Construction of a Historical Map Database as a Basis for Analyzing Land–Use and Land–Cover Changes, Exemplified by the Korean Demilitarized Zone and Inner–German Green Belt (Part 1)

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The year 2018 was truly historic for the two Koreas. Today it is not difficult to imagine that joint activities will indeed take place in the near future to construct railways and recover degraded forestlands in the North. The citizens of both nations will benefit greatly from this work. Taking such joint activities as a foundation, the Koreas will become an integrated part of the Eurasian continent, not merely two isolated ‘islands’. A positive relationship between South and North is more important than ever, and it appears to be the right time to conduct research on the Korean Demilitarized Zone. Since 2015, the Korea Environment Institute (KEI) and the Leibniz Institute of Ecological Urban and Regional Development (IOER) have placed a spotlight on the Korean DMZ and Germany’s Green Belt (Grünes Band). This flagship report is a concrete result of our hard work, and I am very grateful to Dr. Oh Seok Kim (KEI) and Dr. Marco Neubert (IOER) for their intensive collaborative efforts. I am certain that this report reveals an unknown aspect of the DMZ and North Korea, one that must be recognized to ensure the sustainable development of the DMZ.

Prof. Dr. Je Yong Yoon
President of the
Korea Environment Institute
FOREWORD II

The Korean Demilitarized Zone provokes mixed feelings, particularly for Germans. The region is arguably one of the most invaluable biodiversity retreats on Earth; at the same time, it is an iconic landscape representing the historical and political wound of the two Koreas. Neither aspect of the DMZ must be overlooked. In Europe, believing that the past has much to teach us, we commonly analyze historical maps in order to promote sustainability in regional studies. This flagship report is significant not only in comparing the landscapes of the Korean DMZ and Germany’s Green Belt (Grünes Band), two areas that share similar histories of division, but also because our approach could benefit the sustainable development of the Korean Peninsula. I sincerely hope that our joint research can offer fresh perspectives to the Korean DMZ, and am very grateful to Dr. Oh Seok Kim (KEI) and Dr. Marco Neubert (IOER) for their joint work.

Prof. Dr. Dr. h.c. Bernhard Müller
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Abstract

The Korean Demilitarized Zone (DMZ) has attracted global attention due to its unique history of human and natural interaction. Various cities and counties used to inhabit the DMZ, some of them fairly well developed and populous. However, after the Korean War, when the region became a no-man’s land, it turned into an important refuge for flora and fauna. By studying such a rare transitional site of human–nature interaction such as the DMZ, researchers have the opportunity to explore how humans and nature can coexist in a sustainable way. In short, the DMZ is a living laboratory for sustainability science.

Germany’s Green Belt (Grünes Band, hereafter GB) shares a similar history to Korea’s DMZ and exemplifies a promising future. Before the reunification of Germany, the GB was the border region between East and West Germany, and a so-called “Death Strip”. Accessibility was highly limited due to the heavy military presence. Over many decades, the region unexpectedly developed a rich biodiversity due to the unique opportunity for nature to thrive largely undisturbed. After reunification, this unique landscape has been gradually and systematically protected. The Green Belt was created at the instigation of the BUND (Bund für Umwelt und Naturschutz Deutschland e.V., also known as Friends of the Earth Germany) as well as other non-government organizations and initiatives for nature protection, and it is supported by the German federal government. Today Germany’s GB is considered to be the most well-preserved part of the European Green Belt, which runs along the former Iron Curtain.

The Korean DMZ was designated in 1953 under the Armistice Agreement signed by the United Nations Command and the armies of North Korea and China. Most existing research on the DMZ landscape has focused on the period from the 1970s onwards. This is largely because such research relies on satellite imagery, yet it was only in the 1970s that satellite images began to be used to analyze landscapes, land use, and changes in land cover. Such a research gap is problematic because of its considerable length, i.e. from the 1950s to the 1970s.
Historical maps not only include various topographical features such as roads, railways and other infrastructure but also elements of the historical and cultural heritage. Therefore, such sources of information must be used when researching the DMZ landscape. By analyzing historical maps, it is possible to determine how people previously utilized nature before the creation of the DMZ. Such research must be conducted as a first step. Subsequently, it is possible to investigate how the natural environment recovered within the DMZ after access became restricted, providing a basis upon which to make decisions about conservation and future sustainable forms of use when people are once again allowed into the DMZ.

Since 2015 the Korea Environment Institute (KEI) and the Leibniz Institute of Ecological Urban and Regional Development (IÖR in German; IOER in English) have exchanged knowledge and experience through joint workshops and conferences. These discussions encouraged the two renowned research institutes to conduct a joint research project comparing the Korean DMZ and the German GB. The intention was for the study findings to promote the sustainable use of the Korean DMZ in the years to come.

The KEI–IOER joint research to compare the Korean DMZ and the German GB analyzes study areas in each country by overlaying historical topographic maps with recent land-cover maps. Through the analysis, we aim to identify how land-use and land-cover changes in Germany’s former inner-border region occurred over time—specifically, before and after reunification—and to comprehend the implications of these changes so that lessons learned can promote the sustainable use and conservation of the DMZ, for example as a protected area.

In this report, we address three research questions: (1) Can any land-use and land-cover changes be identified in the DMZ region since 1953, based on land-cover maps from 1916, 1951, and 2015? (2) Which part of divided Germany (i.e. East or West) underwent more changes in terms of land use and land cover before reunification, based on land-cover maps from 1937, 1956, and 1990? (3) How do the two case studies differ and what can we learn by comparing the two? If these questions can be answered adequately, then it is expected that the research outcome will reveal the likely development pathway of the DMZ.
Identical criteria were applied to the Korean and German cases when selecting the study areas. First, an area had to be worth protecting in view of its well-preserved nature, endangered wildlife, and/or cultural heritage. Second, an area must have a certain development perspective; that is, the area must possess a transportation network likely to be extended or be adjacent to large cities. Third, data availability must be secured. Furthermore, it was critical that the Korean study area not encroach on any national security issues because, technically, South and North Korea are still at war.

The Korean study area includes the following: Kaesong downtown, Kaesong Industrial Complex, and a sub-area of the DMZ under the jurisdiction of North Korea and China. Kaesong is the largest North Korean city in the vicinity of the DMZ; it is also the nearest large city to Seoul, the capital city of South Korea. Kaesong is adjacent to the Yellow Sea and also lies close to two major rivers, the Han and the Imjin. In view of these geographical factors, it is likely that Kaesong will come under considerable development pressure when relations between the two Koreas thaw. The city also has a valuable natural and cultural heritage. Endangered species such as the red-crowned crane (*Grus japonensis*), the white-naped crane (*Grus vipio*), and the black-faced spoonbill (*Platalea minor*) nest in this area. As Kaesong used to be the capital of an ancient Korean dynasty, there are numerous archeological historical sites such as palace/fortress walls and gates. Hence, the city must be protected not only in view of its valuable environment and ecology but also its history and culture. Through a literature review and process of consultation, we ensured that the study area was not likely to encroach on any national security issues. The raw maps were acquired through academic libraries and online databases.

The Eichsfeld region was selected as the German study area. It is situated in the center of the country, near the city of Göttingen, at the intersection of the states of Thuringia (which formerly belonged to East Germany) as well as Lower Saxony and Hesse (formerly belonging to West Germany). After reunification, the Eichsfeld region became an important national transport hub; a new highway (*Autobahn*) was constructed across the region as one of the so-called German Unity Transport Projects. The region has a thriving agricultural sector due to its fertile loess soils. At the same time, the Eichsfeld region is part of an important ecological corridor—the so-called Green Belt—that connects the Harz Mountains...
(north of Eichsfeld) and the Werra River Valley to the south. Hence, large parts of the region are protected. The raw maps needed to analyze this study area were acquired from several map archives and German survey agencies.

In the case of the two Koreas, topographic maps produced by the so-called Chosen Government General (CGG) were used to retrieve land-cover information for Korea in the 1910s. CGG refers to the Japanese Government General of Korea (“Chosen” is the Japanese pronunciation of the ancient Korean dynasty of Chosun). Military maps drawn up by the United States Army Map Services (AMS) were used to retrieve data for the 1950s. Remotely sensed data of the Korea Multi-Purpose Satellite (KOMPSAT) and digital topographic maps produced by the National Geographic Information Institute (NGII) were used to produce a land-cover map of the study area for the year 2015. In the case of Germany, historical topographic maps had been produced by each state and later collected and managed by the Federal Archives (for former regions of East Germany) as well as the respective surveying agencies. The Authoritative Topographic-Cartographic Information System, Digital Landscape Model (ATKIS-DLM) provides recent land-use information for Germany and was used as a reference for back-editing techniques.

Our three primary research findings, associated with the aforementioned three research questions, were as follows:

First, we identified anthropogenic changes within the North DMZ even though all forms of development are generally forbidden there. Specifically, a river channel has been straightened and widened, and agricultural lands have been expanded (similarly, agricultural use can also be found in parts of the South DMZ). Based on these facts, it is fair to conclude that the area inside the North DMZ has been developed for some time and might be still under development. In addition, palace/fortress walls of the ancient Goryeo dynasty appear to have been severely damaged due to Kaesong’s urban sprawl, leaving only a small part untouched.

Second, during the analyzed time period of 1937 to 1990, more changes can be identified in the East German border region than that of the West (note: while Germany was divided from 1949 until 1989, the maps were available for the named longer time period). This can be attributed to the different political
contexts, planning systems, and the ownership structures, i.e. private property in the West versus collective ownership in the East. The West German border region (called the German Zonal Border Area or Zonenrandgebiet) was mostly decoupled from economic development due to its isolated location at this impervious line of demarcation. The primary economic goal of the East German authorities was industrialization. Numerous changes are thus related to activities of agricultural industrialization such as collectivization, intensification, mechanization, and drainage, as well as the separation of arable and livestock farming. In short, the analysis shows that changes in land use and land cover under a system of socialist or communist planning can actually be more wide-ranging and radical than those under a market-based, capitalist system.

Third, comparison of the Korean and German case studies offers two important insights: (1) Agricultural expansion and intensification were the primary drivers of land-use and land-cover changes in North Korea and East Germany, with such activities affecting the landscape of both countries. In the Korean case study, even land inside the DMZ has been cultivated. From these findings, we infer that socialist or communist regimes place great emphasis on food production and food security; (2) Land-use and land-cover changes are more intensive in the Korean border region than was the case in divided Germany, and it is crucial to note that these changes are/were driven by different historical and political settings. On the one hand, the shift in land use and land cover in North Korea was caused by Japanese colonization in the 1910s, by the Korean War in 1950s, and, since the division of the peninsula, by the land-use policies of the North Korean socialist system. On the other hand, the changes in East Germany mainly resulted from the impact of World War II and the land-use policies of the East German socialist government following the partitioning of Germany. Although there may be some difficulties in comparing the historical maps (due to the diverse map legends serving different topographical purposes) as well as cartographic errors, the Korean case study shows more change than the German one.

Given that we have identified a greater shift in land use and land cover in the Korean case, it is reasonable to conclude that in the years to come the DMZ as well as North Korea will go through more drastic change than that experienced in Germany. This is one critical finding of our report. While here we only analyze
changes during the period of division of the two Korean and two German states, it is not unreasonable to suppose that changes will become more radical under the circumstance of an improved inter-Korean relationship.

Any long-lasting improvement in the inter-Korean relationship requires a decisive shift in the political and societal climate. Such a transformation will have an impact on land-use and land-cover changes on the Korean Peninsula, including the DMZ. Furthermore, inter-Korean cooperation on economic development will certainly lead to increased development pressures, including those affecting the DMZ. This will serve to undermine conservation of the DMZ.

Our comparative research is subject to the following limitations: First, the Korean case does not include the South Korean border region due to security reasons. In order to include both South and North Korean lands it is mandated to include the inner-border as well as the Joint Security Area, which was not allowed. Besides, the existing literature largely focuses on the South Korean border region, whereas very little in the literature deals with the North Korea border region; hence, we concluded that it is more meaningful to work on a North Korean case study instead of a South Korean one. This is in contrast to the German case, which includes both the former East and West German border regions. In future research, we plan to extend the study area to compare South and North Korea. Second, as all of the historical maps were produced by different entities for their own purposes, the associated map legends and land categories are variously defined. For this reason, research outcomes must be interpreted with a degree of caution. Furthermore, data on the Korean and German study areas are related to somewhat divergent time periods and spatial extents.

Keywords: Korean Demilitarized Zone, German Green Belt (Grünes Band Deutschland), Kaesong, North Korea, Eichsfeld, historical map, land-use and land-cover changes, geographic information systems
Kurzfassung


Das Deutsche Grüne Band (GB) hat eine ähnliche Geschichte und ist beispielhaft für eine vielversprechende Zukunft der Koreanischen DMZ. Vor der Wiedervereinigung Deutschlands war das GB ein "Todesstreifen" und die Zugänglichkeit zu dieser Region war aufgrund der starken militärischen Befestigung nicht möglich. Infolge dieser jahrzehntelangen Entwicklung der Region wuchs der Artenreichtum, da die Natur die einzigartige Gelegenheit hatte, weitgehend ungestört zu gedeihen. Nach der Wiedervereinigung wurde, initiiert vom Bund für Umwelt und Naturschutz Deutschland e.V. (BUND) und unterstützt von der Bundesregierung, diese einzigartige Landschaft als GB nach und nach systematisch geschützt. Heute gilt das GB in Deutschland als der am besten geschützte Abschnitt innerhalb des gesamten Europäischen GB bzw. des ehemaligen Europäischen Eisernen Vorhangs.

Die Koreanische DMZ wurde 1953 gemäß des Waffenstillstandsabkommens, auf welches sich die Vereinten Nationen, China und Nordkorea einigten, eingerichtet. Dennoch hat sich der Großteil der Forschung zur DMZ-Landschaft nur auf den Zeitraum nach den 1980er Jahren konzentriert. Dies liegt vor allem daran, dass die Forschung weitgehend auf Satellitenbildern basiert und deren Nutzung zur Analyse des Landschafts-, Landnutzungs- oder Bodenbedeckungswandels erst in


Das Korea Environment Institute (KEI) und das Leibniz-Institut für ökologische Raumentwicklung (IÖR) haben seit 2015 in gemeinsamen Workshops und Konferenzen viele wissenschaftliche Überlegungen ausgetauscht. Schließlich haben sich die beiden renommierten Forschungsinstitute darauf geeinigt, ein gemeinsames Forschungsprojekt zum Vergleich der Koreanischen DMZ und des deutschen GB ins Leben zu rufen, in der Hoffnung, dass die Forschungsergebnisse die nachhaltige Nutzung der Koreanischen DMZ in Zukunft fördern können.


In diesem Bericht werden drei Forschungsfragen thematisiert: (1) Gibt es seit 1953 Landnutzungs- und Bodenbedeckungsänderungen in der DMZ-Region,


Aspekte der nationalen Sicherheit verletzt. Die Originalkarten wurden über Online- und Offline-Bibliotheken erworben.


Einerseits stellte sich heraus, dass es innerhalb der DMZ Veränderungen gegeben hat, obwohl eine Flächenentwicklung dort normalerweise nicht erlaubt ist. Der Flusslauf wurde begradigt sowie verbreitert und die landwirtschaftliche
Nutzfläche erweitert (gleichzeitig gibt es auch in Teilen der südlichen DMZ eine landwirtschaftliche Nutzung). Aus diesen Erkenntnissen lässt sich schließen, dass das Gebiet innerhalb der nördlichen DMZ seit einiger Zeit erschlossen wurde und sich möglicherweise noch in Entwicklung befindet. Außerdem scheinen die Palast-/Festungsmauern der koreanischen Dynastie durch die Ausbreitung der Stadt Kaesong stark geschädigt zu sein, so dass nur kleine Teile davon übrig bleiben.


Drittens, durch den Vergleich der Fallstudien der Koreanischen Halbinsel und Deutschlands haben wir zwei wichtige Schlussfolgerungen gezogen: (1) Die landwirtschaftliche Expansion bzw. Intensivierung ist der wichtigste Treiber für den Landschaftswandel in Nordkorea und der ehemaligen DDR, und eine solche Entwicklung beeinträchtigt die Landschaft in beiden Ländern. In der Koreanischen Fallstudie wurde sogar das Land innerhalb der DMZ kultiviert. Aus diesen Ergebnissen schließen wir, dass die Nahrungsmittelproduktion und Sicherheit eine wichtige Agenda für sozialistische Regime ist. (2) Der Landnutzungs- und Bodenbedeckungswandel Koreas ist intensiver als der

Da die koreanische Fallstudie eine intensivere und massivere Landnutzungs- und Bodenbedeckungsveränderung aufweist als die deutsche, ist die Schlussfolgerung naheliegend, dass sowohl die DMZ als auch Nordkorea einen radikaleren Wandel durchlaufen werden als Deutschland. Das ist eine kritische Botschaft, denn in diesem Bericht haben wir bisher nur die Veränderungen während der Trennung analysiert, und es ist nicht unlogisch zu erwarten, dass die Veränderungen unter den Bedingungen einer verbesserten innerkoreanischen Beziehung einschneidender ausfallen werden.


Diese vergleichende Untersuchung unterliegt folgenden Einschränkungen: Erstens, die koreanische Fallstudie umfasst aus Sicherheitsgründen keine südkoreanischen Grenzgebiete. Um sowohl südkoreanisches als auch nordkoreanisches Territorium einzubeziehen, ist es erforderlich, die innere Grenze sowie den Gemeinsamen Sicherheitsbereich (Joint Security Area, JSA) zu
berücksichtigen, was nicht erlaubt war. Außerdem konzentriert sich die bestehende Literatur weitgehend auf die südkoreanische Grenzregion, während sich nur sehr wenig Literatur mit der nordkoreanischen Grenzregion befasst. Daher kamen wir zu dem Schluss, dass die Bearbeitung einer nordkoreanischen Fallstudie sinnvoller ist, als einer südkoreanischen. Dies steht im Gegensatz zum deutschen Beispiel, welches sowohl die ehemaligen ost- als auch die westdeutschen Grenzgebiete umfasst. Für die zukünftige Forschung ist vorgesehen, das Untersuchungsgebiet um den Vergleich von Süd- und Nordkorea zu erweitern. Zweitens wurden alle historischen Karten von verschiedenen Institutionen für ihre jeweiligen Zwecke erstellt; daher sind die zugehörigen Kartenlegenden und Landnutzungskategorien naturgemäß unterschiedlich definiert, so dass bei der Interpretation der Forschungsergebnisse neben den zeitlichen Differenzen und der räumlichen Abdeckung des koreanischen und deutschen Untersuchungsgebietes Vorsicht geboten ist.

Schlüsselwörter: Koreanische Demilitarisierte Zone, Grünes Band Deutschland, Kaesong, Nordkorea, Eichsfeld, historische Karten, Landnutzungs- und Bodenbedeckungsänderungen, Geographisches Informationssystem
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I. Introduction

1. Background

Korea and Germany share a similar history of partitioning by internal borders. The experience of German reunification, which started in 1989 and was eventually realized in 1990, could provide important lessons for the two Koreas. The comparison of the two cases discussed here makes use of several land-use and land-cover datasets derived from historical topographic maps by means of backward editing as well as recent data of the current situation.

In the aftermath of World War II, Korea and Germany were both partitioned. Korea was split into the Republic of Korea (ROK; hereafter, South Korea), initially controlled by the United States of America, and the Democratic People’s Republic of Korea (DPRK; hereafter, North Korea), which was under Soviet and Chinese control. The pre-war German state was divided into the German Democratic Republic (GDR; hereafter, East Germany), which was under Soviet control, and the Federal Republic of Germany (FRG; hereafter, West Germany), initially controlled by the Allied Forces, which included the United Kingdom, France, and the United States of America. While the partitioning of Germany lasted from 1945 to 1990, the Korean Peninsula has remained divided since 1945.

While many people would agree that the Korean Demilitarized Zone is an invaluable ecological asset to humanity, research on the DMZ has been limited by the ongoing political tensions between South and North Korea. Very little empirical data is thus available to researchers. In order to resolve this problem, two renowned research institutes are working in tandem to reveal the true nature of the DMZ as well as to identify any underlying threats it faces. In this way, we hope that the DMZ’s ecosystems and environment can be carefully preserved for the future.

The objectives of this collaborative venture are twofold: (1) The Korea Environment Institute (KEI) wishes to take advantage of Germany’s experience
of division and reunification, specifically regarding the impact of these processes on landscape change. Here the Germany’s Green Belt (*Grünes Band Deutschland*) is an obvious success story. To analyze the changes, it is necessary to develop basic land-use and land-cover data to illustrate landscape-level changes in the DMZ over time. As our collaboration largely deals with landscape change in the context of national partitioning and (prospective) reunification, we think it is important to include historical land-cover information on the DMZ in order to portray the landscape situation before separation. (2) The Leibniz Institute of Ecological Urban and Regional Development (IOER) has considerable experience in constructing spatially explicit historical databases based on historical topographic maps. The KEI intends to utilize this expertise to set up a spatially and temporally explicit database for the DMZ region and to compare it with the German case study. In this context, the KEI and the IOER have developed a method to exploit historical topographic maps by digitizing these in such a way that data can later be used to analyze and model future landscape change. The aim of this initial comparative case study is to describe the kinds of raw data used, how the data are processed and to give an indication of the resulting digital maps. The KEI will present the Korean DMZ case study and the IOER will introduce the study of the German Green Belt\(^1\) (hereafter GB).

2. Objective and scope

The KEI and IOER are engaged in two strands of joint research. The first, detailed in the present report, considers changes in land use and land cover during a period of national partitioning. The second strand, to be presented in next year’s report, will analyze land use and land cover changes following reunification.

In this report, we investigate developments in the DMZ and former inner-German border region by examining historical maps from three time points.

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\(^1\) Rather confusingly for our purposes, the term “green belt” is often used in South Korea to indicate any green area surrounding a city to mitigate urban sprawl. Here we use the capitalized version, Green Belt, as the standard English translation of *Grünes Band*, even though a more accurate translation of *Band* would actually be “ribbon”.
The temporal coverage of the Korean case is from 1916 to 2015, while that of the German case is from 1937 to 1990. Each case is examined on the basis of three maps. The study areas in Korea and Germany were selected using identical criteria, to be explained in Chapter 3. These areas are not restricted to the DMZ and GB but also include adjacent regions that are likely to impact changes in land use and land cover within the DMZ and GB. Our analysis intends to answer the following three research questions:

(1) Can any land-use and land-cover changes be identified within the DMZ region since 1953? Some experts have argued that the DMZ has been well preserved for the past 66 years following its establishment in 1953, and hence its natural heritage and ecosystems have been conserved for generations. In contrast, others argue that the DMZ might not be as well preserved as generally supposed. According to such arguments, ongoing military tensions between South and North Korea have degraded the DMZ time after time and region by region. We believe that the research conducted in this report may be the first attempt to discern temporal changes within the DMZ region.

(2) Was East or West Germany more dynamic in terms of land-use and land-cover changes? The development of West Germany partly reflects that of South Korea in that both were controlled and supported by the United States of America after World War II. Similarly, East Germany and North Korea were at one time both under the control of the Soviet Union. In short, East and West Germany were under different political regimes, as were as well as South and North Korea. This second research question is significant because, before comparing the German case to the Korean case, it seems logical to try to pinpoint the developmental differences between East and West Germany. In the case of the Korean Peninsula, the changes in land use and land cover in South Korea have clearly been much more dramatic than in North Korea. Regarding the two Germanys, if more changes can be detected in East Germany, then it is vital to identify what were the drivers of such change.

(3) How do the Korean and German cases differ in terms of land-use and land-cover changes? What can we learn from the comparison? It is hoped that
the future of the DMZ and its neighboring regions can be forecast to some extent by comparing the Korean and German cases at the landscape level. Of course, no one can truly predict what will happen in the DMZ region if and when the two Koreas are ever reunified. Changes in land use and land cover occur for various reasons such as economic or political pressure. It is important to understand such drivers because this knowledge will enable us to explain why and how land-use and land-cover changes happen as well as to anticipate the associated impacts.
II. Literature Review

1. Brief History

As the last remaining Cold War frontier after the fall of the Berlin Wall, the DMZ has been described as the most heavily fortified border in the world (Figure 1). Ironically, the ongoing state of tension at the DMZ has had one silver lining, creating a refuge for flora and fauna. With a total size of 896.9 km², 239.6 km long and 4 km wide (Kim et al., forthcoming), the DMZ has been largely undisturbed by human intervention since its establishment in 1953, creating a “paradise of wildlife” (Shore, 2004) or an “accidental sanctuary” (Matthiessen, 1996) for several endangered species on the Korean Peninsula. This state of wilderness is what makes the DMZ unique at the global level; it has even been described as the “single most important and positive outcome of the Korean War” (Kim, 2007). Before the partitioning of the Korean Peninsula, many parts of the DMZ were affected by anthropogenic activity, i.e. there were settlements and agricultural areas, as well as roads and railways throughout the region (Kim et al., forthcoming). The DMZ thus provides a unique demonstration of how, through ecological recovery, humans can live in harmony with nature.

Once a bitterly contested battlefield of the Korean War, the DMZ is now the focus of a battle of ideas, attracting attention from around the world as a possible site for rebuilding peace and sustainability on the Korean Peninsula. Various proposals for the future of the DMZ have been put forward not just by the two governments and international organizations, but also by scholars, non-government organizations, and even internationally recognized figures such as Nelson Mandela and Ted Turner. Many of these discussions on the DMZ highlight its unique ecological value, the opportunities it provides for the Korean Peninsula, as well as its fragile state. It is true to say that the DMZ’s rich and flourishing ecosystem—accidentally shaped by war and subsequently maintained by diplomacy (Brady, 2008)—basically depends on a delicate balance between peace and hostility, and, of course, between conservation and development.
Figure 1. Map of the Korean Demilitarized Zone (1:250,000) produced by the United States Central Intelligence Agency (1969) and acquired through the Library of Congress, Geography and Map Division. The yellow band dissecting the Korean Peninsula is the DMZ. The Military Demarcation Line running through the DMZ is the land border between South and North Korea. The hatched area on the left is the Han Estuary Neutral Zone.
In 1966, preliminary research on the status of the DMZ was conducted for the first time since the armistice. It did not take long for the participating scholars to recognize the genuine value of the well-preserved ecological assets that had accumulated with such remarkable speed (Kang and Moon, 1968). Also in 1966, a group of scientists attending the 11th Pacific Science Congress in Tokyo, Japan, argued that the Korean DMZ should be designated as a national park. This proposal, however, was not adopted as the official position of the Conference due to political and military tensions on the Korean Peninsula (Donga Daily, 29 August 1966). Academic research was initiated soon after: Eighteen American experts and scholars, in collaboration with professors in Korea, visited the DMZ as part of an eight-month investigation on its ecological status (Figure 2). The investigation was the beginning of a collaborative research project lasting six years between the Smithsonian Institute of the United States of America and universities in South Korea. The research team considered the DMZ to be an ideal site for a national park. Perhaps this can be regarded as the origin of current proposals to preserve the DMZ’s ecosystem by turning it into an ecological reserve or so-called “peace park”.

Figure 2. Newspaper article on the joint investigation of the DMZ in 1966 by American and Korean scholars and experts (Donga Daily, 12 September 1966).
In 1971, a senior negotiator of the United Nations Command (who was also a member of the Military Armistice Commission) proposed to North Korea that the DMZ be demilitarized and used peacefully. Shortly afterwards, in an interview with the Washington Post, Chairman Kim Il-Sung of North Korea also argued for the DMZ's demilitarization as part of his proposed four-phase troop reduction on the Korean Peninsula (Holdridge, 1972). In the subsequent months, the two Koreas engaged in dialogue at multiple levels, discussing procedures to locate members of families dispersed during the Korean War and organize family reunions. High-level talks began in November 1971. These efforts culminated in the Joint Communiqué announced on 4 July 1972, which was the first such statement by the two Koreas regarding the reunification of the peninsula. It stipulated that reunification should be achieved through independent and peaceful means without external interference, and that national unity should be sought and achieved by transcending differences in policy, ideology and systems. The Joint Communiqué also proposed the joint development of the DMZ and neighboring regions. This was followed by a proposal in 1979 by the International Union for the Conservation of Nature (IUCN) that the DMZ be preserved as a park.

Meanwhile, the DMZ's natural environment was healing itself by spontaneously establishing a new ecological regime. The key to this development was being “left alone,” as Zimmerman observed in his pioneering article published in the Smithsonian. He called for international cooperation transcending ideological or geopolitical agendas to secure natural habitats and ecosystems in the DMZ, which “could quickly be ruined if a peace treaty were to end the need for a [military] buffer” (Zimmerman, 1981). His concern that political rapprochement between the two Koreas might trigger headlong development of the DMZ, thereby destroying its ecosystem, was not unfounded given the rapid changes in land use occurring in other parts of the Korean Peninsula as it underwent a remarkable economic transformation. Proposals for the DMZ made by the South Korean government in the 1980s focused on good relations and peace rather than nature conservation or sustainability.

The Joint Declaration of June 15 following the 2000 Inter-Korean Summit opened up the DMZ for peaceful usage as mutually agreed by the two Koreas
and relevant authorities. A part of the DMZ was designated as the South–North Joint Administration Area, allowing for the construction of railways and roads. Improved inter-Korean cooperation provoked an explosion in political as well as academic discussions and literature on the DMZ. At the same time, research on the DMZ was hampered by a lack of first-hand experience and observation due to the ongoing strict military control over the area. Few environmental surveys were performed because of the instability of inter-Korean relations, thereby preventing systematic and sustainable research. Until the late 1990s, researchers engaged in risky “unauthorized jaunts”, as reported by Professor Kim Kwi-gon and his team. While successful implementation of the two Korea’s joint projects to re-connect railways and roads might have reduced the risk faced by researchers accessing the DMZ, it temporarily provoked increased concerns about the loss of natural habitats. An article in *The Wall Street Journal* pointed out that global efforts to preserve the natural heritage of the DMZ may “have taken on new urgency in the wake of the successful first summit between the leaders of the two Koreas in June” (Schuman, 2000).

In recent years, more than twenty ecological surveys have been conducted by multiple South Korean governmental agencies to investigate the natural habitat, ecosystems, and biodiversity of the DMZ and the adjacent inner-border region. A recent publication by the Ministry of the Environment estimated the present status of DMZ’s biodiversity and ecosystems: In total, 4,873 species were identified, of which 101 are considered endangered and thus in need of legal protection. These include species such as the red-crowned crane (*Grus japonensis*), the white-naped crane (*Grus vipio*), and the black-faced spoonbill (*Platalea minor*), which would not survive if their habitats were disturbed. Because the study areas for that report were limited to certain areas adjacent to military roads (due to the presence of landmines), the actual biodiversity of the DMZ may be even higher. Certainly, the DMZ as well as its neighboring inner-border regions have the richest biodiversity in South Korea (Ministry of Environment and National Institute of Ecology, 2016). The landscapes of the DMZ encompass rich ecosystems, the historic remnants of the Korean War and the divided states, as well as the historical palace of the ancient kingdom of Taebong (Figures 3–12).
Figure 3. Inner-border region of the Korean Peninsula, photographed by Dr. Marco Neubert during a field trip to the Joint Security Area, i.e. Panmunjeom, in November 2015. The JSA is situated in the western DMZ, between Seoul and Kaesong. The fence that can be seen on the lower left of the photo extending towards the middle right is the South Limit Line, marking the southern border of the *de facto* DMZ. The *de facto* DMZ can be seen in the upper half of the photo as well as the lower area to the left of the SLL. Land under South Korean jurisdiction is on the lower half of the photo to the right of the SLL. Two Potemkin villages, i.e. symbolic human habitats inside the DMZ, can be identified by their flag posts. The flag post to the right is South Korean and the one to the left North Korean. The Military Demarcation Line marking the border between North and South lies between these villages.
Figure 4. Joint Security Area, i.e. Panmunjeom, photographed by Dr. Oh Seok Kim in November 2015. The two blue buildings are where South and North Korean authorities sit together to discuss common agendas. The Military Demarcation Line marking the border between South and North runs between these two buildings. The strip covered with dark pebbles is in South Korea while the lighter strip is in North Korea. Two South Korean soldiers can be seen in the foreground; in the background one North Korean soldier is guarding the entrance to the building.
Figure 5. Warning sign and barbed-wire fence indicating the presence of mines; photographed by Dr. Marco Neubert in November 2015. Such signed fences are commonly found along the DMZ.
Figure 6. Headquarters of the Korean Labor Party, photographed by Dr. Oh Seok Kim during a field trip to Cheorwon in November 2017. The old Soviet-style building was constructed by the North Korean authorities at the end of World War II when they held this part of Cheorwon. The headquarters were severely damaged during the Korean War. The vertical indentations on the stairs were made by a tank of the United Nations Armed Forces during victory celebrations. This part of Cheorwon is now under South Korean control.
Figure 7. Bridge bombed during the Korean War; photographed by Dr. Oh Seok Kim during a field trip to the DMZ Eco Peace Park in November 2017. The United Nations Armed Forces attacked the bridge in order to stop the progress of the North Korean Army.
**Figure 8.** View from the bombed bridge, photographed by Dr. Oh Seok Kim in November 2017. The stream and wetlands around the bridge have remained undisturbed for many decades.
Figure 9. The “Punch Bowl”, photographed by Dr. Oh Seok Kim during a field trip to the eastern DMZ in July 2018. The basin lies alongside the DMZ; the South Limit Line runs along the northern ridge of the “Punch Bowl”. Technically speaking, this is not part of the DMZ. However, access is highly regulated due to its proximity to the DMZ and the inner border. The basin was formed by differential erosion; the bottom is granite and the ridge is mainly formed of gneiss.
Figure 10. Eastern end of the Korean Demilitarized Zone, photographed by Dr. Oh Seok Kim in July 2018. The road and railway on the left connect South and North Korea. Located inside the DMZ, they were formerly used by tourists visiting Mountain Kumgang (meaning “diamond”), one of the most popular national parks in North Korea. As the mountains extend from inland to the ocean, Kumgang not only has high peaks and waterfalls but also lagoons and sea stacks.
Figure 11. Hwajin Lagoon, viewed from the former villa of Kim Il-Sung, the first Chairman of North Korea, photographed by Dr. Oh Seok Kim in July 2018. Once a part of North Korea, this area later came under South Korean control. With a perimeter stretching about 16 km, Hwajin is the largest lagoon on the east coast of South Korea. Because of its mix of fresh- and seawater, the lagoon is home to diverse fish species whose habitats are formed by sea shells and rocks, deformed and decomposed over thousands of years (National Cultural Heritage Administration of South Korea, 2018).
Figure 12. Map of the capital and palace of Taebong Kingdom in the 1910s, produced by Dr. Oh Seok Kim based on a topographic map by the Chosen Government General. The palace walls are located inside the DMZ. One major road runs alongside the east side of the inner palace wall and, in one place, briefly runs through the outer palace wall. The railway, which used to connect Seoul (South Korea) with Wonsan (North Korea), also dissects the outer palace wall. This site is located in Cheorwon, which was divided between the two Koreas after the Korean War.
2. Definitions and basic facts

To avoid confusion, we should first clarify the meaning of the term DMZ, which is used ambiguously in the literature. There are three separate definitions depending on the implied spatial extent.

The first is the legal definition of the DMZ. As mentioned earlier, the DMZ was formed in 1953 under the armistice agreed by the United Nations Command, North Korea, and China (National Archives Catalog, 2018). Under this agreement, the location as well as the spatial extent of the DMZ cannot be altered unless a new agreement, superseding the existing armistice, is made at an international level. According to the armistice, the Military Demarcation Line dissecting the Korean Peninsula is 239.6 km in length. The DMZ constitutes a 4 km-wide buffer zone around the MDL. Therefore, the total area of the DMZ is 896.9 km². These figures are derived from the original armistice maps, processed using geographic information systems (Kim et al., forthcoming).

The second definition has to do with the actual demilitarized areas of the DMZ, i.e. the “*de facto* DMZ” (Figure 13). Although the armistice is formally respected by the various involved parties and South Korea, in practice it is not consistently observed. South and North Korea have both intruded into the DMZ over the years; accordingly, the DMZ has become partly militarized and ecologically degraded. Military equipment and facilities, such as landmines, observation and guard posts as well as electric fences, have been placed within the 4 km-wide buffer zone. This *de facto* DMZ is delineated by fences with some sections having a width of less than 1 km (Jung et al., 2015).

The third definition, usually termed “DMZ Il-won” in Korean, expands the DMZ to include two additional buffers along the southern border. The first is the Civilian Control Zone (CCZ), running alongside the DMZ; the second is the Border Region adjacent to the CCZ. Both the CCZ and the Border Region are thus under South Korean jurisdiction (Figure 13). This third definition of the DMZ (or DMZ Il-won) is commonly used by the government of South Korea, and often excludes the northern part of the DMZ. It is also frequently adopted by researchers seeking on-site experience and observations, as they are only permitted to visit the DMZ Il-won rather than the *de facto* DMZ.
Figure 13. Schematic diagram of the Korean Demilitarized Zone, illustrated by Dr. Oh Seok Kim. The DMZ, Military Demarcation Line, Joint Security Area, and Han Estuary Neutral Zone are defined by the Armistice Agreement (National Archives Catalog, 2018). However, the armistice is not perfectly obeyed by the various involved parties and South Korea, leading to divergences between the DMZ boundaries and actually South/North Limit Lines. The Civilian Control Zone and Line as well as the Border Region are delineated by the South Korean law.
In this report we employ the first definition of the DMZ, divided into two subzones: the South and North DMZ (Figure 13). The majority of existing studies have focused on the South DMZ, which is under the jurisdiction of the United Nations Command, and the DMZ Il-won with little analysis done of the North DMZ (Kim et al., forthcoming). Our work deals with land-use and land-cover changes in the North DMZ as well as its adjacent border regions.

In comparison to the situation on the Korean Peninsula, the spatial extent of the Germany’s Green Belt is clear. Germany was partitioned in the aftermath of World War II, leading to the creation of the German Democratic Republic (GDR or East Germany), under Soviet control, and the Federal Republic of Germany (FRG or West Germany), controlled by the Allied Forces, i.e. the United Kingdom, France, and the United States of America. This division lasted from 1945 to 1990, a period in which the East German government constantly fortified the 1,378 km inner-German border. This was part of the so-called “Iron Curtain”, which, running more than 12,500 km from Scandinavia to the Mediterranean, divided the Soviet bloc from Western Europe (Figure 14). The inner-German border, often referred to as the “Death Strip” (Figure 15), served in part to prevent citizens of East Germany from migrating to the West.

The long period of separation, the massive border fortifications, as well as the different political systems between the two Germanys, has had a strong impact on land use. Here are some pertinent facts: The Green Belt is 1,393 km in length and covers an area of 177.12 km². Over 1,200 endangered species that are on Germany’s Red List can be found on 146 different types of habitats. Hence, the Federal Environment Ministry (Bundesumweltministerium) is funding the project “Closing Gaps in the Green Belt Germany” (Lückenschluss Grünes Band) under the Federal Programme for Biodiversity. The BUND is using this project to realize its goal of closing the gaps that since 1989 have appeared in the habitat network of the Green Belt, thereby preserving a “memorial landscape” as a reminder of the painful era of German division. Specifically, 64% of the area consists of endangered habitats appearing on Germany’s Red List; 29% are nature reserves; 64% are EU-protected areas (Natura 2000); 21% are inland waters; 21% are extensive grassland; 7% are unused fallow land, and 29% are
woodland. No less than 87% of the Green Belt is in a near-natural state with 13% damaged or destroyed, largely through crop growing or the creation of grassland. In 2007 the German Federal Government adopted its National Strategy for Biodiversity, of which a flagship project is Conservation of the Green Belt. Since 2009 the protection of the Green Belt has also been enshrined in Article 21 of the German Federal Nature Conservation Act (*Bundesnaturschutzgesetz*) (BUND, 2017).
Figure 14. Preserved section of Iron Curtain fortifications in Čižov, Czech Republic (formerly the Czechoslovak Socialist Republic), close to the Austrian border; photographed by Dr. Marco Neubert in November 2018. The picture shows two rows of electrified security fencing as well as a watchtower and so-called “dragon’s teeth”, designed to impede tanks and vehicles.
Figure 15. Schematic diagram of the inner-German border fortifications (the so-called “Death Strip” or “Iron Curtain”) in the 1980s (Stacy, 1984, “U.S. Army Border Operations in Germany”, Military History Office, with the added red illustration by Drs. Oh Seok Kim and Marco Neubert).
III. Data and Methods

1. Selection of study areas

Identical criteria were applied to the Korean and German cases in order to identify study areas. First, an area had to be worth protecting in view of its well-preserved natural environment and/or endangered species. Second, an area should have the potential for development; that is, the area should have a major transportation network or be adjacent to large cities. Third, sufficient data must be available. In addition to these, it was vital that the Korean study area should not encroach on any national security issues, because technically South and North Korea are still at war.

1.1. The Korean case

The selected Korean study area encompasses a patch of the North DMZ, downtown Kaesong, and the areas in between (Figure 16). Selecting this as the study area was useful for a number of reasons. First, the research is one of a handful of attempts to investigate the North DMZ, potentially providing spatially explicit outcomes, even if these are only partial in nature. Second, this is a site of tension and cooperation between the South and North. The DMZ patch included in the study area is adjacent to the Joint Security Area; the non-DMZ area includes current and possible future development sites of the Kaesong Industrial Complex, the factory jointly operated by the South and North. The study area is covered by a subset of one topographic map at scale 1:50,000, and the area is about 104 km² (10.6 km by 9.6 km). The elevation is approximately 10 m above sea level rising to 430 m on the Songak Mountain.

Of North Korea’s large cities, Kaesong is located closest to the DMZ (towards the northwest) and to the Joint Security Area (Figure 16). From 919 to 1394 it was the capital of the so-called Goryeo Dynasty (Park, 2010). When Seoul became the capital under the following Chosun Dynasty, Kaesong became an international trading center for ginseng. The business and market were secure...
enough for Korean merchants to maintain its leading trading position even during the period of Japanese colonization (Yang, 2012). After the end of the World War II, it became part of South Korea; in 1953, after the end of the Korean War, it became part of North Korea. The South–North Joint Declaration of 15 June 2000 led to the development of the Kaesong Industrial Complex, which started operations in 2003 but ceased in 2016 (Park, 2015).
Figure 16. Location of the Kaesong region, chosen as the Korean study area. The study area in the lower map encompasses downtown Kaesong City, the Kaesong Industrial Complex, and a section of the northern Korean Demilitarization Zone. The geometry of the DMZ and MDL is from Kim et al. (forthcoming); base map sources: National Geographic, ESRI, USGS, NOAA, Garmin, NPS, DeLorme, HERE, UNEP-WCMC, NASA, ESA, METI, NRCAN, GEBCO, Increment P Corp.
1.2. The German case

The German study area chosen for detailed analysis is the Eichsfeld region in central Germany, with Göttingen as the nearest well-known city (Figure 17). The area covers the former border area between East Germany (specifically the state of Thuringia) and West Germany (specifically Lower Saxony and Hesse). The area is about 438 km² (26 by 18.5 km). The study area is covered by six sheets of topographic maps at scale 1:25,000 of which five have been processed so far. The region is largely rural with some wooded hills and a large number of smaller towns. The fertile, loess-covered lowland encourages intensive agriculture. The elevation is approximately 200 m above sea level rising to 543 m on the Goburg Mountain. The newly built highway A38 passes through a small mountain (the Heidkopf, elevation: 354 m) by means of the Heidkopf Tunnel. The tunnel also helps to preserve the continuity of the Green Belt. Three criteria were used to select the study area:

- Nature protection: the area forms an important corridor between two large protected regions, namely the Harz mountains in the north and the Werra river valley in the south, and there exist ongoing nature protection projects;
- Development: The area became a transport axis after reunification with the newly built highway A38 (completed at the end of 2009); agricultural has been intensively developed;
- Data: sufficient data and historical maps are available.
Construction of a Historical Map Database as a Basis for Analyzing Land-Use and Land-Cover Changes, Exemplified by the Korean Demilitarized Zone and Inner-German Green Belt (Part 1)

Figure 17. Location of the Eichsfeld region, chosen as the German study area; base maps: National Geographic, ESRI; additional features: administrative boundaries (dark grey lines): VG 25 © GeoBasis-DE/BKG 2018; map sheet boundaries (red lines), the former fortified and fenced, approximately 500 m wide protective strip along the inner-German border (red) and the about 5 km wide restricted zone (light red); authors’ own work based on Adam and Erdmann (2015). Deviations from the predefined widths were mainly due to natural conditions and the location of existing settlements.
2. Data

Only the raw topographic maps used to produce land-cover maps are introduced in this chapter. Other spatial layers, including recent land-cover maps based on remotely sensed data or digital topographic maps, are not dealt with as such layers, maps and their data contents are frequently discussed in the literature as well as on websites.

It is important to acknowledge a few major differences between the Korean and German study data, as these can affect the final interpretation of the research outcome. First, the scales of Korean and German historical topographic maps are different. Only maps at scale 1:50,000 are available for Korea, whereas in Germany there are maps at scale 1:25,000. Second, the size of the study areas is different: the German case study (438 km²) covers a larger area than the Korean case (104 km²). Specifically, the German study area is constituted by five maps at scale 1:25,000, while the Korean case is a subset of one map at scale 1:50,000. Third, the temporal ranges of the two cases are different: While the Korean case covers almost a century, i.e. the years 1916 to 2015, the German case is only about half that period, i.e. from 1937 to 1990. Both cases are constructed from three time points and portray the situation of national partitioning in Korea and Germany, respectively.

2.1. Korean historical maps

Only historical topographic maps using modern coordinate systems were considered for analysis. Old maps lacking accurate coordinates hamper attempts to overlay map features from the past with those of today, thereby preventing meaningful time-series analyses. The topographic map series issued by the Chosen Government General (CGG) was selected because, unlike earlier maps, it employs an accurate coordinate system (Table 1). CGG was a governmental agency run by the Japanese authorities to control Korea and its people following Japan’s invasion and toppling of the Chosun Dynasty (“Chosen” is the Japanese pronunciation of “Chosun”). In this report we have
decided to use the older name CGG rather than the recent term Japanese Government General of Korea. According to the legend of the CGG topographic maps, the map series identifies more than 100 categories of land-use and land-cover information, represented as points, lines, and polygons (Figure 18, Appendix A).

Table 1. List of historical topographic maps of Korea.

<table>
<thead>
<tr>
<th>Issuer</th>
<th>Year</th>
<th>Number of Maps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japanese Army</td>
<td>1870s – 1911</td>
<td>300</td>
</tr>
<tr>
<td>Chosen Government General (Japanese Government General of Korea)</td>
<td>1910 – 1918 (revised until 1941)</td>
<td>722</td>
</tr>
<tr>
<td>United States Army Map Service</td>
<td>1946 – 1954</td>
<td>720</td>
</tr>
<tr>
<td>South Korean Army</td>
<td>1950 – 1960</td>
<td>Unknown</td>
</tr>
<tr>
<td>National Construction Research Institute</td>
<td>1962 – 1963</td>
<td>350 (South Korea)</td>
</tr>
<tr>
<td></td>
<td>1974 – 1975</td>
<td>239 (South Korea)</td>
</tr>
</tbody>
</table>

Source: Beom, 2003, p.23; cited with translation and revision

Military maps produced by the United States Army Map Service (AMS) were designed and published for use in the Korean War. Compared to CGG maps, the AMS maps feature basic and limited topographic features (Figure 19, Appendix B). For example, while the AMS maps employ only two symbols to indicate walls and levees, the CGG maps use seven symbols to distinguish walls made of different materials such as wood, rock, wire, etc. Similarly, the AMS maps feature only one category of forest in contrast to the seven sub-categories identified in the CGG maps. In addition to the historical maps issued by the CGG and the AMS, recent digital topographic layers of Keasong and the rest of North Korea are available from the National Geospatial Information Institute (NGII) of South Korea, although access to data on the DMZ is limited. In this report, recent NGII data serves to create a digital base.
Figure 18. Status of Kaesong in 1916: Topographic map (1:50,000) issued by the Chosen Government General; additional features: hatched area marks the Korea Demilitarized Zone provided by Kim et al. (forthcoming).
Figure 19. Status of Kaesong in 1951: Military map (1:50,000) issued by the United States Army Map Service; additional features: hatched area marks the Korean Demilitarized Zone provided by Kim et al. (forthcoming).
Construction of a Historical Map Database as a Basis for Analyzing Land-Use and Land-Cover Changes, Exemplified by the Korean Demilitarized Zone and Inner-German Green Belt (Part 1)
2.2. German historical maps

Table 2 indicates the issue dates of the six selected topographic map sheets taken from historical maps at scale 1:25,000 to provide data for the German study area. Figures 20–24 are excerpts from these maps, indicating land-use status in the study site. In addition to the historical maps, recent digital topographic data is available for the years 2000 and 2014 from the German-wide Authoritative Topographic-Cartographic Information System, Digital Landscape Model (ATKIS-DLM). As the recent ATKIS data can be used as a digital base dataset, it is not necessary to manually digitize all forms of land use indicated by each sheet, but only the differences between the current dataset and the content of the historical maps identified by a process of overlaying. This method, called backward editing (Kienast et al., 1991), has been applied in several similar studies (Neubert and Walz 2002; 2005; Haase et al., 2007; Kim and Neubert, 2016).

Table 2. List of historical topographic maps of Eichsfeld, Germany.

<table>
<thead>
<tr>
<th>Topographic map sheets</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1937</td>
</tr>
<tr>
<td>4525 Friedland (Lower Saxony)</td>
<td>1937 1945* 1956 1971* 1991</td>
</tr>
<tr>
<td>4526 Gleichen (Lower Saxony)</td>
<td>1937 1945* 1956 1969* 1993</td>
</tr>
<tr>
<td>4527 Berlingerode (Thuringia)</td>
<td>1937 1945* 1956 1993</td>
</tr>
<tr>
<td>4625 Witzenhausen (Hesse)</td>
<td>1937 1945* 1956 1969* 1993</td>
</tr>
<tr>
<td>4626 Heilbad Heiligenstadt (Thuringia)</td>
<td>1937 1956 1988</td>
</tr>
<tr>
<td>4627 Leinefelde (Thuringia)</td>
<td>1937 1956* 1988*</td>
</tr>
</tbody>
</table>

* Map not processed so far.

The historical map from 1937 showing the status before separation (the oldest analogue topographic map used in this analysis) is the plane survey sheet (Messtischblatt) at scale 1:25,000. It was originally issued in 1909 and revised in 1937. Also called the Prussian Land Survey, it is available for the whole of Germany. The Saxon State and University Library Dresden/German Photographic Collection [Sächsische Landesbibliothek — Staats- und Universitätsbibliothek Dresden/Deutsche Fotothek] makes a digital georeferenced version of this map available online. The originals can be obtained from the respective surveying agencies of the German federal states, also in scanned form.
Three different sources were used for the 1956 map (the status of early separation) since the administrative responsibilities, map layouts as well as the tiling of the maps differ between East and West Germany. For the West German states of Lower Saxony and Hesse, topographic maps at scale 1:25,000—originally from the respective surveying agencies (Surveying and Cadastral Authority of Lower Saxony/Hessian Authority for Land Management and Geoinformation)—were ordered in scanned format and had to be georeferenced before digitizing. The maps are updated versions of the historical map from 1937. For East Germany, maps at scale 1:25,000 are available from the Archive of Germany (Bundesarchiv) and can be ordered in scanned format. The originals were published by the East Germany’s Ministry of National Defense (Ministerium für Nationale Verteidigung). In this report we make use of the previously restricted map edition produced for “affairs of state” (AS). The edition intended for the public (AV) contains distortions and lacks several map elements.

The situation is similar for 1990, i.e. the year of reunification. Again, three different sources were used to provide spatial data. For Hesse and Lower Saxony, we made use of actual survey maps provided by the respective surveying agencies. For the eastern part of the study area, East Germany’s maps from the Archive of Germany were once again taken as the base for mapping.
Figure 20. Status of Eichsfeld in 1937: Plane survey sheet (Messtischblatt) at scale 1:25,000; issued in 1909 and revised in 1937.
Figure 21. Status of Eichsfeld in 1956 (western part, Lower Saxony and Hesse): Topographic map at scale 1:25,000.
Construction of a Historical Map Database as a Basis for Analyzing Land-Use and Land-Cover Changes, Exemplified by the Korean Demilitarized Zone and Inner-German Green Belt (Part 1)
Figure 22. Status of Eichsfeld in 1956 (eastern part, Thuringia): Topographic map at scale 1:25,000; produced for “affairs of state” (AS).
Construction of a Historical Map Database as a Basis for Analyzing Land-Use and Land-Cover Changes, Exemplified by the Korean Demilitarized Zone and Inner-German Green Belt (Part 1)
Figure 23. Status of Eichsfeld in 1990 (western part, Lower Saxony and Hesse): Topographic map at scale 1:25,000.
Figure 24. Status of Eichsfeld in 1990 (eastern part, Thuringia): Topographic map at scale 1:25,000; produced for “affairs of state” (AS).
Construction of a Historical Map Database as a Basis for Analyzing Land-Use and Land-Cover Changes, Exemplified by the Korean Demilitarized Zone and Inner-German Green Belt (Part 1)
3. Methods

The purpose of digitization was to extract land-use and land-cover layers from the historical map series. Once the digitization process was complete, each land category was quantified for all three time periods, enabling comparison of change in land use and land cover over time.

The procedure of producing land-use and land-cover maps from historical maps involves eight steps. Here, we briefly explain the entire procedure before going into more detail later. First, reference maps such as digital topographic maps and recent land-cover maps are downloaded and pre-processed. It is particularly important to select a standard coordinate system to permit the overlaying of diverse datasets. In the current analysis for the Korean case, we used the coordinate system of South rather than North Korea to allow for the possibility of future research on this topic. Second, the scanned topographic maps are georeferenced using the chosen coordinate system. Third, it is necessary to analyze the legends of each raw topographic scanned map as these are produced by different entities for diverse purposes, and thus they may even employ divergent systems of land-use and land-cover classification. Further account must be taken of the divergent legend schemes of Korea and Germany. In the current investigation, land-cover elements such as built, agriculture, forest, wetland, grassland and barren were digitized as polygons. Other landscape elements such as railways, highways, roads, rivers, streams and historic palace walls were digitized as polylines and polygons. Fourth, digitization was carried out manually in a process involving backward editing and Theissen polygons techniques. Fifth, maps were validated by generating a relevant topology. Sixth, we identified and corrected features showing errors. Seventh, a series of change detection analyses was performed in order to visualize changes in land use and land cover. Finally, choropleth maps were produced in order to compare changes of landscape over time.
3.1. Korean land-cover maps

The historical 1:50,000 topographic map of Kaesong (surveyed in 1916 and printed in 1918) produced by the CGG was acquired, scanned, and georeferenced. Unlike modern topographic maps, CGG maps not only provide basic topographical information but also detailed categories of land use and land cover encompassing various types of buildings (e.g., public offices, schools, religious sites), transportation infrastructure (e.g., railroads, roads, lanes), agricultural land (e.g., paddy fields, cereal grain fields, orchards), forests (e.g., deciduous/coniferous forests, bamboo groves), rivers, lakes/reservoirs as well as information on soils and geology. Technically, up to 108 layers can be extracted from the CGG maps. In this case study, only five land-use and land-cover categories were generated (i.e. Built, Agriculture, Forest, Barren/Grass, and Water, in addition to Palace Wall) in order to match the categories of the other maps for different time periods.

The Built layer refers to urban areas and other impervious surfaces, and thus portrays building footprints and blocks, as well as transportation infrastructure. As most of the building footprints and blocks are drawn as enclosed shapes, they could be directly digitized in polygon vectors. Railroads and roads were first digitized as line vectors running along the center lines of symbols before generating corresponding buffer zones to transform the lines into polygon vectors. The road network in the CGG and AMS maps have six and four hierarchies, respectively. Finally, all the layers were merged into one Built layer.

The Agriculture layer merely indicates paddy fields because no other agricultural lands are found in the study area (apart from orchards, which are included in the Forest layer). The CGG map specifies paddy fields by the appropriate symbol and line feature. When a set of lines delineates a polygon and rice paddy symbols are scattered within the polygon, the polygon is considered a paddy field.
Because the land-use and land-cover categories Forest and Barren/Grass are not drawn as polygons in the CGG maps, it was necessary to construct polygon layers of these categories for the change detection analyses. In short, the digitization process was conducted according to the following rules: Point symbols, indicating coniferous and deciduous trees, orchards, and barren/grass land, were digitized in point vector format, and the corresponding attributes entered. Thiessen polygons were generated from the point layer in order to delineate many small land parcels represented by one-point vector symbols. Finally, the attributes were assigned to the polygons in order to create the polygon layers of Forest and Barren/Grass.

The Water layer was constructed using two methods. As large rivers, lakes, and reservoirs are represented as polygons, these could be directly digitized into polygon vectors. In contrast, smaller rivers and streams are shown as lines; these had first to be digitized as line vectors before buffer zones were generated to transform the lines into polygon vectors.

We acquired and georeferenced the scanned historical 1:50,000 topographic map of Kaesong (Series L751, photogrammetrically mapped in 1951) by the AMS. Although the map’s horizontal and vertical controls originate from the CGG map, the contents of the AMS map are more limited. Consequently, only five land-use and land-cover categories match with those of CGG. The construction of the Built, Agriculture, Water, Railway, Roads, and Palace wall layers is identical to those of the CGG map. The Forest layer, on the other hand, has a different design. Forests are represented using a series of patterns that are neither points nor lines, but which can be understood as polygons lacking clear line boundaries. In order to maximize the accuracy of the digitization process, the back-editing technique (Figure 25) was applied using the land-cover maps of 1916 and 2015 as reference layers. The rest is regarded as Barren/Grass.

The up-to-date land-cover map of the study area was produced from multiple spatial datasets. First, digital topographic maps from 2014 at scale 1:25,000 were acquired from the National Geographic Information Institute (NGII). The maps include detailed topographic features in vector format such
as contours, rivers, building footprints, paddy fields, and other land uses. Compared to the pixel-based land-use and land-cover maps with spatial resolution 30 x 30 meters, a digital topographic map has a higher spatial resolution yet relatively limited information on land use and land cover. For example, many individual land parcels lack any attributes. Therefore, in order to supplement the digital topographic maps with more information on land use and land cover, the Korea Multi-Purpose Satellite (KOMPSAT-3) images for the year of 2015 were acquired from the Korea Aerospace Research Institute (KARI) and classified in order to generate attributes for the digital maps (Jung et al. 2015). As the spatial resolution of KOMPSAT-3 is 2.8 x 2.8 meters, sixteen land-use and land-cover land categories were first classified before reducing this number to seven in order to enable comparison with the land-use and land-cover maps of 1916 and 1951.

### 3.2. German land-cover maps

The Germany-wide Authoritative Topographic-Cartographic Information System, Digital Landscape Model (ATKIS-DLM) provided the base data for the backward editing of the Eichsfeld study site. This ATKIS dataset was used to investigate the state of land use after reunification in the year 2000 as well as in 2014. Implemented in stages from 1989, ATKIS was created from digitized German base maps at scale 1:5,000 as well as topographic maps at scale 1:10,000 or 1:25,000. It is continuously updated by means of ortho-photos. The target scale of the vector dataset is 1:25,000. Information on attributes was allocated using the object catalogue. The cartographic design or representation was carried out in accordance with the regulations of the signature catalogue (e.g. double lines for multi-lane roads). The topology of both polygon and line features was checked before using the data from 2000 for backward-editing.

The following nine polygon feature classes were selected for further processing and, where necessary, combined: Settlement area, broadleaved forest, coniferous forest, mixed forest, arable land, grassland, heath and bush areas, waters, and wetland. The following nine line feature classes were chosen:
Highway, federal road, state road, county road, municipal road, driveway, unknown/others, railway line, water course. The selection was based on recognizability of these classes in the historical maps. The fact that some of the older maps are only available in black and white prevented a more detailed subdivision of the land-use classes (1937, 1956 western part). It is worth noting that more roads are digitized in the German than in the Korean case.

The topographic maps of 1990 were acquired in scanned format from three different providers (as described in Section 2.2). The sheets were cut to the map edges and uniformly georeferenced. A differentiated procedure had to be applied to the East German maps since these differ from the West German topographic maps regarding their sheet division as well as their projection. Also the layout and content of the former East German maps were somewhat different regarding the required map characteristics. In the event of ambiguities, the respective mapping guidelines were used. An example of ambiguity is the differentiation between forest types (coniferous, deciduous, and mixed) in the East German maps, as these are only marked by a symbol within the area concerned. Thus the transition to another type of forest could not be precisely delimited. However, the information available from the more recent dataset using the backward-editing method provided clues to the delimitation of the boundaries.

The maps from 1956 (acquired from the same sources as those from 1990) were cut to the map edges and georeferenced uniformly. The maps between East and West also differ for this time period and hence needed different handling. The fact that the maps of Lower Saxony and Hesse (western part) were only available in black and white restricted the ability to differentiate those areal features represented merely by signatures (e.g. forest types, grassland).

The oldest topographic map series from 1937 was available already digitized and georeferenced from a library. Here there were also uncertainties in the delimitation of areas in some cases due to the use of symbols rather than coloring (the maps were black and white).
3.3. Change detection

In both cases we conducted change detection analysis to demonstrate changes over time. A standard approach would have produced a long list of legends due to the many possible land-use and land-cover transitions when comparing numerous maps over time, making it difficult for readers to interpret results. In our research, therefore, we designed a simpler and more comprehensible legend. We did not differentiate the type of transitions when conducting change detection analysis. Instead, we only considered the number of changes in land use and land cover. As the case studies took account of three time periods, a maximum of two changes are possible.

Through change detection analysis, it is possible to identify whether the DMZ was in use and determine whether East or West Germany went through more intensive development in terms of land-use or land-cover change. Further, we are able to say whether East Germany or North Korea has experienced more intensive use.
IV. Results

1. The Korean case

We may reasonably describe the land-cover map of 1916 as portraying the original landscape of Korea. Although the maps were produced by the CGG, which was a major colonial agency operated by Imperial Japan, the actual landscapes had not yet been much disturbed by the Japanese. Figure 26 shows that the study area originally included extensive areas of forest. It is worth noting, however, that two hilly areas are partially deforested. The Songak mountain located in the north of Kaesong downtown is semi-forested; this is reflected in the name, Songak, which literally means “pine and rock”. The other hilly area in the south of Kaesong downtown is also partially deforested. Agricultural lands are concentrated near the DMZ, close to Imjin River. The major road starts from Kaesong downtown to the DMZ, dissecting the study area in an east–west direction. The lower-level road runs in a south–north direction. There are two railway lines, one running east to west and the other south to north. Watercourses flow from Kaesong to Imjin River or the DMZ. Finally, the palace wall of the Goryeo Dynasty is marked (Figure 26).

Kaesong downtown grew from 1916 to 1951 due to urban sprawl. Agricultural lands also underwent expansion. While extensive deforestation was carried out in the named period, some areas were also reforested, mostly in hilly areas. The south to north railway line disappeared, while one road in the same direction was upgraded from county to province level. The palace wall of the Goryeo Dynasty was partially removed and uncovered between 1916 and 1951 (Figures 26 and 27).

In 2015 we see that while Kaesong downtown is still the largest built-up area, it is not the only one: The first district of Kaesong Industrial Complex also contains extensive impervious surfaces. The road network is better organized in the industrial complex than downtown, indicating the recent introduction of a
planning scheme. Kaesong downtown now has wider roads and green infrastructure in the center. The Songak mountain has become reforested while other parts of the study area have undergone deforestation. More land is under cultivation than before. The first level road (east–west direction) has become straightened, indicating that it is now a modern highway. The other roads remain relatively unchanged. It proved difficult to detect lower level unpaved roads using remote sensing. The course of the river has been straightened, even within the DMZ. This could be related to the Kaesong Industrial Complex, as water is a vital resource for the operation of factories. Most of the palace wall has been removed, leaving only isolated sections in mountainous areas (Figure 28).
Figure 26. Land use in Kaesong in 1916.
Construction of a Historical Map Database as a Basis for Analyzing Land-Use and Land-Cover Changes, Exemplified by the Korean Demilitarized Zone and Inner-German Green Belt (Part 1)
Figure 27. Land use in Kaesong in 1951.
Construction of a Historical Map Database as a Basis for Analyzing Land-Use and Land-Cover Changes, Exemplified by the Korean Demilitarized Zone and Inner-German Green Belt (Part 1)
Figure 28. Land use in Kaesong in 2015.
Construction of a Historical Map Database as a Basis for Analyzing Land-Use and Land-Cover Changes, Exemplified by the Korean Demilitarized Zone and Inner-German Green Belt (Part 1)
2. The German case

The map from 1937 represents the land-use status in the Eichsfeld region before World War II and the partitioning of Germany (Figure 29). The map is based on a series of historic topographic maps that cover the whole of the country. The structures on both sides of the (later) border were similar. All settlements were small villages, with the exception of Heilbad Heiligenstadt. The landscape still contained some areas of wetland. Agricultural fields were mostly small, and a dense network of driveways crisscrossed the rural landscape.

The 1956 map shows land use at an early stage of separation (Figure 30). The mapping was split at the former state border to include only authoritative information from either side. In West German areas, we see evidence of small-scale changes in land use. In the border area, connecting roads have been closed and fortifications built. In the East German part, the extent of grasslands has increased and the remaining wetlands drained.

The map from 1990 gives a snapshot of the land-use situation just before reunification (Figure 31). Here major changes in the East are visible: The intensification of agricultural activities have resulted in larger fields, many of the driveways have been eliminated and small streams diverted. Some new roads have been built, settlements have grown in size and some smaller water bodies have been created. Along the inner-German border, the Green Belt (largely grassland) is visible, representing the fortified protective strip of width 500 m.

Outlining our findings regarding land-use development, the following main changes were observed: the decline of driveways and roads in the East German border region up to 1989 (due to border access restrictions, and the collectivization of agriculture); road/highway construction after reunification (partly spontaneous construction measures from November 1989, also large planned infrastructure projects after reunification, e.g. Autobahn A38); agricultural areas dominating in all periods, larger farms in the East German part (collectivization of agriculture, intensification, mechanization), some land...
consolidation in the West German part; the ongoing development of settlements; 
the Green Belt along the former border (former protective strip and partly 
surrounding areas); re-use of land after reunification (mainly due to the Wall Act 
of 1996: right of first refusal for expropriated former owners); a sharp decline in 
wetlands (mainly due to agricultural use); greater land-use changes in the East 
German part; most changes in the period from 1956 to 1990 (fortification, 
collectivization of agriculture); and the decline of structural diversity up to 1990, 
after which structural diversity increases again.
Figure 29. Land use in Eichsfeld in 1937.
Construction of a Historical Map Database as a Basis for Analyzing Land-Use and Land-Cover Changes, Exemplified by the Korean Demilitarized Zone and Inner-German Green Belt (Part 1)
Figure 30. Land use in Eichsfeld in 1956.
Figure 31. Land use in Eichsfeld in 1990.
Construction of a Historical Map Database as a Basis for Analyzing Land-Use and Land-Cover Changes, Exemplified by the Korean Demilitarized Zone and Inner-German Green Belt (Part 1)
3. Change detection comparison

The three research questions could finally be answered by means of change detection analysis. First, we have identified changes within the North DMZ even though no development activities are normally permitted there (Figure 32). The river channel has been straightened and widened, and agricultural lands have been expanded (similarly, agricultural use can be detected in parts of the South DMZ). Based on these findings, it is fair to conclude that the area inside the North DMZ has been developed for some time and may still be under development. In addition, the palace walls of the Goryeo Dynasty appear to have been severely damaged due to Kaesong’s urban sprawl, with only fragments now left.

Second, during the division of Germany, i.e. between the analyzed time period of 1937 to 1990 (the available maps show a slightly divergent time period to partitioning, which lasted from 1949 to 1989), there were more changes in East than in West Germany (Figure 33). This can be attributed to differences in the political context, the planning systems as well as the ownership structure, namely private property in the West versus collective ownership in the East. The West German border region, called the German Zonal Border Area (Zonenrandgebiet), was mostly decoupled from economic development due to its isolated location alongside the impervious line of demarcation. The primary economic goal of the East German authorities was industrialization. Numerous changes were thus linked to the industrialization of agricultural activities such as collectivization, intensification, mechanization, and drainage, as well as the separation of arable and livestock farming. In short, we find that land-use and land-cover change under a socialist- or communist-planned economy may be more massive and radical than changes occurring under a marked-based, capitalist system.

Third, by comparing the case studies of the Korean Peninsula and Germany, we have learned two important lessons: (1) agricultural expansion and intensification are/were the major drivers of land-use and land-cover change in North Korea and East Germany, and such expansion affects the landscape of both countries. In the Korean case study, even the lands inside the DMZ have come under cultivation. From these findings, we infer that food production and security is an important agenda for socialist or communist regimes; (2) land-use and land-cover change in Korea’s border region have been more intensive than
that of Germany, and it is crucial to note that this difference is due to the disparate historical and political settings. On the one hand, the changes in North Korea can be attributed to Japanese colonization, the Korean War, as well as the land-use policies of the North Korean socialist authorities since separation. On the other hand, the changes in East Germany were mainly due to the impact of World War II as well as land-use policies imposed by the East German socialist system thereafter. Although there may be some uncertainty in the historical maps (due to their different purposes, divergent map legends as well as cartographic errors), the Korean case study reveals a greater level of change than the German one (Figures 32 and 33).
**Figure 32.** Land-use changes in Kaesong from 1916 to 2015.
Construction of a Historical Map Database as a Basis for Analyzing Land-Use and Land-Cover Changes, Exemplified by the Korean Demilitarized Zone and Inner-German Green Belt (Part 1)
Figure 33. Land-use changes in Eichsfeld from 1937 to 1990 (predominantly partitioning period).
Construction of a Historical Map Database as a Basis for Analyzing Land-Use and Land-Cover Changes, Exemplified by the Korean Demilitarized Zone and Inner-German Green Belt (Part 1)
V. Conclusions and Policy Implications

It is reasonable to conclude that the DMZ as well as North Korea will go through greater change in terms of land use and land cover compared to the German experience. In this report we have only analyzed the changes during separation; therefore, it is not unreasonable to expect that changes will be intensified in the wake of recent inter-Korean rapprochement. In order for this inter-Korean relationship to further improve, it must be supported by political and societal shifts. These will no doubt affect land-use and land-cover change on the Korean Peninsula, including the DMZ. If inter-Korean cooperation on economic development is realized, this will place greater development pressure on the DMZ. Hence, it is vital to ensure the conservation of this relatively pristine area.

2018 was a truly historic year for the two Koreas: The Panmunjeom Declaration was jointly announced in April of that year with the Pyongyang Declaration following in September. While such a thaw in hostilities is to be welcomed, it is uncertain whether this will prove beneficial for environmental conservation on the Korean Peninsula. The reopening of the Kaesong Industrial Complex appears at the top of the list of the Pyongyang Declaration. Although the complex is an iconic economic collaboration between the South and North, its environmental impacts have never been evaluated. Of course, environmental impact assessments are generally required in South Korea before the construction of large factories. Moreover, this report has identified damage to the historical palace walls of Kaesong. According to the masterplan of the Kaesong Industrial Complex, its completion would likely mean the removal of the remaining parts of this historical heritage. It will prove even more challenging to prevent and/or minimize such impacts to the environment, to history, and to culture in the DMZ than in North Korea.

This comparative research is subject to the following limitations. First, the South Korean region was excluded from consideration in the Korean case study due to security reasons. In order to include both South and North Korean lands it is mandated to include the inner-border as well as the Joint Security Area, which was not allowed. Besides, the existing literature largely focuses on the South Korean border region, whereas very little in the literature deals with the North
Korean border region. We chose to focus on the North Korean region due to the expected drastic changes there in the wake of improved inter-Korean cooperation. In contrast, the German case includes both border regions, i.e. those formerly belonging to East and West Germany. In future research, we plan to extend the study area to compare South and North Korea. Second, all of the historical maps used in the investigation were produced by different entities for their own purposes; therefore, the associated map legends and land categories are variously defined. One must thus be cautious when interpreting research outcomes, also in view of the divergent time periods and spatial coverage of the Korean and German study areas. In future research we intend to widen our analysis to cover the entire DMZ and GB, including neighboring areas. This would help decision-makers draw up sensible land-use planning measures for the DMZ.

Finally, it is important to note that maps do not always represent an objective reality; the interpretation of maps can also be problematic, especially historical maps. In the case at hand, some topographic features may have been deliberately omitted or distorted in the East German maps (such as the omission of fortifications and military objects at the border strip). Furthermore, developments in land use that take place between map editions cannot be directly illustrated. Clearly, a map is merely a snapshot of a landscape at a particular point in time.
References


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für Wald, Schnee und Landschaft, 328, p.36 (in German).


Construction of a Historical Map Database as a Basis for Analyzing Land-Use and Land-Cover Changes, Exemplified by the Korean Demilitarized Zone and Inner-German Green Belt (Part 1)
Appendix A. Topographic map of Kaesong in 1916, produced by the Chosen Government General.
Appendix B

Appendix B. Military map of Kaesong in 1951, produced by the United States Army Map Service.
국문요약

역사지도 데이터베이스 구축을 통한 한국 비무장지대(DMZ)와 독일 브뤼네스반트의 토지이용 및 토지피복 변화 분석 (I)

한반도 비무장지대(Demilitarized Zone, 이하 DMZ)가 세계적으로 각광받는 주된 이유는 밀도 높은 원시림이 우거져서가 아니다. 과거 많은 사람이 살던 지역이 한국전쟁을 기점으로 수십 년에 걸쳐 자연히 생태가 복구되면서 다시금 자연의 보고가 되었기 때문이다. DMZ를 연구하고 이해함으로써 인간과 자연 간의 지속가능한 공존 가능성을 살펴볼 수 있다는 점은 DMZ의 중요한 가치 중 하나이며, 동시에 이를 현명하게 보존해야만 하는 이유이기도 하다. 독일의 브뤼네스반트 또는 그린벨트(Grünes Band 또는 Green Belt, 이하 GB)는 장차 한반도 DMZ가 어떠한 방향으로 나아가 할지를 여실히 보여주고 있다. 재통일 후, 독일 연방정부와 비정부기구는 이 지역의 숲은 중요성을 인지하고 이를 GB로 발바꿈한 후 함께 체계적으로 보존해왔다. 오늘날 독일의 GB는 유럽의 GB 또는 과거 “철의 장막” (Iron Curtain) 중 보전이 가장 잘된 사례로 손꼽힌다.


근현대지도는 한반도 남북 분단 이전의 철도, 도로 등과 같은 주요 인프라 분포, 이와 연계한 토지이용 경향, 과거 문화·역사 유적 등을 나타내므로 이를 DMZ 연구에 활용할 필요가 있다. 근현대지도를 활용하면 분단 이전에 인간이 DMZ에서 어떤 식으로 자연을 이용하여 살았는지에 대해서 연구할 수 있다. 이에 대한 분석
이 선행되어야, 분단 이후 DMZ에서 인간이 떠나면서 자연의 보고로 변화하는 과정이나, 미래에 다시 인간이 DMZ에 접근할 수 있을 때 어떤 식으로 토지이용을 해야 간과 자연이 지속가능하게 존중할 수 있는지 등에 대해서 연구할 수 있을 것이다. 이에 한국환경정책·평가연구원(Korea Environment Institute, 이하 KEI)과 독일 Leibniz Institute of Ecological Urban and Regional Development(이하 IOER)는 근·현대지도에 기반을 둔 한반도 DMZ와 독일 GB의 비교연구를 할 필요가 있음을 합의하였고, 본 KEI-IOER 공동연구를 수행하게 되었다. 근·현대지도를 활용한 토지이용 연구는 국내에서는 드물지만 독일을 비롯한 유럽 전반에서 이와 같은 연구가 활발한 편이다.

본 연구는 한반도 DMZ와 독일 GB 일부 및 인근 접경지역을 연구지역으로 삼아 이들의 토지이용 및 토지비용 변화를 비교하여 과거 독일 재통일 전후, 독일 GB를 기준으로 실제 어떤 변화가 있었는지 파악하고, 이에 근거해 균형 잡힌 관점으로 한반도 DMZ 및 인근 접경지역의 변화를 이해하는 것이 주된 목적이다.

본 연구의 연구절문은 아래와 같다. 첫째, 1세기 간 세 시점(1916, 1951, 2015년)의 토지비용지지도를 근·현대지도, 위성영상 및 수치지형도에 근거하여 각각 구축하고 시계열 변화를 분석해 본 결과, DMZ 내 또는 인근 지역의 변화가 있었는가? 둘째, 반 세기 간 세 시점(1937, 1956, 1990년)의 시계열 변화를 분석해 본 결과, 구동독과 구서독 중 어느 지역이 더욱 많이 변화하였는가? 셋째, 한반도 DMZ 사례와 독일 GB 사례를 비교함으로써 우리는 무엇을 알 수 있는가?

동일한 연구지역 선정 기준을 한반도와 독일에 적용하였다. 해당 기준은 첫째, 양호한 자연환경과 별종위기종 유무 등으로 인해 자연보존이 필요한 지역, 둘째, 대도시와 인접하고 주요한 교통축이 있어 개발압력이 높을 것으로 예상되는 지역, 그리고 셋째, 자료확보가 가능하고 연구보안에 민감하지 않은 지역이다.

한반도 연구지역은 북한의 개성특급시 시내, 개성공업지구, 군사분계선 북쪽의 DMZ 일부 등을 포함한다. 개성특급시는 DMZ에 인접한 북한의 가장 큰 도시이며, 한국의 수도인 서울특별시와 가장 가까운 북한 대도시이기도 하다. 더 나아가 한강, 임진강과 같은 주요한천과 인접해 있고, 서해와도 인접하므로 남북교류가 활발해지면 서울과 개성을 중심으로 하는 국토개발이 급속도로 이루어질 가능성이 높다. 반면, 두루미, 저여쇄 등과 같이 세계적인 별종위기종의 서식처로 양호한 자연환경
다익연구지역은 아이슈펠트(Eichsfeld) 지역으로 국가 중앙에 위치해 있다. 구 동독의 튀링기아(Thuringia), 구서독의 로워색소니(Lower Saxony)와 헤세(Hesse) 등 모두 3개 주를 포함하고, 인근의 유명 도시로 꼴딩겐(Göttingen)이 있다. 이 지역은 독일 재통일 이후 주요 교통축으로 활용되어 고속도로인 아우토반(A38)이 신설되었고, 양호한 풀스 토양으로 인해 집약적 농업개발에 대한 압력도 높은 지역이다. 반면, 연구지역 북쪽에 위치한 하르츠산(Harz Mountain)과 남쪽에 위치한 베라강 계곡(Werra River Valley)과 같은 큰 규모의 보호지역이 존재하는 주요 생태네트워크의 일부인바 자연보전의 필요성이 높은 지역이기도 하다. 독일 연방정부를 통해 연구지역의 기후 지도 원천자료를 확보하였다.

한반도 사례는 일제강점기 조선총독부가 제작한 지형도(1910년대)와 미군정기 미국육군지도청이 제작한 군사지도(1950년대)에 기반을 둔다. 근·현대지도 토지이용 및 토지피복 데이터베이스(이하 DB) 구축 방법론을 개발하였고, 최신 시점의 자료는 기 구축한 토지피복지도와 수치지형도를 활용하였다. 독일 사례는 각 주 정부에서 제작한 기기 지형도에 근거한 근·현대지도 토지이용 및 토지피복 DB를 구축하였고, 연방 정부에서 구축한 최근 시점의 토지피복지도를 바탕으로 DB를 구축하였다.

분석결과, 첫째, DMZ 인근의 개성 지역은 물론, DMZ 내에 토지이용 및 토지피복 변화가 있었던 것으로 밝혀졌다. 이를 통해, DMZ의 경계가 해당 공간의 완전한 경관보존을 보장하지는 않는 것을 확인하였다. DMZ 내에서 경작지 확장 및 하천적정화공사의 혼적이 확인되었다. 개성 시내를 둘러싸고 있던 과거 고려시대 궁성의 성곽은 남쪽 구릉지에 있는 일부를 제외한 대부분이 훼손된 것으로 나타났다.

둘째, 구동독 지역의 토지이용 및 토지피복 변화가 구서독에 비해 변화의 면적과 빈도가 두드러지는 것으로 나타났다. 이는 공산·사회주의 집단농장 체제를 구축하고 점검지역을 군사진지화하면서 발생한 변화였다. 이를 통해, 구서독의 자본주의
와 시장경제 기반의 경제논리에 의한 토지이용 변화보다는 구동독의 정책적 또는 정치적인 논리가 더 큰 변화를 야기할 수 있는 것을 확인하였다.

셋째, 한반도와 독일 사례를 비교함으로써 배울 수 있는 점은 크게 두 가지로 정리할 수 있다. 먼저, 북한과 구동독의 토지이용 변화는 경제적 확장이 주를 이룬다. 북한의 경우에는 심지어 사람이 쉽게 접근할 수 없는 DMZ 내에서도 경작지가 확장되었다. 이를 통해서 북한과 구동독 모두 공산·자치주의 체제하의 식량생산에 초점을 두고 토지이용이 대세임을 알 수 있다. 마지막으로 북한의 토지이용 변화가 구동독의 변화보다 더 두드러지고 점략적인 것을 확인할 수 있었다. 북한 토지이용 변화의 주된 동인은 일제강점기, 한국전쟁, 공산·사회주의 체제 등으로 요약할 수 있고, 구동독 사례의 주된 동인은 제2차 세계대전과 공산·사회주의 체제 등을 생각할 수 있다. 북한의 경우는 일제강점기에서 한국전쟁 시기로 넘어갈 때와 이후에 공산·사회주의를 도입한 시점의 토지이용 변화를 시기별로 비교할 때 그 경향이 상이한 반면, 독일 사례는 제2차 세계대전(1939년~1945년)을 치렀음에도 불구하고 전쟁 전후를 비교하였을 때, 확연한 토지이용 변화가 나타나지 않았다.

한반도 사례가 독일 사례보다 더 집약적인 토지이용 및 토지피복 변화의 경향을 보이므로 장차 어떠한 형식으로든 남북 간 교류가 현재보다 활발해진다면, 독일이 과거에 경험하였던 경전환화보다 한반도의 경전환화가 더 심할 것으로 예상할 수 있다. 남북교류가 활발해지기 위해서는 정치적, 정책적 배경이 맞춰져야 한다. 따라서, 이러한 사회적 여건의 변화는 DMZ 토지이용 및 토지피복 변화에 영향을 줄 수밖에 없다. 더욱이 남북 간 경제적 교류가 활발해진다면, DMZ는 인근 지역으로부터 밀려 들어오는 개발업적으로 인해 더 많은 변화가 예상되므로 적어도 본 보고서의 연구지역인 북서부 DMZ의 보존 및 보전은 난항이 예상된다.

본 공동연구의 주된 한계점은 두 가지가 있다. 독일 사례는 구서독과 구동독의 영역을 모두 포함하는 반면, 한반도 사례는 북한 지역만 포함하고 한국 지역은 포함하지 못하므로 한독의 토지이용 및 토지피복 변화를 비교분석하는 데 있어 제약적일 수밖에 없다. 한국의 서울과 북한의 개성을 문헌을 통해 비교해보면, 서울의 토지이용 변화가 개성보다 활발한 것은 명백한 사실이므로 독일의 사례에서 동서를 비교한 것처럼 군이 한반도의 남북을 비교할 필요가 없었다. 마지막으로 근현대지도의 원천자료는 이들을 제작한 주체가 모두 다르므로 시기별로 토지이용 및
토지피복의 변화 정의가 차이가 있을 수밖에 없으며, 한반도와 독일 연구지역의 시간적, 공간적 범위가 다른바 두 사례의 비교에는 한계가 존재한다.

주제어: 비무장지대(DMZ), 독일 그뤼네스반트, 개성, 북한, 아이쉬펠트, 근현대 지도, 토지이용 및 토지피복 변화, 지리정보시스템(GIS)
Construction of a Historical Map Database as a Basis for Analyzing Land–Use and Land–Cover Changes, Exemplified by the Korean Demilitarized Zone and Inner–German Green Belt (Part 1)