major changes in both the forest and agricultural sector. The independency of the countries and the policy shifts changed land use management and altered the way people used land resources. It is important to put these events in relation to the detected land use changes to enable stronger inferences.

3.2.2. Armed conflicts

The legacy of history, the of Soviet occupation and Russia’s powerful influence are main determinants for the political situation in the Caucasus nations (Cornell 2000; Zürcher et al. 2005). The treaty of Turkmanchai in 1828 marks the beginning of Russia taking over the control of the South Caucasus, and by April of 1921, Russia had succeeded in taking over control of all three states in the South Caucasus. The time of the Soviet Union from 1921-1991, was dominated by Lenin and Stalin and the idea of socialism (Cornell 2000, 2002). The collapse of the Soviet Union in 1991 was a severe socio-economic shock and led to major changes in the Caucasus region. The breakdown of the federal system of the Soviet Union and its planned economy forced the four countries to suddenly face tasks like nation building and decision making (Cornell 2000; Lerman 2001; Nussberger 2008; Witmer & O’Loughlin 2011; Freni 2013). Because the entire Caucasus region shows high ethnic differences and different national ambitions, major conflicts over territory and ownership took place. Socio-economic differences within and between countries, for instance due to unequal living standards, cultural differences, and economical disadvantages led to ethnic discrimination (Yamskov 1991; Freni 2013). This combination of factors resulted in four armed conflicts in Chechnya, Abkhazia, South Ossetia and Nagorno-Karabakh (Figure 3-2) (Nussberger 2008; Kolossov & O'Loughlin 2011; Baumann et al. 2015). Millions of people were displaced and forced to leave their homes (Zürcher 2007). The Chechen wars were the most brutal ones with 68.400 casualties and the Nagorno-Karabakh

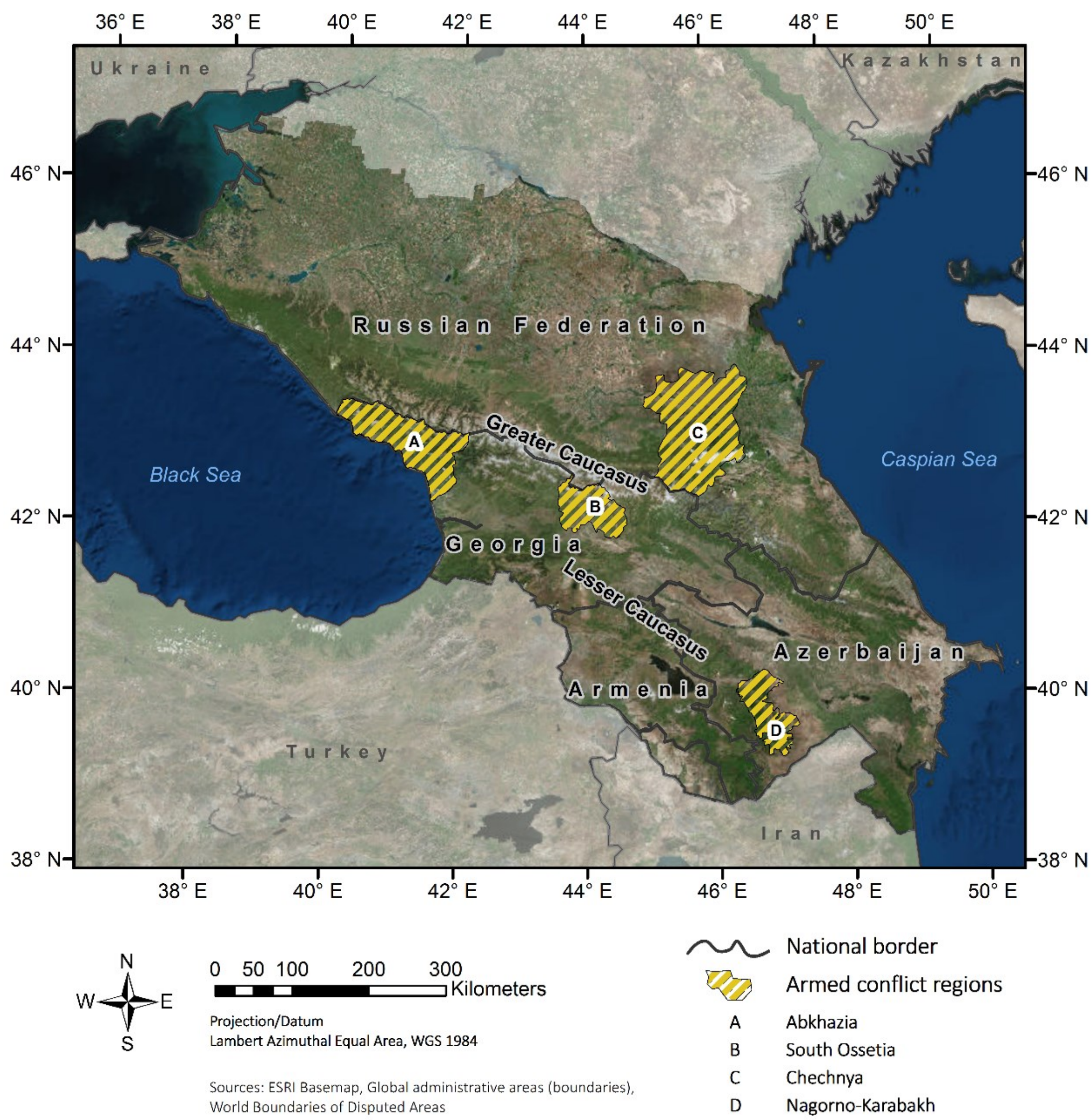

Figure 3-2: Overview of study area with major armed conflicts in Abkhazia, South Ossetia, Chechnya and Nagorno-Karabakh.

conflict displaced by far the most people (Table 3-1). Most of the armed conflicts which broke out in the early 1990s have yet to be resolved (Table 3-2) (Baev 2013).

Table 3-1: Number of casualties and displaced people for the four wars in the Caucasus (source: Zürcher 2007)

	# of casualties	# of displaced people
Chechnya 1994-1996, 1999-2002	68.400	881.000
Abkhazia 1992-1993	10.000	230.000-250.000
South Ossetia 1991-1992	600	42.000
Nagorno-Karabakh 1992-1994	20.000	~1.000.000

Table 3-2: Time line for the four wars in the Caucasus after the collapse of the Soviet Union.

1991	Collapse of the Soviet Union			South Ossetia	
1992			Abkhazia	South Ossetia	Nagorno-Karabakh
1993			Abkhazia		Nagorno-Karabakh
1994		Chechnya			Nagorno-Karabakh
1995		Chechnya			
1996		Chechnya			
…					
1999		Chechnya			
2000		Chechnya			
2001		Chechnya			
2002		Chechnya			
…					
2008				South Ossetia	
…					
2016					Nagorno-Karabakh

When armed conflicts happen, they take priority over reforms, causing economic investments to focus on the war itself. This is particularly the case for Armenia, Azerbaijan and Georgia (Bhatty 2002). Wars meant greater investment in military, as well as damage and destruction of infrastructure. During war time, the already challenging tasks of implementing economic reforms and state building were further impeded by deteriorating inter-regional and international trading as well as more corruption and crime.

3.2.2.1. Chechnya

Among the four Caucasian wars, the Chechen wars were the most tragic ones and were a legacy of the Soviet Union. The first (1994-1996) and second Chechen war (1999-2002) (Table 3-2) were armed conflict between the Russian Federation and the Chechen Republic, which is located in the east of the North Caucasus (Figure 3-2).

In 1944, under the Stalin regime, hundreds of thousands of Chechens and Ingush were deported to Central Asia and died as they were suspected of collaborating with the German Nazis. Their land was given away to adjacent countries and this led to major problems when the deported people came back to their home. Although the Chechen population was twice as big in 1979 as in 1959, the political sphere was dominated by Russians and the frustration of the Chechen people was high (Cornell 2000). In 1989, the Chechen Doku Zavgayev became leader of Chechnya, but was replaced by Dzhokhar Dudayev after the coup against Mikhail Gorbachev. Dudayev became president of the "Chechen Republic" in November 1991 (Cornell 2000; Zürcher 2007). After the collapse of the Soviet Union at the end of 1991, Boris Yeltsin did not recognize Chechnya's independence and sent troops to Chechnya, which failed, but successfully weakened Dudayev by deteriorating Chechnya's economy. Chechnya's economy crashed in 1992/1993 and the internal problems worsened and in April 1993 half of the people demonstrated against the president. In 1994, Dudayev and the opposition leaders, strongly supported by Russia, chased Chechnya into a civil war. The Russian involvement united the people behind Dudayev and prevented his downfall. Several factors may have inspired Russia's invasion which ultimately led to war; the increasing role of oil and a planned pipeline to the Caspian Sea, and the failed downfall of Dudayev. The Russian military killed Dudayev in 1995, but this did not change the people's decisiveness to fight for their independency. By summer 1996, the rebels regained control over Grozny and ended the war having earned recognition of Chechnya's statehood. In order to get reelected Yeltsin sought peace with Chechnya (Zürcher

1997). Although Chechnya won the war, the political situation was very unstable since then and resulted in a second Chechen war in 1999, yet to be resolved. The second Chechen war was started by Islamic rebels from Chechnya who invaded Dagestan to "liberate" it and unify it with Chechnya. Russian military entered Chechnya and pushed back the rebels and controlled all large settlements in the area. Large-scale military actions ended in 2002 (Zürcher 2007). The Chechen wars were exceptionally brutal and violent wars, with over 50,000 civilians killed and even more casualties, hundreds of thousands of refugees and the capital of Grozny fully destroyed (Zürcher 1997, 2007).

3.2.2.2. Abkhazia

The armed conflict in Abkhazia was fought from 1992 to 1993 (Table 3-2) in the region of Abkhazia, which is located on the coast of the Black Sea south of the Greater Caucasus (Figure 3-2). The armed conflict was between the Georgian government and Abkhaz militants, who wanted Abkhazia to secede from Georgia. Prior to the Soviet Union, Russia tried to gain influence by dividing the population in sub-ethnic groups after failing to take control over Georgia. Russia started to support minorities like Abkhazians and taught Russian as a second language in Abkhazia instead of Georgian. During the Soviet Union, this strategy was promoted even further, resulting in an anti-Georgia attitude. In 1921 the Bolshevik took over Tbilisi and declared Abkhazia as a Soviet Socialist Republic. In 1931 Abkhazia came under Georgian jurisdiction and lost the title of a "treaty republic". This move was seen as illegal by the Abkhazians as it was mandated by the Georgian Joseph Stalin. The Transcaucasian Federation was cancelled in 1936 and Abkhazia became part of the Georgian Soviet Socialist Republic. Under Stalin both Abkhazia and Georgia suffered, but compared to other Soviet Union countries, were still in a relatively good position. Abkhazia was resource rich and Georgia was very attractive for Russian tourists (Zürcher 2007). Though named for the controlling Abkhazian nation, Abkhazia experienced a massive influx of Georgians who soon became the majority. Most of the administrative positions in the government were filled by Abkhazians. Tensions between the two regions were always present, but suppressed by the strong Soviet hand. Under Gorbachev the political situation developed quickly and chaotically as Georgia saw the chance for independence. After demonstrations in Tbilisi in 1989, Russian troops repressed the tensions, but Georgia declared its independence in 1991. Abkhazia was open to a federation with Georgia, if it offered greater autonomy. It was declined by Georgia, who declared independence. In 1992

Georgian troops invaded Abkhazia to try to gain control over Abkhazia. Many fighters from the North Caucasus helped the Abkhazians to push back the Georgian military. The Sochi Agreement in 1993 stated a ceasefire and the Abkhazians regained most of the region. Russia used the unstable situation to position Russian troops in Georgia and to strengthen its influence in the region (Coene 2010). The war left many homeless and the number of refugees and internally displaced persons (IDPs) is estimated to be 250,000, with 10,000 killed on both sides (Zürcher 2007).

3.2.2.3. South Ossetia

The South Ossetia armed conflict from 1991 to 1992 (Table 3-2) was located in the region of South Ossetia, south of the Greater Caucasus and part of the former Georgian Soviet Socialist Republic (Figure 3-2). The armed conflict was between the Georgian government and South Ossetian militants, who wanted South Ossetia to become independent from Georgia. In 1918, South Ossetia did not want to stay in Georgia, when Georgia declared independence prior to the Soviet Union. At the beginning of the existence of the Soviet Union, South Ossetia became an autonomous oblast (AO) (the third lowest autonomous territorial unit in the Soviet Union (Rezvani 2008)), thus remaining under Georgian control. North Ossetia became an AO two years later, influenced by Russia. During the time of the Soviet Union, Georgia was always afraid of Russification and the smaller minorities gaining too much power with the help of Russia. In 1989 Georgia adopted a new law that declared Georgian the only official language in the country, leading to an even stronger motivation to South Ossetia to join North Ossetia. Later South Ossetia proclaimed their region as an independent democratic Soviet Union after ongoing discrimination from Georgia. They held elections without Georgia's approval (Coene 2010). When Georgia declared its independence from the Soviet Union in 1991, South Ossetia was not part of the decision as it saw itself as an autonomous region and was seeking a reunification with Russia. A ceasefire in June 1992 ended the war though violations of the ceasefire continued until 1995. In 1997 the Georgian president Eduard Shevardnadze visited South Ossetia and signed a peace declaration with the president of South Ossetia, however it did not end the frozen war. In 2008 tensions flared up and have yet to be resolved. Between 600 and 700 people died in the South Ossetia war and many more, an estimated 42,000, were displaced and had to leave their homes (Cornell 2000; Zürcher 2007; Coene 2010).

3.2.2.4. Nagorno-Karabakh

The Nagorno-Karabakh conflict between Armenia and Azerbaijan over the region of Nagorno-Karabakh, located in the South Caucasus and part of the Lesser Caucasus (Figure 3-2), escalated to a full scale war between 1992 and 1994 (Table 3-2), but is still ongoing. After 1823, Russia organized an exchange of people in Karabakh and many Armenians moved to the region, accounting for half of the population in 1880. With the oil boom in Baku at the Caspian Sea in the late 19th century, issues with Azeri started to rise. Supported by Russia, Armenians benefited from the oil causing first violent conflicts between Armenians and the Azeri. In early 1918, when the Russians started to invade the South Caucasus, Turkish leadership also advanced its interest in the Caucasus and a peace treaty led the way to form the Transcaucasian Federation in Tbilisi. An invasion by the Ottoman armies ended the federation and resulted in independence of Georgia, Azerbaijan and Armenia under terms made by Turkey. The establishment of the three countries was difficult, as nationalities overlapped considerably. The Armenians in particular, were spread out over the entire South Caucasus. However, disputes over the Nagorno-Karabakh region continued and by 1921, the Red Army of the Soviet Union took control of all three nations. In the early 1920s Stalin divided the Armenian and Azeri people by creating the Armenian enclave of Nagorno-Karabakh, which became an autonomous oblast in 1923, aiming to strengthen his power after the principle of "divide and rule" (Cornell 2000).

During the era of the Soviet Union, the conflict was suppressed under Joseph Stalin and ignored by Nikita Khrushchev. It reemerged under Gorbachev and his glasnost policy (Cornell 2000). In 1988 the first wave of Azeri refugees (tens of thousands of peoples) arrived in Baku, after being forced to leave Armenia. By 1990, the parties' paramilitary groups grew in size resulting in multiple clashes and by June 1991 the conflict claimed more than 800 casualties before escalating into a full-scale war from 1992-1994 with the ethnic cleansing of Khojaly by Armenians. In a counter offensive by the Azerbaijani military, 40,000 Armenians left and sought refuge. In 1993 the Armenian military took back the previously lost areas and an additional 60,000 people were forced to flee after further offensives. Armenians took advantage of inner political problems in Azerbaijan to extend into nearby regions, adding at least half a million refugees in Azerbaijan in addition to those who already fled. This ended in a military victory of the Karabakh Armenians, and Nagorno-Karabakh was slowly integrated to Armenia. The conflict led to more than 20,000 casualties and almost 1.5 million refugees and displaced people, which caused major problems in Azerbaijan, where the displaced people represent almost 15 percent of the population (Zürcher 2007).

In summary, armed conflicts have social, economic and ecological implications and the consequences affect humans, land and biodiversity (Mitri et al. 2014; Gaynor et al. 2016). Densely populated areas are usually the most affected, because armed conflicts have not only a high local effect, but can spillover into areas far away (Baumann & Kuemmerle 2016). Furthermore, depending on the political circumstances, armed conflicts can cause indirect long-lasting effects through trade embargos or a decline in foreign investment (Le Billon 2000; Baumann & Kuemmerle 2016). Wildlife is often affected by a combination of military tactics, institutional changes, the displacement of people, altered economies and many other factors (Gaynor et al. 2016). In order to develop post-conflict recovery plans and to prevent harm due to future conflicts, mapping land use is an essential step for policy decisions (UNHCR 1998).

4. Chapter I: Land use classification and change detection in the Caucasus Mountains between 1985 and 2015.

4.1. Introduction

Land use change is a major source of global environmental change (Foley et al. 2005). Managing natural resources as well as providing ecosystem services are fundamental for human well-being (Foley et al. 2005; Gómez et al. 2016). Humans convert natural ecosystems to satisfy human specific demands. Most of the human activities come at the expense of natural resources. Although huge areas of forests have been cleared, there is a promising trend in a global slowdown of deforestation as forest management has changed within the last 25 years (FAO 2015). Forests are essential for humans and not only provide wood, but also deliver long-term environmental benefits like clean air and mitigation of climate change (FAO 2015). On the other hand, agriculture accounts for more than one-third of the land area globally (FAO 2016). Intensive irrigation of agricultural land causes degradation of water quality and water flow regulation (Foley et al. 2005) and when humans convert ecosystems into a different land use the related benefits get lost (DeFries et al. 2004). However, natural expansion of forest occurred when agricultural fields were abandoned after the collapse of the Soviet Union (Lambin & Meyfroidt 2011). In order to understand land use change and to create sustainable land management, it is essential to detect spatial and temporal patterns of change. Having this information at hand allows us to assess the underlying drivers which led to the observed pattern.

Land use change drivers can be categorized as proximate or underlying drivers (Lambin & Geist 2006; Meyfroidt 2016). Proximate drivers can be defined as more immediate and direct forces and occur mostly on a local level. Underlying drivers can be seen as the causes which underpin proximate drivers. They can be related to for instance social, political, economic or cultural circumstances and have a broad spatial scale from local to global (Geist & Lambin 2001). Political changes and armed conflicts are socio-economic shocks which can alter land systems rapidly, but can have long-lasting effects (Jepsen et al. 2015).

In order to map long-term rather than short-term changes, it is essential to have detailed information over multiple time periods (Hansen et al. 2013). Remote sensing is widely used for identifying and assessing land use types on a broad temporal and spatial scale (Rogan & Chen 2004). With the opening of the Landsat archive (Woodcock et al. 2008; Wulder et al. 2012) the spatial and temporal coverage of imagery increased fundamentally. Landsat data provide a high spatial resolution (30 m) and a revisit time of 16-days, which makes it ideal for land use mapping and allows for capturing even fine scale forest changes than MODIS (Moderate Resolution Imaging Spectroradiometer) can (Cohen & Goward 2004; Potapov et al. 2011; Griffiths et al. 2014). Remotely sensed data might not always be adequate for land use change assessment due to infrequent data availability or clouds and shadows (Gómez et al. 2016). To overcome shortcomings and to increase the amount of cloud-free and radiometrically consistent imagery, seasonal multi-year best-available-pixel (BAP) compositing can help to monitor large areas and to asses forest cover changes (Griffiths et al. 2013; Frantz et al. 2016). Using annual BAP (Frantz et al. 2016) we are able to compare different time periods and to assess land use change in the Caucasus Mountains for more than three decades.

In mountainous regions, satellite-based land use mapping is affected by atmospheric and especially topographic effects (Tan et al. 2013; Vanonckelen et al. 2013). Depending on the topography, different solar illumination angles result in a variation of recorded reflectance. Topographic illumination effects, especially shadows and steep slopes, can cause distortions and therefore preprocessing techniques are crucial to improve accuracy of satellite imagery classification (Vanonckelen et al. 2014). Topographic correction methods aim to remove topographic effects by calculating the radiance the area would receive without topography.

Studies for one or two Landsat footprints have shown that topographic correction improved overall accuracy for both Landsat TM-5 and OLI-8 (Pimple et al. 2017) and class accuracy especially for coniferous and mixed forest classes (Vanonckelen et al. 2013). Forest change maps derived from topographic corrected Landsat imagery highly differed from forest change maps calculated from original imagery and increased the overall accuracy up to 34% (Tan et al. 2013). Yet, large-area studies which look at more than two Landsat footprints are missing. The Caucasus Mountains with its steep slopes, high elevation profile and broad coverage of forest is an ideal study area to assess topographic correction on change detection for a large area.

To date, most studies in the Caucasus looked at land use change on a smaller regional level rather than on a broad spatial scale. Studies found highest canopy removal within the Sochi National Park after 2000 related to the Olympic Games (Bragina et al. 2015), but relatively small forest canopy changes compared to other studies in Eastern Europe like Romania or former Soviet Union Western Russia where forest loss was much higher (Baumann et al. 2012; Griffiths et al. 2012). In Nagorno-Karabakh and Azerbaijan agricultural abandonment was high near the battle ground in Nagorno-Karabakh after active fighting (Baumann et al. 2015). In Georgia forest loss increased little since 1990s, with an even smaller amount of forest gain (Olofsson et al. 2010). Although local studies exist for the Caucasus region, broad scale cross-national studies are missing.

In this study my goal is to map forest and agricultural changes across the Caucasus region from 1985 to 2015 using Landsat imagery, applying image preprocessing and 'random forest' for classification. My specific research questions are:

1. Does broad-scale topographic correction of Landsat imagery improve classification accuracy?
2. How was forest and agricultural land distributed before the collapse of the Soviet Union, how did that change over time and what are the spatial patterns and the differences between the countries?

4.2. Methods

In order to calculate Caucasus wide composites based on Landsat imagery, I have analyzed 35 WRS-2 footprints and 10,891 Landsat 4-8 images from the U. S. Geological Survey archive (USGS) (Figure 4-1). I have converted the L1 digital number (DN) values to a surface reflectance by masking clouds and cloud shadows and applying radiometric and geometric correction. To identify clouds and cloud shadows I have applied a modified Fmask algorithm (Zhu & Woodcock 2012; Zhu et al. 2015; Frantz et al. 2015). The radiometric module included a DN to top of atmosphere (TOA) reflectance conversion (Chander et al. 2009) and a correction of adjacent effects, and was based on the radiative transfer code correction and an added topographic correction factor (Tanre et al. 1979; Teillet et al. 1982; Kobayashi & Sanga-Ngoie 2008). I have used a water vapor database calculated from MODIS data to account for gaseous transmittance and a combined database- and image-based approach by using a dark object database to estimate aerosol optical depth. I further have applied topographic correction by using a modified C-correction using the 1-arc-second (~30 m) digital elevation model (DEM) from the Shuttle Radar Topography Mission (SRTM).

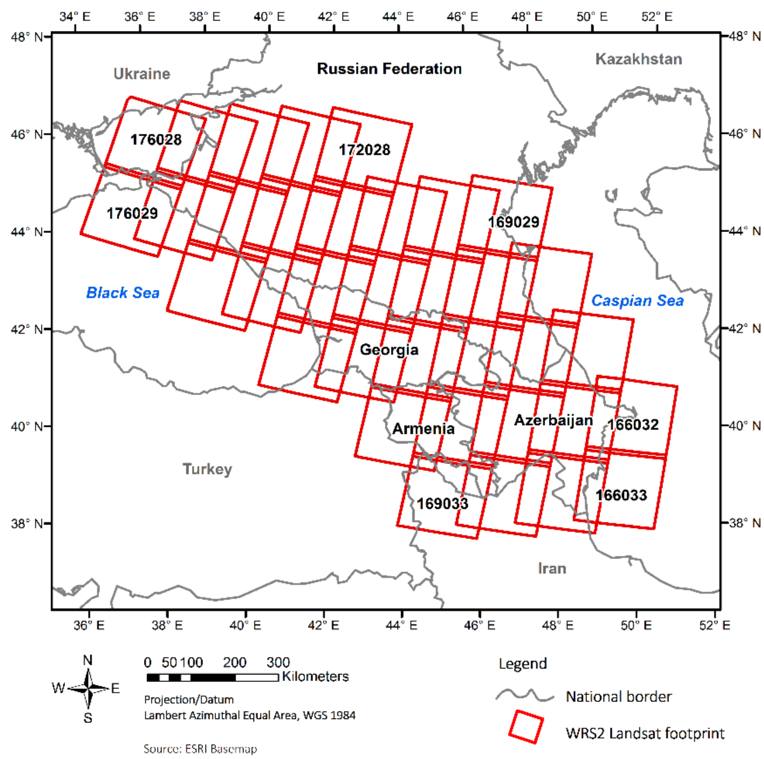

Figure 4-1: Overview of WRS2 Landsat footprints covering the Caucasus region between the Black Sea and the Caspian Sea.

I will calculate pixel-based composites for the target years 1985, 1990, 2000, 2005, 2010 and 2015 to generate a gap-free product with clear-sky observations covering my entire study site. Gaps in imagery availability do not allow for dense time series analysis. I will determine the suitability of each pixel based on several individual scores, such as acquisition day, acquisition year, distance to clouds or cloud shadows, potential contamination with haze, spectral correlation and off-nadir view angle. The highest sum of all scores defines the best pixel observation which in turn is used for the composite (Frantz et al. 2016). To avoid errors due to phenological differences within a pixel I will embed land surface phenology (LSP) in my compositing. Land surface phenological metrics have been derived for each pixel by applying the Spline analysis of Time Series (SpliTS) algorithm, which fit spline models to remotely sensed time series (Mader 2012). The pixel-based LSP will be used to dynamically adjust the day of year (DOY) for each pixel. I will define start of season (SOS), peak of season (POS) and end of season (EOS) as anchor sequence for my composites (Frantz et al. 2017). Depending on the data availability for the compositing period I will add ± 1 or ± 2 years to the target year (Figure 4-2).

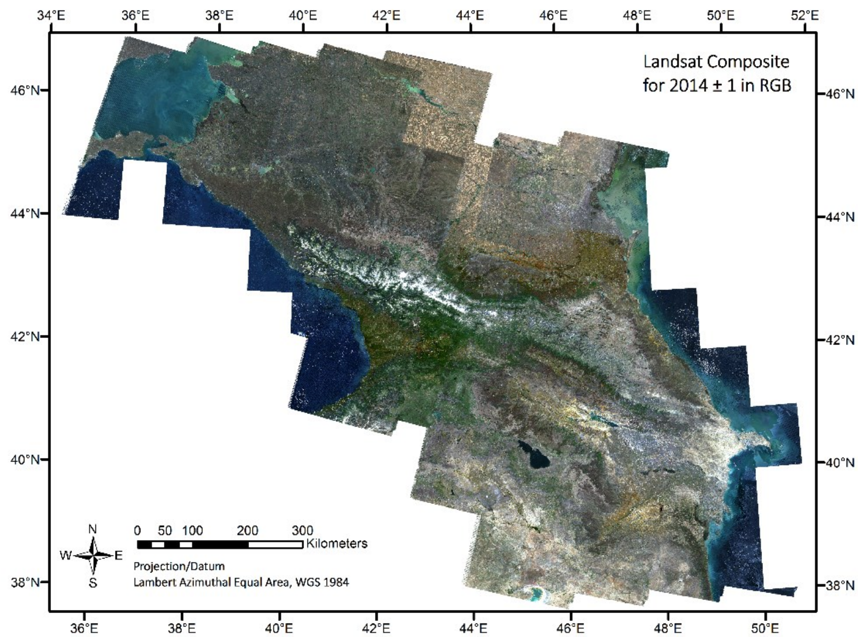

Figure 4-2: Start of season Landsat composite for 2014 ± 1 year.

To quantify land use change I will create layer stacks with the best-observation composites for each year and metrics layers for each composite to quantify forest loss/gain and agriculture abandonment/expansion. In order to assess topographic effects on classification accuracy, I will apply a modified C-correction to one set of layer stacks (2010/2015) but not to a second one (2010/2015) to assess accuracy for change detection. I will also compare classification accuracy for both topographically corrected and uncorrected single year classifications (2015) (Figure 4-3). The modified C-correction is using a precompiled DEM and is a physical based correction of topography with an additional parameter C, which is empirically derived for each pixel in order to avoid overfitting (Kobayashi & Sanga-Ngoie 2008).

To obtain training data for the classification maps, I will select homogenous areas and digitize polygons for each class, including classes of changes, based on Google Earth. I will classify stable coniferous forest, stable mixed forest, stable deciduous forest, permanent active agriculture, permanent rangeland, permanent bare ground, wetland, water, permanent snow and ice, urban, as well as change classes of forest loss/gain for one lumped forest class type (from forest to agriculture/rangeland/bare ground/urban and vice versa), agricultural abandonment (from active agriculture to rangeland), new agricultural land (from rangeland/forest to active agriculture) and urban expansion (rangeland/bare ground to urban). Forest types will be identified based on different seasons including fall and winter imagery. Agriculture will be identified based on the shape of the cultivated fields, the cover of the field during one year and plowing patterns on the field. Areas with a mix of soil, sand, sparse vegetation, shrubs and grassland will be labelled as rangeland. Bare ground is defined as high altitude areas with rocks and soil. Google Earth high-resolution imagery and the Landsat composites themselves will be used to identify areas of interest. In addition, I obtained ground truth data during a field trip in 2016 in Azerbaijan and Georgia.

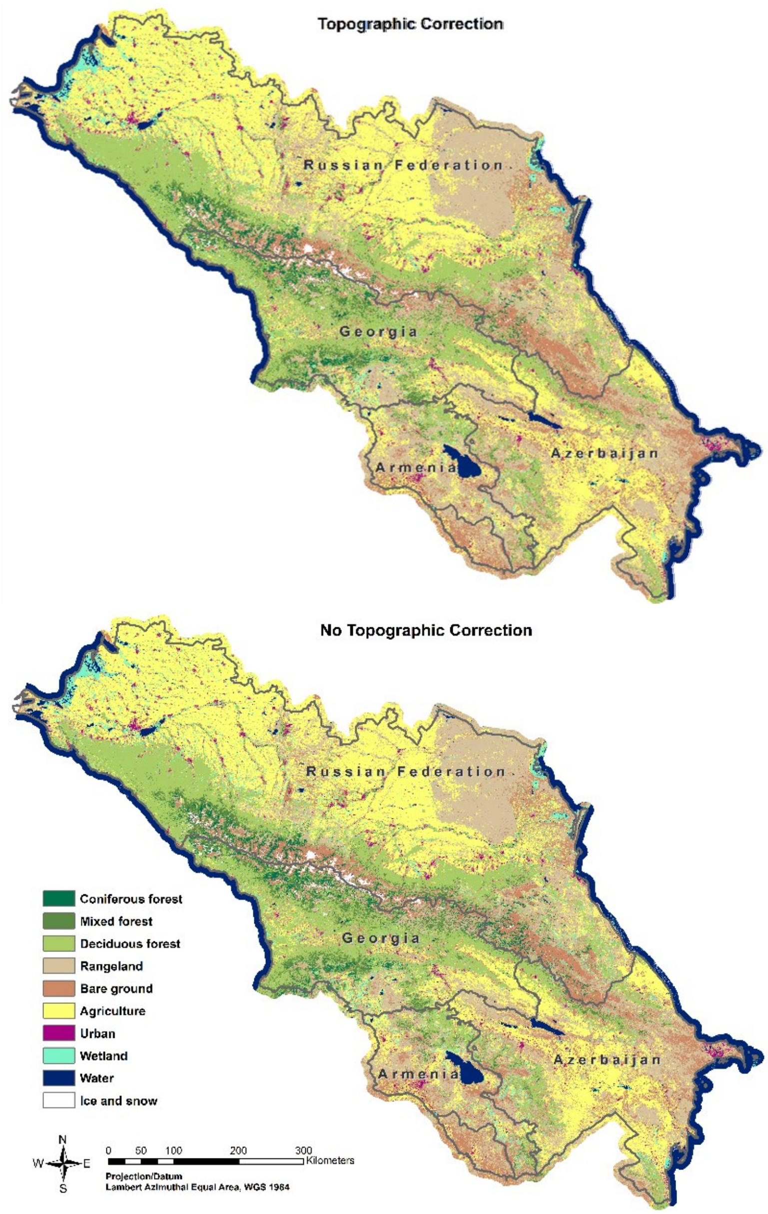

Figure 4-3: Land use map for the Caucasus with and without topographic correction for 2015.

I will randomly collect 3000 pixels with a minimum distance of 30 m per class as training samples for the 'random forest' classifier. 'Random forest' is a classifier that consists of a collection of tree-structured classifiers chosen by drawing a subset of training samples through replacement (Breiman 2001; Belgiu & Drăguţ 2016). It is widely used in the remote sensing community for classification due to its high accuracy, its ability to handle noisy and highdimensional input data and the fact that it is generally computationally inexpensive (Belgiu & Drăguţ 2016) . In a follow up step I will run a majority filter including eight surrounding pixels in order to eliminate separate single pixels and to reduce the salt and pepper effect. I will use the Global Urban Footprint (GUF) layer provided by the German Aerospace Center (DLR) in order to map urban areas.

To evaluate my classification maps, I will perform accuracy assessments including overall accuracy as well as user's and producer's accuracy for all my classification maps (Congalton 1991). I will gather stratified random samples of 200 points in each stable class and 200 points for all change classes of my classification map and I will correct the resulting confusion matrix by the area proportions of each class (Olofsson et al. 2014; Griffiths et al. 2014).

4.3. Expected results

I expect a higher accuracy for my topographically corrected classification. I expect the topographic correction to improve the separability of the different forest types, mainly coniferous forest and mixed forest and I expect a better distinction of coniferous forest and bare ground in steep terrain by removing topographic effects. I expect that the topographic correction has a higher influence in the mountainous regions where shadows and steep slopes are a major challenge for classification. Regions with little difference in elevation like lowlands with agricultural fields and urban areas should hardly be influenced by topographic effects.

Regarding my land use detection, on a temporal scale I anticipate major changes in forest cover and agriculture close to the collapse of the Soviet Union and after the armed conflicts in the early 1990s. I expect an increase in forest cover over time due to improved forest management and regrowth on abandoned agricultural fields. For agriculture I expect different results. I expect agricultural abandonment in the rural areas of Armenia, Azerbaijan and Georgia and an increase in agricultural activity close to the large urban centers. I expect little changes in the northern part of the Caucasus in Russia, as it was and still is an important agricultural area.

4.4. Significance

My study will make novel contributions to the scientific community by providing explicit spatial and temporal information about patterns and rates of land use change in the Caucasus region from 1985 to 2015 for Armenia, Azerbaijan, Georgia and the North Caucasus in the

Russian Federation. My main methodological contribution is to assess the application of a topographic correction method for classification accuracy for a large study area (Frantz et al. 2016). To my knowledge this will be one of the first studies which will apply topographic correction on a broad-scale, including multiple Landsat footprints. My study will provide insight for conservation and management implications by identifying areas of forest gain and forest loss as well as agricultural abandonment and expansion for the whole Caucasus region. Land use policies require such information to improve livelihood, protect biodiversity and safeguard ecosystem services.

5. Chapter II: Land use change in the Caucasus Mountains and the role of armed conflicts.

5.1. Introduction

Armed conflicts are among the most drastic shocks on land use and occur frequently on a global scale (Baumann & Kuemmerle 2016). The effects may be severe and long-lasting. Economic crises, socio-economic breakdowns and humanitarian crises like armed conflicts are among the fast drivers of change. Local effects of armed conflicts can result in illegal logging of forest or high rates of agricultural abandonment (Hostert et al. 2011; Baumann et al. 2015; Baumann & Kuemmerle 2016). The effects of armed conflicts on land use can vary depending on political conditions in the country (Eklund et al. 2017) and vary dramatically over space (O'Loughlin & Witmer 2011). On the one hand, there was widespread cropland intensification of land controlled by the Islamic State (IS) in the northern part of Iraq, and in areas inside and outside of the IS zone (Eklund et al. 2017), and on the other hand, agriculture was abandoned close to the warzone in the Nagorno-Karabakh conflict between Armenia and Azerbaijan (Baumann et al. 2015). Further, violent events of the civil war in Dafur, Sudan, for instance were strongly linked to a internally displaced persons (IDPs) flow (Alix-Garcia et al. 2013). The resulting major land use changes showed a regrowth of vegetation in the countryside and a decrease of vegetation in the periphery of large cities as the numbers of IDPs increased (Alix-Garcia et al. 2013). There was also a degradation of natural resources in the surrounding areas of refugee/IDP camps (Spröhnle et al. 2016).

The Caucasus has a long history of armed conflicts and war-torn countries. The conflicts between Georgia and Abkhazia, Georgia and South Ossetia, Armenia and Azerbaijan and Russia and Chechnya arose after Mikhail Gorbachev's policy of perestroika and glasnost and turned into full-scales wars after the collapse of the Soviet Union (detailed description under 3.2.2). All four armed conflicts resulted in more than 2,000,000 displaced people (Zürcher 2007). The displacement of thousands of people due to armed conflicts can have far reaching effects and land use change can be linked to conflict induced migration (Baumann et al. 2015). IDPs and refugees are often unable to return to their homes and seek for new land in other parts of the country in order to make a living, consequently creating new patterns of land use far away from the conflict zone.

Geospatial information is a crucial factor for humanitarian organizations to deliver help and access to natural resources to refugee's livelihood (UNHCR 1998). In order to get that information remote sensing can be key. Thanks to the opening of the Landsat archive, researchers can make use of the full depth of high spatial satellite imagery, covering large areas since the 1970s. Especially in war-torn areas, where field surveys are dangerous, remote sensing can provide accurate ground information on land use (Witmer 2015). With a high spatial resolution of 30 m, Landsat is commonly used satellite for land use change detection (Cohen & Goward 2004).

The Caucasus region with its multiple armed conflicts forced millions of people to flee, raising the question of how strongly and in which way armed conflicts affect land use. Observational data can be used to make inferences about the effects of armed conflicts on land use on a broad spatial and temporal scale (Butsic et al. 2017). In order to make context specific and regionalized land use policy, spatial explicit assessment of land use dynamics are important (Kuemmerle et al. 2016).

In this study my goal is to assess the causal effects of armed conflicts on land use change by employing quasi-experimental methods such as 'matching' and 'difference-in-differences'. My specific research questions are:

1. What were the local effects of armed conflicts on land use change and how far did the effects spill over into adjacent and father away areas?
2. How did the effects of armed conflicts differ between the four countries Armenia, Azerbaijan, Georgia and Russia?

5.2. Armed conflicts and internally displaced persons (IDPs)

Armed conflicts in the Caucasus left people without homes and forced them to leave their land. Internally displaced persons (IDPs) were under weak governmental protection and durable solutions remain unresolved. In Azerbaijan and Georgia the absence of peace treaties made it impossible for IDPs to return to their homes or to find housing and jobs elsewhere (IDMC 2011). 230,000 IDPs were registered in Georgia in 2010, as a result of the armed conflicts in Abkhazia and South Ossetia in the early 1990s. An estimated 40,000 IDPs returned to Abkhazia, but in South Ossetia there were still 10,000 IDPs in 2010. Other than one district in Abkhazia, Gali, both Abkhazia and South Ossetia did not allow IDPs to return to their homes as authorities were afraid of ethnic unbalance. The IDPs who returned to Gali started to recultivate their agricultural land. In South Ossetia, many people were prevented from returning to their homes by the installation of a 50 km fence along the border (IDMC 2011).

In Armenia 8,400 people remained internally displaced due to the Nagorno-Karabakh conflict in 2010 and 65,000 fled from areas close to the border of Azerbaijan and Armenian enclaves in 1992. Some returned to their homes, but in general the situation remained problematic without governmental support (IDMC 2011). The Azeri government registered 586,000 IDPs by the end of 2010. Less than 10 % returned to their homes. In Azerbaijan IDPs were spread over the country’s districts, but nearly half of them moved to Baku. The government handled IDP policy as temporary and offered help only until return to Nagorno-Karabakh was possible. However, the help provided was not intended to solve long term displacement (IDMC 2011). Nevertheless, Azerbaijan promoted options for enhancing IDP self-reliance.

In the North Caucasus, the peak of displacement was reached between 1994 and 1999 with up to 800,000 people due to the internal armed conflict in Chechnya. Many IDPs fled from Chechnya to Ingushetia, but governmental disagreement between districts made it hard for IDPs to find a permanent home. In 2009 the United Nation Refugee Agency (UNHCR) reported around 80,000 IDPs in the North Caucasus.

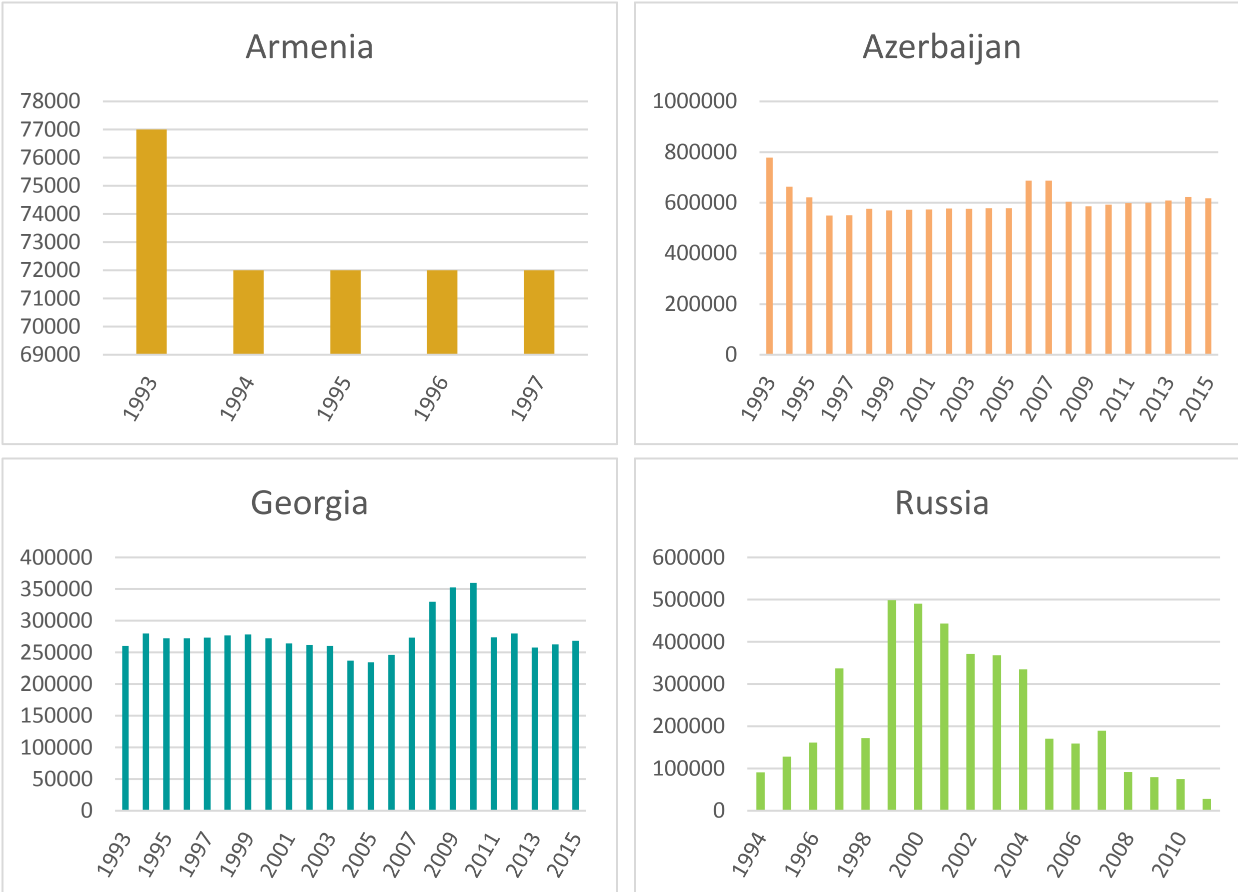

Figure 5-1: Internally displaced persons (IDPs) in Armenia, Azerbaijan, Georgia, Russia (source: UNHCR)

5.3. Methods

I propose to assess the effects of a) the South Ossetia war in 1991-1992, b) the Abkhazian war in 1992-1993, c) the Nagorno-Karabakh conflict (1992-1994) and d) the first and second Chechen war (1994-1996, 1999-2002) on land use change (Figure 3-2). I will use the land use maps from Chapter I for 1985, 1990, 2000, and 2010. The changes between 1985 and 1990 capture land use trends before the collapse of the Soviet Union, changes between 1990 and 2000 will capture the land use trends during the wars and the changes between 2000 and 2010 will detect the land use trends after the war. I am aware that the collapse of the Soviet Union can cause similar effects of land use change as armed conflicts. However the collapse of the Soviet Union should have nationwide consequences, whereas armed conflicts will induce a strong spatial component due to their inherent local war zones.

In order to identify the effects of armed conflicts on land use change I will use a quasi-experimental design, the 'difference-in-differences' (DiD) method, to compare land use change within and outside the battle fields (treatment) over time (1985 – 2010) (Figure 5-2).

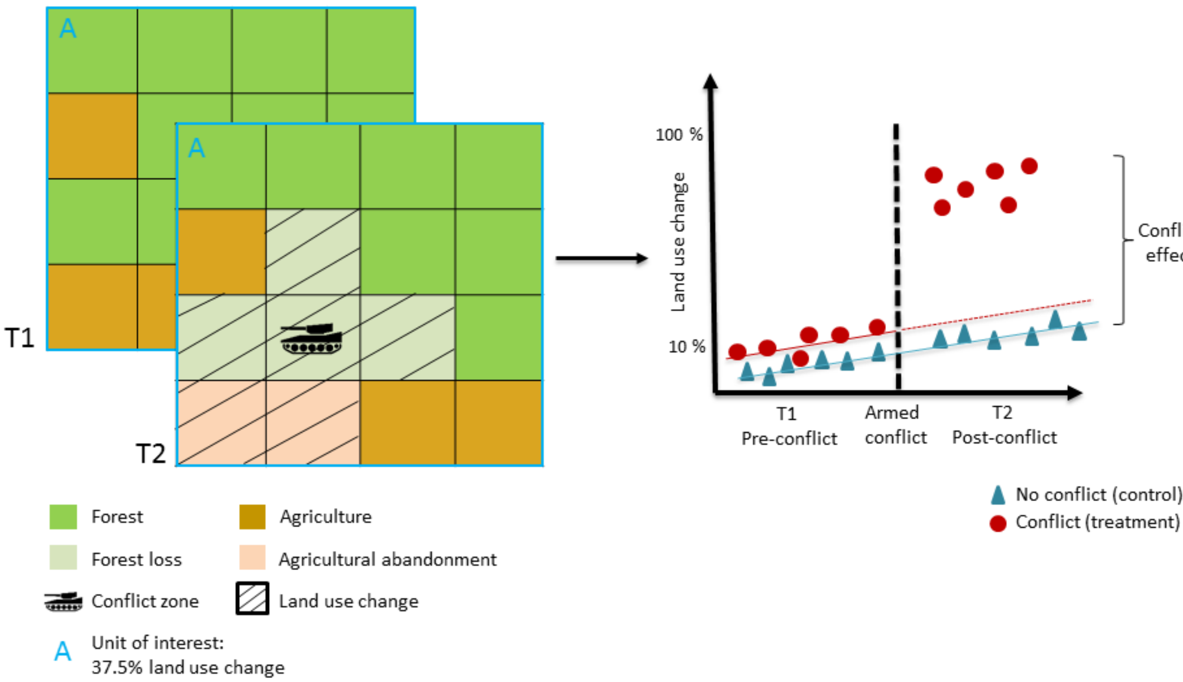

Figure 5-2: Visualization of Difference-in-Differences method. The event of an armend conflict can be interpreted as the treatment effect [modified after Butsic et al. (2017)].

This quasi-experimental approach is ideal for my data set as there is temporal variation in the treatment (armed conflicts) and observations before and after the treatment are available (Butsic et al. 2017). Further, quasi-experimental approaches correct for the non-random placement of the treatment, here armed conflicts, across the landscape (Jones & Lewis 2015). The 'difference-in-differences' has two major assumptions. First, the treatment and the time-invariant unobservable are additively separable, and second, we assume that without the treatment, the treatment and the control group would result in a similar land use change outcome (Butsic et al. 2017). Although, the later assumption is not testable, it can be visually examined. The DiD approach models the treatment effect as the difference between the treated (area of armed conflicts) and the control group (without treatment) before and after a treatment (occurrence of an armed conflict) (Meyer 1995).

In order to define conflict zones, I will test multiple buffers up to a radius of 35 km around major conflict sites, because most agricultural abandonment was found within 35km in the Nagorno-Karabakh conflict (Baumann et al. 2015). I will derive major conflict sites from the

Peace Research Institute Oslo (PRIO) 'conflict site' data base and the Georeferenced Event Dataset from the Uppsala Conflict Data Program (UCDP GED). Further I will subdivide my study area in micro-landscape units (~1 km^2) in order to receive land use change percentage as an outcome for each of my micro-landscape units (Sims 2014). For both time steps (pre-conflict and post-conflict) I will collect 200 sample micro-landscape units within the buffer defining the conflict zone (treated units) and 200 sample micro-landscape units outside the area (control units). In order to find comparable sample units regarding the remaining covariates for both the control and the treatment group, I will employ 'matching' statistics using a propensity score, which is the probability of a given area to receive a treatment based on a set of covariates that could influence land use change in certain area such as slope, aspect or distance to settlement (R package 'MatchIt').

In a follow up step I will use a fixed effects linear model to assess the difference between the pre-conflict and the post-conflict time period. Fixed effects control for time-invariant omitted variables (Wendland et al. 2015). This will allow me to estimate the effect of armed conflicts on land use (forest change, agricultural abandonment). The formula for the fixed effects panel regression model is the following:

$$\begin{aligned} &\mathit{Land\ use\ change\ in\ a\ microlandscape} \\ &\quad = \alpha + \gamma * conflict_i + \lambda * d_t + \delta(conflict_i * d_t) + m_i + X_{it} + \varepsilon_{it} \end{aligned}$$

conflict: dummy for treatment

d_t: dummy for observation in post-conflict

m_i: pixel level fixed effects

X_{it}: time-varying variables

ε_{it}: error term

I will use the R-package 'plm' which includes linear regression models for panel data. I will use distance to road, distance to settlement, slope, aspect and elevation as my covariates. Further, I will use two dummy variables. The first one defines the time period and is 0 for the time before the armed conflict and 1 for the time after the armed conflict. The second dummy variable captures the actual conflict zones in the post-conflict time step (conflict period * armed conflict) and is denoted as 1. The coefficient of this dummy variable represents the effect of armed conflicts on land use change (Butsic et al. 2017). I will use a T-Test to test the significance of a single given parameter, namely time period * armed conflict intensity, given all the other parameters in the model.

To test for distant effects I will again use the ‘matching’ statistics procedure and compare the land use changes within the four war zones with land use changes within the countries being involved in the conflicts (Chechnya vs. Ingushetia, Abkhazia vs Georgia/North Caucasus, South Ossetia vs. Georgia/North Ossetia, Nagorno-Karabakh vs. Armenia/Azerbaijan). I will calculate the change rates of forest loss and gain, agricultural abandonment and new cultivated lands for each region.

5.4. Expected results

I expect to find high rates of agricultural abandonment within the active conflict zone and in the adjacent areas for all four conflicts.

For Abkhazia I expect high rates of agricultural abandonment as many people with Georgian ethnic background had to leave the area and resettled in urban areas in Georgia. I expect some new agricultural fields close to the Abkhazian border as people were hoping to return to their homes after the conflicts ends. I expect small rates of forest change as Georgia’s forest is mostly located in the Greater Caucasus, which is hard to access.

I expect similar results for South Ossetia as for Abkhazia. However, I expect higher rates of new agricultural fields in North Ossetia, where many people who left their homes had relatives and forest loss close to the new agricultural fields. For both Abkhazia and South Ossetia I expect forest gain on abandoned fields in later time periods.

For the Chechnya war I expect a high local agricultural abandonment located close to Grozny as the city was almost completely destroyed. I expect agricultural expansion in neighboring Ingushetia and the northern part of Chechnya. I expect to find higher rates of deforestation in adjacent forest south of Grozny in the foothills of the Greater Caucasus.

For Nagorno-Karabakh I know that forest changes were low, but agricultural abandonment rates were high in the conflict zone and in areas close to it. New agricultural development was found in Azerbaijan, where most of the IDPs returned to. I expect to confirm the results from Baumann et al. (2015). In addition I expect new cultivated land in Armenia.

5.5. Significance

With this chapter, I will help to understand the spatial effects of armed conflicts on deforestation and agricultural abandonment. I will make a novel contribution to science by identifying differences in causal effects of armed conflicts on land use and by improving the understanding of distance effects of armed conflicts for a large study area.

'Difference in difference', 'matching' statistics and panel data are widely used in economics to identify the effect of for example public interventions (Abadie 2005), but have so far been rarely applied in land use science (Butsic et al. 2017). My main methodological contribution is to be one of the first studies that applies both techniques to identify the drivers of land use change and to make causal inferences to armed conflicts.

My study will provide social benefits by identifying land patterns, which need to be considered by humanitarian organizations to respond to a humanitarian crises. In order to provide access to land to refugees, organize resettlement and return of IDPs and to improve the livelihood of poor and affected people, knowledge about land use trajectories are fundamental.

6. Chapter III: Effectiveness of protected areas in the Caucasus Mountains related to socio-economic shocks.

6.1. Introduction

Protected areas (PAs) are dedicated to safeguard forest and wildlife and are a cornerstone protecting biodiversity and ecosystems (UNEP-WCMC and IUCN 2016). Further, protected areas provide carbon storage, watershed protection and other ecosystem services such as recreation (DeFries et al. 2007). However, when forest is not protected, it is also an ecosystem which provides human needs such as fire wood and timber (Foley et al. 2005) and is exposed to increasing pressure depending on the socio-economic situation in the region (DeFries et al. 2007; Naughton-Treves et al. 2011). Illegal logging and forest degradation are two of many threatening processes forests are facing. Protected areas are a major conservation tool in order to prevent these threats. Given the high value of forest ecosystems for biodiversity conservation, it is important to understand whether conservation tools like protected areas fulfill their goals.

The Caucasus is one of the world's 25 biodiversity hotspots, harboring 1,600 endemic plant species and 32 endemic mammal species including the Caucasian leopard (Myers et al.

2000). The forest biome which covers 18.52% of the Caucasus Ecoregion is a priority biome for many of the endangered species like the Caucasian leopard, the Bezoar goat or the Caucasian salamander (Zazanashvili et al. 2012). Protected areas cover 28.1% of the Caucasus biodiversity hotspot region (Myers et al. 2000), but illegal logging and fuel wood harvesting are major threats in the region (Zazanashvili et al. 2012).

Successful management and sustained financing of protected areas are essential to safeguard the Caucasian flora and fauna diversity and maintain healthy populations. But this is not always given in times when socio-economic shocks such as policy shifts occur. The collapse of the Soviet Union in 1991 was a policy shift that led to wide-ranging institutional changes causing rapid and large-scale land use changes such as agricultural abandonment and illegal logging (Prishchepov et al. 2012). The Transcaucasian countries declared independence shortly after the collapse in 1991 and faced the transition to a market-orientated economy, which entailed a drop in the countries' GDP, high inflation and weak law enforcement (EBRD 2000). At the same time, the countries were involved in armed conflicts making it even harder to impose law and order in the country.

The collapse of the Soviet Union and armed conflicts might have been a threat to protected areas and it is unclear how effective protected areas were in preventing illegal logging as they might fail to fulfill their goals due to weak law enforcement. Most studies which looked at protected area effectiveness took place in the tropics and showed divers outcomes. The majority of African parks had significantly less forest loss inside the parks than outside with accessibility as a main driver (Bowker et al. 2017). A similar result is found for the Brazilian Amazon where protected areas lowered deforestation loss within their boundaries (Pfaff et al. 2014, 2015). In Eastern European countries the effectiveness of protected areas differs among countries (Butsic et al. 2015). Protected areas had either positive or no effect on forest disturbance. Unlike findings in the tropics, in European Russia protected areas show little effect in reducing forest disturbance. However strictly protected areas tend to prevent forest disturbance compared to the outside (Wendland et al. 2015). In the Western Caucasus protected areas showed little effect on decreasing forest disturbance as there was generally low forest canopy removal in the area (Bragina et al. 2015). However, this result might not be representative for the entire Caucasus region, as this study area in Western Caucasus is not near any armed conflicts.

The freely available Landsat archives resulted in a broad-scale, high resolution map of my study region (maps from Chapter I), which allows me to assess effectiveness of protected areas for multiple time periods. In order to assess the effectiveness of protected areas in reducing forest cover loss before and after 1991, I will use protected areas as a "natural experiment". In this study my goal is to assess the effectiveness of protected areas by using the quasi-experimental approach of 'matching' statistics and fixed effects panel regression models. My specific research questions are:

1. Were protected areas effective in preventing forest disturbance?
2. Were protected areas established before 1991 more effective than protected areas established thereafter?
3. Were protected areas with a higher protection category more effective than protected areas with a lower one?

6.2. Protected areas

My study area in the Caucasus covers 210 protected areas. Georgia has the highest number of protected area (73), followed by the North Caucasus (70), Azerbaijan (35) and Armenia (32). However, the area covered by protected areas differs. The North Caucasus in Russia covers the largest area of protected areas (28,444 km^2) and is followed by Azerbaijan (8,876 km^2), Georgia (5,977 km^2) and Armenia (3,660 km^2). There were 101 protected areas prior to the collapse of the Soviet Union and a total of a 102 from 1991 to 2015, with 30 from 2011 to 2015 (Figure 6-1).

The protected areas cover IUCN categories from I-V, whereof 57 are under strict protection (I-II) and 149 are multiple-use areas (III-V) (Figure 6-2). Strict protected areas cover a total of 20,848 km^2 and multiple-use areas cover a total of 26,109 km^2. The four Caucasus countries, Armenia, Azerbaijan, Georgia and Russia have continually extended existing PAs or added new ones to the existing PA network within the last 10 years in order to preserve biodiversity (Zazanashvili et al. 2012).

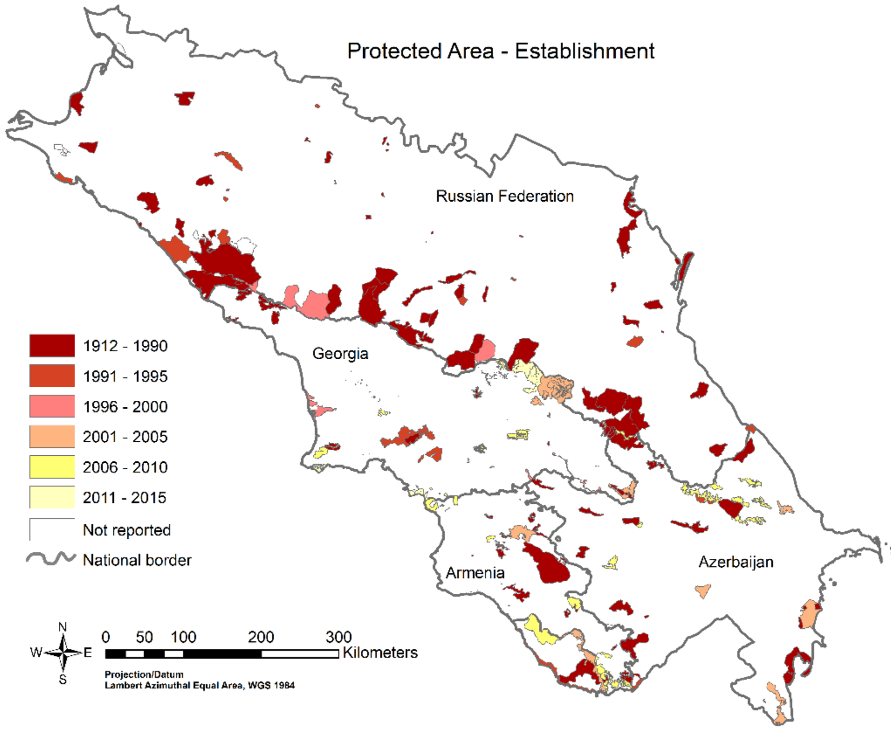

Figure 6-1: Protected areas in the Caucasus Mountains with year of establishement (source: WDPA).

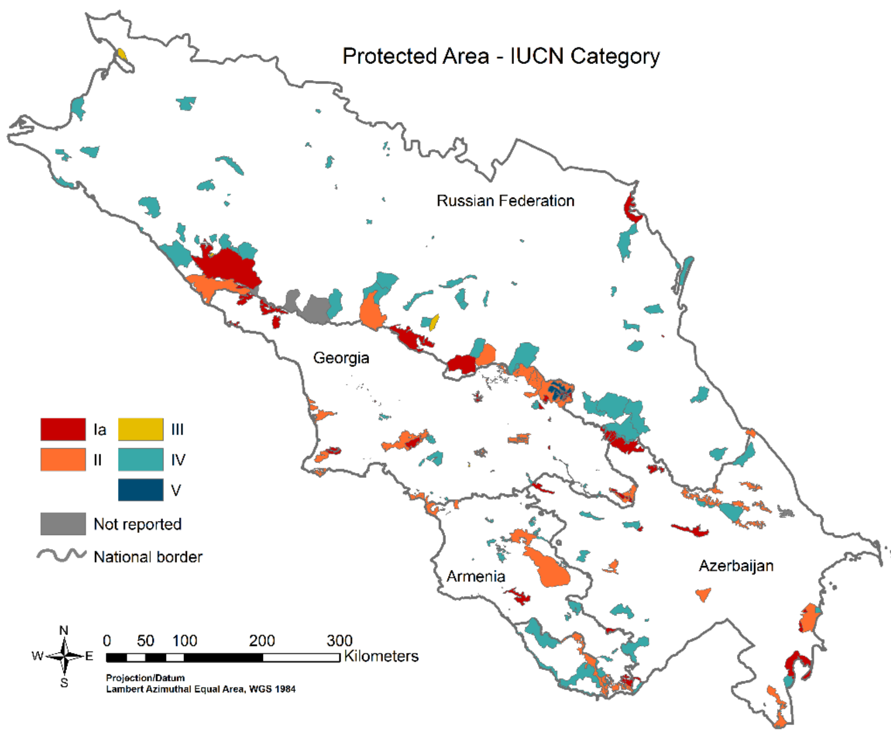

Figure 6-2: Protected areas in the Caucasus Mountains with IUCN category (source: WDPA).

6.3. Methods

I will examine protected area effectiveness using 'matching' statistics and fixed effects panel regression to compare forest disturbance within and outside the protected areas, before and after 1991, and different protection categories over time (Wendland et al. 2015; Butsic et al. 2016). Matching can control for potential bias in my observable covariates and the fixed effects linear probability model can control for time-invariant unobservable covariates (Wendland et al. 2015). Quasi-experimental approaches are ideal to control for the non-random allocation of protected areas across the landscape (Joppa & Pfaff 2009; Jones & Lewis 2015). I will use covariates that are relevant for both the treatment and the outcome. Therefore I will use my maps from Chapter I, the 1-arc-second (~30 m) digital elevation model (DEM) from the Shuttle Radar Topography Mission (SRTM) and the open street map road data source. I will derive establishment of protected areas (before and after 1991), protected area category (IUCN, I-V) and protected area delineation from the World Database of Protected Areas (IUCN & UNEP 2014).

I will use forest disturbance maps compiled into four 5-year and one 10-year time periods (1985/1990, 1990/2000, 2000/2005, 2005/2010, 2010/2015) previously derived in Chapter I. Forest disturbance is defined as forest cover change based on both forest loss through harvesting by humans and natural disturbances such as wind throws. I will compare 1) protected areas vs. non-protected areas, 2) protected areas established before and after the collapse of the Soviet Union, and 3) the different protection categories (Butsic et al. 2016).

In my first data set, I will use matching to separate forest disturbance (outcome) within protected areas (treatment) from forest disturbance outside protected areas (control) by choosing covariates as similar as possible for both groups, which will be slope, aspect, elevation, distance to forest edge, distance to road and distance to settlement. I will repeat the same matching procedure for the second data set, which will compare protected areas established before and after 1991. Here I will match pixels from protected areas established before 1991 with pixel from protected areas established after 1991. For the third data set, which will compare different protection categories, I will match pixels from protected areas with a protection category I-II with pixels from protected areas with a protection category III-V.

For each matched data set, I will randomly sample 1% of all pixels that are forested within each protected area and I will sample 4 times as much forested pixels outside protected areas with a minimum distance of 150 m between samples to avoid autocorrelation (Wendland et al. 2015). To estimate the propensity score, which is the probability of a pixel to receive treatment, I will use logistic regression. I will use a dummy variable to record whether a pixel remained constant forest ('0') or whether it was disturbed for each given time step ('1'). If a pixel is classified as disturbed ('1'), I will remove it from the dataset for the following time steps.

For each of the three matching data sets I will use fixed effects panel regression to account for unobserved static variables (Wooldridge, Jeffrey 2013).

1. Protected vs. unprotected areas

   $Y_{it} = \beta_0 + \beta_1 * Time + \beta_2 * Protec. + \beta_3 * (Time * Protec.) + \beta_4 * (Country * Time) + \beta_5 * (Country * Protec.) + \beta_6 * (Country * Time * Protec.) + x_{it} + m_i + \varepsilon_{it}$

2. PAs established before 1991 vs. PAs after 1991

   $Y_{it} = \beta_0 + \beta_1 * Time + \beta_2 * est.Protec. + \beta_3 * (Time * est.Protec) + \beta_4 * (Country * Time) + \beta_5 * (Country * est.Protec) + \beta_6 * (Country * Time * est.Protec.) + x_{it} + m_i + \varepsilon_{it}$

3. PAs protection category I&II vs. PA protection category III-V

   $Y_{it} = \beta_0 + \beta_1 * Time + \beta_2 * Protec.cat + \beta_3 * (Time * Protec.cat) + \beta_4 * (Country * Time) + \beta_5 * (Country * Protec.cat) + \beta_6 * (Country * Time * Protec.cat) + x_{it} + m_i + \varepsilon_{it}$

x_{it}: Time-varying covariates: β_{11}*(distance to settlement) + β_{12}*(distance to forest edge) + β_{13}*(distance to road)

m_i: Pixel level fixed effects: β_7*(Country) + β_8*(slope) + β_9*(elevation) + β_{10}*(aspect)

ε_{it}: error term

Due to the complexity of the model and the difficulty to interpret the coefficients of multiple interaction terms, I will estimate marginal effects, which represent the percentage point change in the likelihood a pixel is disturbed in a given country in a given year from changing an independent variable (Wooldridge, Jeffrey 2013; Butsic et al. 2016). I will carry out all the model calculations in STATA.

6.4. Expected results

I expect less forest disturbance within protected areas than outside protected areas. However I expect higher rates of forest disturbance within and outside protected areas after the collapse of the Soviet Union, when law enforcement was weak and when an energy crisis hit the countries so people relied on fire wood for daily purposes. Most of the forest in all countries remained state owned after the collapse of the Soviet Union and the import of lumber from Russia decreased due to the armed conflicts which increases the likelihood of illegal logging. On the other hand, I expect smaller changes in forest disturbance inside protected area boundaries in Russia, as Russia's forest economy did not rely on the import from either Armenia, Azerbaijan or Georgia and did not suffer from a lack of lumber supply.

Regarding the establishment of protected areas, I expect protected areas established after 1991 to be more effective in preventing forest disturbance than protected areas before 1991, due to better planning and monitoring of newly established protected areas.

For the comparison among different protection categories, I expect less forest disturbance in the categories (I&II) than in the categories III-V, due to strict control of human use and higher conservation value.

6.5. Significance

My third chapter will make novel contribution to science by demonstrating whether protected areas in regions rich in biodiversity fulfill their task of preventing forest disturbance by revealing a causal inference to socio-economic shocks.

This chapter will present econometric methods, which have so far only few applications in the land use science community, but become more popular in order to test protected area effectiveness. Panel data are commonly used in economics and health sciences, but have fewer applications in land use sciences in order to evaluate treatment effects over time. By comparing 'apples with apples', 'matching' statistics is an ideal tool to evaluate forest disturbance inside and outside of protected areas, between different time steps and different protection categories.

I will provide conservation and management implications by identifying protected areas, which do not prevent forest disturbance. This is especially important for institutions or nongovernmental organizations (NGOs) such as the World Wildlife Fund (WWF) and the International Union for Conservation of Nature (IUCN), which tackle threats to the ecoregion's biodiversity and help to meet national and global conservation targets.

7. Overall significance

My proposed interdisciplinary dissertation will blend remote sensing, land use science and conservation. The Caucasus enables me to analyze the effects of armed conflicts and policy shifts at a broad temporal and spatial scale. The environmental diversity of high mountains and the socio-economic shocks such as armed conflicts and the collapse of the Soviet Union, provide an ideal natural experiment to assess land use changes. The approach of my research is replicable for other war-torn areas worldwide and methods such as the topographic correction will be useful for preprocessing satellite imagery in other mountainous regions.

My study is posed to make novel contributions to the scientific community by providing a better understanding of the effects of armed conflicts on land use, and furthering our ability to anticipate future land use changes. By assessing major changes in land systems in Armenia, Azerbaijan, Georgia and Russia since Soviet times, I will highlight the effects of socio-economic shocks like the collapse of the Soviet Union and armed conflicts. The Caucasus with its long history of warfare provides an ideal framework, but it is a relatively understudied area. My research will highlight the long-term changes in land use induced by humans due to armed conflicts and institutional changes taking “geography” into account and considering the temporal information embedded in my panel data.

My main contribution methodologically is to employ a large-area preprocessing framework for Landsat imagery to process large data volumes that include cloud and cloud shadow detection as well as atmospheric and especially topographic correction. To date, topographic correction is not an integrated step in preprocessing satellite imagery and most studies have evaluated topographic correction only on a small-scale. In my study in ‘Chapter I’ I will assess classification accuracy over multiple Landsat footprints. My results will help to improve classification accuracy by applying topographic correction on a large study area with high elevation differences such as the Greater and Lesser Caucasus. By using the full Landsat archives and an advanced Landsat preprocessing framework, I can analyze a large study area since 1985. With more accessible data through Sentinel-2 and future satellite launches including Landsat 9, it will become even more important to advance processing of large data volumes in an automatic and open source manner, which will be applicable by remote sensors and conservations.

Further I will use panel data and will develop multiple regressions models in order to apply econometric methods to explain causal effects on land use change after socio-economic shocks such as policy shifts or armed conflicts. Quasi-experimental methods are an ideal tool when systems and processes cannot be experimentally controlled, but observational data are available. 'Matching' statistics and 'difference-in-differences' are such methods that allow us to make inferences between armed conflicts and land use change. My research will advance quasi-experimental methods to assess effects of armed conflicts on land use. My models will be applicable to other areas which experience socio-economic shocks such as armed conflicts, which unfortunately are taking place around the world and are ongoing.

Last but not least, my research will provide information for policymakers and conservationist. The outcome of my 'Chapter II' will inform policymakers and humanitarian organizations how armed conflicts affect the landscape in the Caucasus. This geospatial results can provide a comprehensive overview of a large area and can improve the understanding of the situation on the ground over a long time period. My results can help to improve the livelihood of refugees and IDPs by facilitating better land management. Further, the outcome of my 'Chapter III' will inform conservationists and NGOs like the WWF in the region whether or not protected areas preserve forest during politically insecure times and can provide insight on how to design more effective protected areas. My spatial and temporal analysis will detect forest disturbance rates inside protected area boundaries compared to outside. This will help to improve monitoring efforts and to identify so called "paper parks". In the last 10 years, governmental institutions and NGOs have established many new protected areas in the Caucasus and supported biodiversity conservation. They can use my maps for conservation to protect local endangered species like the Snow Leopard. However, this is only helpful, if we are able to develop effective long-term management strategies which are also successful in times of economic hardship, political instability and potential future conflicts.

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