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**Author**

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Documenting Peri-Urban Land Use Change

A thesis submitted in partial satisfaction  
of the requirements for the degree Master of Arts  
in Geography

by

Jessica Wynn Standifer

2019



## ABSTRACT OF THE THESIS

Jakarta, Indonesia:

Documenting Peri-Urban Land Use Change

by

Jessica Wynn Standifer

Master of Arts in Geography

University of California, Los Angeles, 2019

Professor Helga Leitner, Chair

Continued widespread urban growth places unprecedented pressure on formerly rural, now urban fringe communities creating new regional planning challenges in cities of the global South. This thesis investigates processes of peri-urbanization in the Jakarta metropolitan region between 1995 – 2015, documenting land use change using a Landsat remote sensing and GIS analysis. The study results found that regional urban land use increased over 20 percent, and vegetation declined by 20 percent during this time. Peri-urban land transformations show distinct spatial and temporal patterns, beginning in the west with large new town developments since the late 1980s, and shifting east, then south, after 2005. By looking specifically at the various sub-regions of the metropolitan area, in addition to changes over time, this study corroborated current literature regarding regional planning and identified specific densification patterns. While peri-urbanization has spread in distance since the early 1990s, land classification maps also indicate extreme densification throughout the region.

The thesis of Jessica Wynn Standifer is approved.

Thomas Welch Gillespie

Eric Stewart Sheppard

Helga M Leitner, Committee Chair

University of California, Los Angeles

2019

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## **Introduction**

Recent scholarship has highlighted future challenges for cities as development continues to rapidly increase in size and territory. Rapidly rising population numbers have spurred debate since the industrial revolution. Population predictions range from doomsday claims to incredibly positive assertions referencing human exceptionalism. Undoubtedly however, cities are crucial spaces for multi-disciplinary future research, as the world's population is predominantly urban. In this increasingly urbanizing time period, cities need to be sensibly planned and managed, looking forward to future challenges and goals. A critical question for Geographers and many others alike, is how to sensibly plan for urban growth, and what challenges will arise from continued urbanization.

Over 50% of the world's population lives in cities, and by 2030 it is predicted that over five billion people will live in cities (Florida 2011). Importantly, cities are sites of economic success, but alongside economic significance, cities can also be sites of environmental degradation. According to a World Bank report, changing the impact on climate change in cities would dramatically reshape the global footprint (World Bank 2010). For this, and many other reasons, research needs to address the impact of newly urbanizing zones. While the significance of researching cities is widely recognized, the implication of expanding urban growth into formerly rural, peri-urban surroundings is much less often addressed. Seldom do studies highlight the broad impacts presented by the changing land use in peri-urban zones.

Many studies have shown the improvement in quality of life for those moving to the city, yet urbanization can also exacerbate inequality, sanitation issues, and environmental challenges (World Bank 2015). According to a World Bank report (2015) peri-urban regions are growing, and urbanizing, at a faster rate than central cities. Behind China, Indonesia had the second

highest increase in urban land area between 2010-2015, and urban population density grew by 1,974 persons per square kilometer. Much of this growth has transcended administrative boundaries. This growth has resulted in metropolitan fragmentation, where many cities “spillover” into other administrative districts, or even have grown to fully encompass numerous municipal boundaries. This increase in urban land overwhelmingly has had a lack of coordinated and efficient planning of new developments, but has led to confusing, inefficient, and increasingly dangerous spatial patterns. This lack of oversight has led to congestion, increasing pollution, as well as a loss of productivity (19 World Bank 2015).

This research relies on urbanization and peri-urban studies literature as a foundation for the peri-urban analysis conducted in our study site, Jakarta, Indonesia, visible in Figure 1. In these fields, I have divided the relevant literature between firstly, those using descriptive and qualitative analyses, and secondly, with studies which utilize quantitative methodologies. Both categories of literature have informed this study. Specifically, in this literature review I will summarize the contributions made to peri-urban literature that: 1) highlight qualitative and descriptive methodologies; and 2) utilize GIS, remote sensing, and other quantitative methodologies. After framing the general peri-urbanization literature, this study will then discuss relevant literature to the Jakarta metropolitan region, specifically highlighting peri-urbanization challenges.

Peri-urbanization literature aims to address the widespread phenomena of continued urban growth into formerly rural landscapes. However, few studies use large scale temporal land use land cover documentation to highlight and discuss the effects of peri-urbanization. This study aims to connect regional land use change in Jakarta, Indonesia to a temporal timeline using a remote sensing analysis. Furthermore, in combination with peri-urbanization and other regional

literature, this study will identify and discuss significant land use and development trends in the peri-urban zone. In the wake of large scale developments, the social, economic, and environmental impacts of peri-urbanization are crucial to unravel, but notably differ when comparing across space.

*Figure 1* Reference map of the study site, Jakarta, Indonesia.



Data provided by WFP Geonode.

For this study the city of Jakarta's surrounding municipalities are viewed as the peri-urban interest zone. These municipalities include: Tangerang, Depok, Bekasi, and Bogor. Today, the metropolitan region known as "Jabodetabek" has grown to become one large metropolis. Behind Tokyo, Jakarta has the second largest contiguous urban region, ranked by population, in the world (Demograhia 2018). However, just 50 years ago, each municipality surrounding Jakarta was not connected by urban growth, but remained independent of one another, and significantly smaller in size. In the past, the city boundaries for Jakarta and the surrounding municipalities were well defined. Today, unraveling the pattern of growth in the periphery where farmland, industrial development, and mega highways are all entangled is much more complex.

This study will utilize multiple methodologies to document and analyze land use change in the peri-urban region of Jakarta, Indonesia. While current scholarship has analyzed the growing dynamics of urban agriculture in Jakarta (Indraprahasta 2013; Purnomohadi 2000), throughout the developing world (Bryld 2003), peri-urban agriculture (Pribadi 2015), and broad urban expansion into the periphery (Herlambang et al 2018; Firman et al 2017; Winarso et al 2015; Firman 2009; Firman 2004), scholars in the field have not adequately documented overall land use changes in the Jakarta region. Globally, only few large scale land cover land use temporal studies exist. This methodology could be instrumental in identifying, confirming, and/or disproving broad claims regarding trends of peri-urbanization globally. Applying a critical GIS approach, this study will address: 1) firstly, how land use in the peri-urban region of Jakarta changed between 1995 and 2015; 2) secondly, what types of land uses and development projects are replacing formerly rural lands; and, 3) lastly, what lessons can be applied from this case study to general debates of peri-urbanization globally? This study hopes to discuss peri-urban

trends, challenges, and consequences. Attempting to use the case of Jakarta, Indonesia to better understand specific, but also broad peri-urbanization trends.

### *Introducing the Study Site: Jakarta, Indonesia*

The capital of Indonesia has experienced unprecedented growth, today the region contains over 32 million residents. In South East Asia, Jakarta is found on the island of Java, just one of the thousands of islands which comprise the island state of Indonesia. Java is prone to many environmental challenges, including flooding, and active volcanoes. The region of Jabodetabek experiences environmental challenges fairly often; in 2013, during the rainy season, massive flooding forced over 20,000 residents to evacuate their homes, and many lost their lives (Jazeera 2013).

The peri-urban region of Jakarta has been shaped predominately by large scale private developers in recent years. Through various acquisitions of land rights and development projects companies such as Lippo, Sinarmas, PT Ciputra, and others have had a significant role in the planning of the Jabodetabek region, transforming land use with large scale projects. It is important to consider that these large scale developers work independently of one another, which has caused widespread regional planning challenges. New town projects beginning in the 1980s and continuing onward today, provide “self-sufficient” cities, called new towns, for residents who desire to leave the congested city. New towns provide services including hospitals, schools, shopping centers, and more. Furthermore, many are drawn to new town development projects for the promise of security, which appears to be lacking in the metropolitan region. However, despite what development companies preach, and talk of post-suburbia (Firman 2017), the

periphery remains dependent on Jakarta for employment and many services (Firman 2004), which has exacerbated traffic congestion (Firman 2009; Firman 2004).

The accumulation of large scale developments throughout the region has shaped Jakarta's formerly rural periphery into a bustling, urban community. Today, Jakarta's peri-urban region encompasses land which was distinctly rural only 30 years ago. Although a regional spatial development plan has been created by city planners and officials, repeated projects have disregarded the city's supposed goals (Firman 2004). Due to this disregard, the emerging region has largely not been planned by city officials, but by the interests of private development companies. Furthermore, large scale new town and industrial developments, both completed and planned projects, often do not consider current infrastructure, population, or regional needs, rather the development's financial potential. Projects have included new towns, industrial developments, as well as large scale luxury amenities such as shopping malls, golf courses, and resort communities. Projects align with historic goals for making Jakarta a globally desirable city (Silver 2013). However, arguably, the profit driven development of the periphery has created long-term issues for the future of Jakarta. Notable themes arise in advertisements for numerous new town developments, which repeatedly boast of live, work, play, "green" communities. BSD City, once the largest new town development, today surpassed by plans of "Meikarta", continues to sell the idea of serenity. A place to escape the undesirable city. Advertisements often depict large green spaces, clear skies, and happy, healthy residents. Yet thus far large scale development in the periphery has had consequences (Firman 2009; Firman 2004).

### *Defining Peri-Urbanization*

Before summarizing the foundation of current knowledge relevant to this field, it is

essential to discuss how this study will define the “peri-urban” region. Many definitions for the peri-urban interface, or urban fringe, have been developed in recent years. Peri-urban is a term that although is widely discussed, is contextual and imprecise. Peri-urban areas are defined by processes and periods of transition (Webster et al 2014). Peripheral zones can be represented by more wealthy development in some areas, or consist of sprawling low-income settlements in others regions. However, generally speaking, the peri-urban interface is one of the fastest growing settlement types, and could become the most common living location in coming years. Often, peri-urban zones encompass new development on the fringe of the city, between urban and rural life (Ravetz et al 2013).

When discussing peri-urbanization in a broad sense, it is important to consider that cities are contextual, and peri-urbanization is present in various ways. Although terms such as urban and rural are commonly used to describe settlement patterns, these have less meaning when discussing the transition zones between urban and rural areas. Cities no longer have a uniform concentric zone, like was once hypothesized, but have expanded into formerly rural areas through a variety of patterns and development types. What has become known as “peri-urban” encompasses suburban sprawl, urban patchworks, and development which has followed specific corridors, but forgotten others. Formerly rural communities have grown due to their proximity to cities; adapting from the once rural locale, after becoming swallowed by development as the city grows. One way these regions differ from previous growth is that their resources and industry are largely catered toward, and utilized by, the greater metropolitan region.

A United Kingdom based program, the Natural Resources Systems Programme, in 1999 conducted a literature review on peri-urbanization in relation to natural resources. According to the Natural Resources Systems Programme study, “the peri-urban interface is characterized by

strong urban influences, easy access to markets, services and other inputs, ready supplies of labour, but relative shortages of land and risks from pollution and urban growth” (5 Phillips et al 1999). They argue that the peri-urban interface can be divided into two regions: 1) a region directly impacted by urbanization; 2) an area that is indirectly affected, but is connected through market, such as agricultural and other natural resource industries.

Others have utilized a more broad definition of “peri-urban”, acknowledging the variation of density and land use across different regions. However, broadly speaking, the area surrounding an urban core, which encompassing smaller municipalities, is increasingly connected to the urban core, can be seen as the peri-urban region. It is important to recognize that cities around the world are located in different geographic regions, with different constraints. Some peri-urban regions will develop quicker, due to growing pressures from the metropolis, others may be constrained by geographic barriers and develop more slowly. Cities each have a unique culture, population, geography, and environment impacting development patterns. While it is essential to clearly describe the study site, and identify commonalities with the urban fringe, it is also important to note that each city is unique and will not fit one categorical analysis. Still, despite situational differences, the peri-urban zone is one of transition between rural and urban settlements.

McGregor and Simon (2012) call the peri-urban interface ‘an approximate continuum’ referring to this zone as an extension of the city, not an entirely unrelated entity. Cities are connected to their peri-urban zones, through economic processes, resource dependence, and through human interaction (McGregor and Simon 2012). Peri-urban residents are comprised of a variety of background experiences. Some choose to move to peri-urban regions to escape the urban core, looking for more affordable, often nicer and newer accommodation, as well as a new

lifestyle. However, many continue to commute into cities for employment. Others follow the rural to urban migration pattern, hoping to come to the city for work, and find housing in the peri-urban zones. A third category includes those who have resided in the peri-urban before the development explosion, often in the agricultural industry. However, each of these residents is influenced by the connectivity between the urban core and peri-urban zone.

As cities continue to expand, the urban fringe is active with growth, which can be accompanied by consequences. Peri-urban zones are experiencing immense growth pressures, which often fall into regions not maintained by the city governments (McGregor and Simon 2012). This fracturing of responsibility is a major challenge for the future of peri-urbanization and regional planning efficiency. Thus, peri-urbanization presents a number of challenges and consequences for governments and residents if not properly planned for. For example, many peri-urban zones have experienced industrial growth, which can lead to issues around chemical runoff from manufacturing. Furthermore, challenges arise due to air pollution, acid rain, and poor sanitation. Those in the agricultural industry are often most adversely affected by peri-urbanization. Crop output can be severely hindered due to acid rain and air pollution challenges accompanying urbanization. Aside from agricultural challenges, rapid growth in the peri-urban zones can lead to poor sanitation in and around informal settlements, another indication that without proper planning, urbanization can present countless obstacles for local governments.

## **Literature Review**

Common themes have emerged in much of the literature discussing peri-urban land transformation, regarding many of the continued challenges of urbanization.

### *Social Impacts and Potential of Eviction*

Many studies draw attention to the impact of the loss of agricultural lands on residents' livelihoods in the peri-urban space (Li et al 2018; Neimark et al 2018; Pribadi et al 2018, Amour et al 2017). Noting that many studies conducted in China have found that land acquisition negatively impacts rural households, one study chose to investigate the long-term consequences to livelihoods (Li et al. 2018). Performing a qualitative analysis, using household level data collected for a case of Jining City, between 2008-2017, the study identified a number of significant trends. Rural households which lost lands had unemployment levels increase from 11.6% to 43.0%. Additionally, before land acquisition, 43.8% of participants identified as farmers, after land acquisition, only 4.1% remained farmers. Generally, the study found that livelihood security decreased, with significant challenges arising from unemployment, but 4.8% of participants did increase their annual incomes in the period after land acquisition. Notably, researchers found that "a lack of success in employment transformations of these landless farmers have been deemed to be the key reason of their deteriorated livelihoods" (114 Li et al 2018). This study was small in scope, and representative of only one community in China, however, the results reiterate common concerns in the peri-urbanization literature.

As peri-urban regions become the fastest growing spaces in the much of the developing world, and urban built up areas continue to expand (Li et al 2018; Chen et al 2014), many ecological, social, and economic consequences have been associated with growth. Recent research (Neimark et al 2018) conducted in Mali discusses focuses on the causes of peri-urban resident displacement. Neimark et al (2018) highlight new laws in Mali which have caused issues with land tenure for residents in the periphery, encouraging forceful evictions. Furthermore, many who are evicted never receive any form of compensation to alleviate

financial burdens. In Mali, and similar to many other regions, in peri-urban spaces the nature of land ownership is often less formalized. Many residents have lived on the land for generations. However, as land values increase, lack of land tenure documentation has become a crucial equality issue; many residents have been forcefully evicted.

### *Ecological Impacts*

A descriptive study conducted by the Rockefeller Foundation further discussed challenges to the ecosystem posed by peri-urbanization, concluding that rapid loss of peri-urban ecosystems will have many unintended impacts. The report found that degradation to peri-urban ecosystems is associated with declining ecosystem services. Importantly, services such as water systems are crucial for safety, health, and sanitation. The report points out that,

water provision, storm-and waste-water regulation, along with protection from natural disaster and erosion, are the impacted services that most acutely affect poor or vulnerable populations. The poor may be disproportionately impacted by loss of ecosystem services due to lack of political power around land use decision making and limited alternatives for livelihoods, housing, or basic services. Vulnerability extends to urban populations that depend on the ecosystem services provided by or flowing through peri-urban areas.

Often, the loss of ecosystems is irreversible and the replacement of associated services is costly, if even possible. (Rockefeller Foundation 2013)

Impacts to the ecosystem have unintended and elevated consequences for low income populations.

### *Planning and Management*

A study conducted in 2003 describing the early and emerging field of the peri-urban interface highlights the importance of regional planning measures for the future of peri-urbanization (Allen 2003). This study highlights the complex dynamics and challenges facing residents in the peri-urban zone, citing loss of agricultural and rural employment, and declining livelihoods as a result of inadequate planning initiatives in newly built zones. Allen (2003) argues that a collaboration of planning approaches, including, rural, regional, and urban planning need to be implemented to address this new phenomenon of peri-urbanization. The peri-urban zone contains a mosaic of natural, agricultural, and urban ecosystems, living in tandem (Allen 2003). Peri-urban social structures are also heterogeneous, and in the process of transition, much like the surrounding ecosystems, as investment and interests change. This zone faces challenges because they often share the territory of more than one administrative unit, fracturing government oversight. When attempting to create a strategic approach to environmental planning and management, administrative and geographic boundaries can create significant challenges (Allen 2003). Today, many others highlight the unstructured nature that peri-urbanization has taken (Firman et al 2004; McGregor and Simon 2012), however as peri-urbanization continues, future coordinated planning and management will be essential.

### *GIS and Quantitative Literature Findings*

As previously discussed, this study utilizes both qualitative and quantitative analysis to begin laying the foundation of current knowledge in the field. Specifically, the quantitative analysis employed focus on the use of geospatial information systems and various spatial datasets. The review presented here includes studies in countries throughout Asia, Africa, North

America, and Europe to understand land use methodologies and contextual challenges faced. Using this array of global studies, many trends and key takeaways arise.

### *Utilizing Volunteered Geographic Information and Survey Methodologies*

Several studies analyzed in this literature utilize unique methodologies which provided insight for my own analysis. While the methodology utilized by this study consists of solely a land use land cover classification, future analysis utilizing remote sensing findings, combined with survey results, volunteered information, or additional GIS data, could provide more detailed results. Furthermore, through the use of additional datasets, the following studies overcame challenges which are inherent when using remotely sensed data in the developing world.

One study (Heider et al 2018) in Mexico City, highlights the impact of volunteered geospatial data for better understanding peri-urban development. This study focuses on a conservation zone, and changes to various vegetation types in the region due to informal settlement growth and other urbanization. With urbanization patterns changing, and peripheral zones growing at faster rates than central cities, new methodologies to collect and analyze data are crucial. This Mexico City study specifically focuses on informal settlements in conservation zones in the peri-urban region surrounding Mexico City. Arguing that volunteered geospatial information (VGI) combined with remote sensing techniques provide new insights on road developments and changing land use in peri-urban zones. Through VGI initiatives in Mexico, committed citizens can make complaints about conservation threats and share the exact spatial location of threats (Heider et al 2018).

Similarly, in Uganda, a study was conducted to map and describe the peri-urban interface of Kampala, the Ugandan capital, and Kamuli, as a basis for understanding deeper challenges

associated with peri-urban growth (Makita et al 2010). The study utilized a sampling method and participant survey to identify the socio-economic characteristics of each location. This method took into account the dynamic nature of urbanization. Sampling sites were chosen using a stratified random sampling method in each of the cities. Through the sampling method, in chosen locations, a questionnaire given to the survey respondents helped describe various types of land use and the type of lifestyle in the selected location. The responses received were used to classify land use and lifestyle for each selected study site, afterwards, these findings were further corroborated by structured interviews. Furthermore, statistical analyses were used to calculate the number of households per square mile. From this study, it was determined which land samples were urban (47), peri-urban (11), and rural (16). However, the methodology utilized by this study, while bringing local knowledge into the classification process, does not provide a complete picture. The study was only able to classify the sites chosen by a random sampling method, this choice of method did not establish a regional map, or regional trends. Rather, this study aimed to improve classification descriptions, and cater urban planning solutions to the various sites based on density and lifestyle needs.

### *Documenting Land Use Change*

To inform analysis used in this study, it is crucial to review literature utilizing similar methodologies. This research will utilize a remote sensing methodology classifying land use land cover change in Jakarta, Indonesia. Therefore, referencing numerous studies conducted around the world to provide input and knowledge regarding analysis, as well as to overcome data and methodological challenges faced in this analysis.

A study recently conducted in West Bengal, India utilized remote sensing imagery to perform a land use/land cover classification to study urbanization (Shaw and Das 2018). Using census data and Landsat imagery, a land use classification analysis was conducted over a nearly 30-year time period in West Bengal. However, unlike Makita et al (2010), Shaw and Das (2018) classify land use for their entire research site. Shaw and Das (2018) study this region of India due to the low percentage of urban land use before the 2011 census, compared to other regions in the country, allowing this study to analyze recent, large scale land use change. Notably, the 2011 census found that urban population in West Bengal grew by 124.81%. The United States Geological Survey Landsat TM satellite imagery was used for this study to conduct a land use/land cover classification, built-up density, urbanization intensity, and other analysis. This study found that between 1987-2015, the built-up area increased by nearly 30 percent, and vegetation also increased by 4 percent. However, water bodies declined significantly, and agricultural land also declined. Furthermore, the study found that 35 percent of vacant land in 1987 was converted into residential land by 2015.

### *Impact of Peri-urbanization on Agriculture*

An important topic in much of the peri-urbanization, and broad urbanization literature are the effects of urbanization on agriculture. While the loss of croplands resulting from increased urbanization is often cited in the literature, previously, the global threat to agricultural lands was widely unknown (Amour et al 2017) . Amour et al (2017) conducted an analysis aimed to solve this issue; they created a global projection comparing urbanization with croplands. Specifically, this study compared the year 2000 cropland dataset and 2030 urban area prediction models. By conducting a GIS analysis, researchers compared GIS shapefiles for croplands and urban

expansion, to identify at-risk global croplands. According to Amour et al (2017), between 2000-2030 urban populations are expected to double, but urban areas are expected to triple. This global expansion of urban land is a phenomenon that justifies further research and investigation into peri-urbanization. The study found that over 60% of global irrigated cropland is located near an urban area. Furthermore, while only about 2% of global cropland was found at risk, nearly 80% of global cropland loss is projected to occur in Asia and Africa. The island of Java in Indonesia, home to the country's capital, Jakarta, is identified as a hotspot for cropland loss. However, 25 percent of cropland loss is expected to occur in China. Urban expansion is also predicted to affect the globe's best producing croplands, impacting overall production more so. Multi-nodal urban region's croplands, as opposed to urban areas with one urban core, will be more greatly affected. However, a notable limitation of this study is the reliance on urban growth models, which may not accurately predict how cities will expand in the future.

Another study (Deng et al 2015), using a statistical analysis of land use data in China, also found that development expanding into small peripheral towns accelerates agricultural land loss. Using built-up area data provided by the Chinese Academy of Sciences, between the late 1980s and late 2000s, Deng et al (2015) categorized land into: "village", "town", or "city". Regions were placed within this descriptive classification based on the km<sup>2</sup> of built up land. By using these classifications, Deng et al (2015) found that regions with different levels of development will expand differently. In denser regions, where land intensification has already occurred, agriculture is less often present. Likewise, in "villages" or less built-up zones, land intensification will be much more aggressive, potentially impacting rural and agricultural lands much more. This finding indicates that different levels of urbanization and density lead to different impacts to agriculture, requiring different policy solutions.

### *Growth Trajectories and Characteristics of Peri-Urban Projects in Jakarta, Indonesia*

Since the 1980s, Jakarta has witnessed immense growth, accompanied by distinct social and political changes. A recent study describing the history of regional urban development framed Indonesia's many economic and political regimes, in relation to real estate development patterns and partnerships (Herlambang et al 2018). The article divides the capital's recent history into three notable time periods: 1) 1988-1997, the Suharto period; 2) 1998-2006, the period after the Asian Financial Crisis and fall of Suharto; and, 3) 2007-present, characterized by reenergized developers investing in real estate. Herlambang et al (2018) support their claims with data collected by Herlambang and Liong, corroborated by interviews, discussing the geographic distribution of key types of real estate developments in the periphery alongside social and political changes.

During the Suharto era, 1988-1997, Jakarta's city limits expanded as peri-urban development popularized. During this period, the most common form of development were new towns (Herlambang et al 2018). New town developments are aimed at being self-sustaining, satellite cities, outside of the busy DKI Jakarta zone. The appeal for many middle and upper class resident who chose to live in new town developments, removed from the city center, is the supposed safety, cleanliness, and lifestyle that is arguably unavailable in the city. Selling an idyllic image of the new town, developers have created an oasis with beautiful new schools, parks, and hospitals, removed from the poverty found in the city. Despite the goals of real estate developers however, new towns remain dependent on the urban core for many reasons (Firman 2004). Furthermore, Firman (2004) has claimed that popularized developments, such as new towns, have created social, economic, and political challenges. New town developments have caused increased separation between social classes (Firman 2004; Herlambang et al 2004). As

middle and upper class residents move into new developments, they to choose to self-segregate. This process of self-segregation will inevitably lead to more prominent challenges as populations remain divided, with money and power as a leading component. Strikingly, the majority of Jakarta's population do not live in such developments, but live in dense, informal, kampung style accommodations. Aside from the social consequences, during this period, land banking became extremely popular. Real Estate Developers, through connections with elite politicians (Herlambang et al 2018), gained access to large swaths of land throughout Jakarta's once agriculture rich, peri-urban space. Furthermore, as new developments gained populations, traffic congestion has grown to an all-time high.

After the Asian Financial Crisis, between 1998-2006, Suharto was deposed, and Jakarta's once booming real estate market was stunted. The property sector fell enormously (Herlambang et al 2018), and many real estate development companies went out of business. Without a booming job market in the periphery, those now living in new town developments on the outskirts of the urban core, were forced to face long commutes into the city center. This furthered traffic congestion. While little real estate development occurred during this time, much of the construction activity was focused on improving the facilities and amenities available in new town developments, in order to keep residents. Competing with roaring traffic concerns, clean, newly built amenities acted as incentive for facing long commute times. Towards the end of this time period, shopping malls, high rise apartment buildings, and superblocks also became popular. Shopping malls, mostly located in Jakarta DKI, provided a serene escape from the heat and city. High rise apartment buildings and superblocks began in attempts to provide more housing availability. After the Asian Financial Crisis, foreign investment quickly left Jakarta,

however by 2005, foreign investment had returned to levels similar to before the crisis, moving the real estate sector forward (Herlambang et al 2018).

In the most recent time period, 2007-today, development has continued to prosper in the periphery. Development has dramatically increased, for superblocs, shopping malls, and other projects. Just recently, the largest project to date, Meikarta, began construction on what will be a new town development over 8000 hectares, or nearly 20 thousand acres (Herlambang et al 2018). While after 2010, new town development began to increase once again, prior, superblocs were in high demand, both in the urban core and periphery.

Today, new developments in the periphery remain connected to Jakarta's urban core, however, some argue that the future may shift this dependence. Hudalah and Firman (2012) argue that Jakarta is approaching post-suburbia. Post-suburbia has been discussed often in the West, as suburban zones increasingly become urban centers of their own. In post-suburbia, centers of economic activity are no longer as predictably spatially clustered. Hudalah and Firman (2012) argue that increased industrial estate activity in the peri-urban zone has been a driver for this shift in economic activity, and catalyst for the future post-suburban eventuality.

Furthermore, a more recent study conducted by Firman and Fahmi (2017) also argues that Jakarta is in the beginning stages of post-suburbia. However, both articles highlight the seeming benefit of changing spatial dependence. Firman and Fahmi (2017), citing that today not only are residents in the periphery commuting into the urban core, but urban residents are commuting outward to industrial estates in the periphery. The dynamics of peri-urbanization are changing, becoming less reliant on their original host. Similarly, shifts are occurring throughout East Asia. Historically, East Asian peri-urbanization was driven by industrial developments, while manufacturing remains crucial, peri-urbanization is experiencing dynamic changes as new high

value employment moves to the periphery (Webster et al 2014). Such shifts lead some to conclude that urban planners and city officials should look to the private sector for assistance with regional planning (Firman and Fahmi 2017). While Firman and Fahmi (2017) discuss the widespread conversion of non-urban to urban land use, they seemingly disregard the resulting large scale consequences of mass-urbanization and peri-urbanization in Jakarta.

While distinct patterns are clear in the landscape of peri-urban development, Herlambang et al (2018) argue that elite networks have played a vital role in shaping regional land use. While the government has put policies and regulations in place to try limiting land speculation in order to control urban growth, it is also true that private development firms have been encouraged through informal elite networks. Herlambang et al (2018) reiterate that elite informal networks existing between members of private development firms and government offices, continue prioritizing economic gains through real estate decisions.

#### *Environmental Impacts Affecting Jakarta*

Similar to many other studies conducted on peri-urbanization, Jakarta faces many environmental consequences to increasing urban land use. Notably, however, the geographical spread of Jakarta's growth will present unique challenges which are not uniformly felt. Directly south of the metropolitan region, Depok and Bogor will face challenges due to deforestation and increasing flooding which may not equally affect communities to East or West (Pridabi et al 2018). It is important to discuss the unequal distribution of environmental consequences resulting from Jakarta's peri-urbanization.

A recent article (Pribadi et al 2018) focuses on the consequences of peri-urbanization to agriculture, but also addresses a variety of other challenges and consequences affecting the

region. While a loss of agricultural and natural space has occurred due to increasing urbanization, other serious challenges also persist. Challenges include: the heat island effect, loss of water catchment zones, soil erosion, and negative effects to water resources and water management. Water is a serious concern in Jakarta, and other flood prone deltas, as water pollution and increasing flooding pose grave consequences for local residents. Increasing runoff due to urbanization and deforestation was a significant cause of the 2007 major flood event in Jakarta (Steinberg 2007). This is just one example of numerous flooding events which have forced thousands of residents to evacuate, negatively impacting livelihoods and infrastructure. Furthermore, agriculture in the peri-urban zone has been linked with improvements in environmental quality as well as the enhancement of resilience in socio-economic crises, including natural disasters (Pribadi and Pauleit 2015). Therefore, threatening agricultural lands with increasing urban development will impact food production as well as numerous other social and economic factors.

Importantly, Pribadi et al (2018) found that agricultural lands surrounding the Jakarta Metropolitan region did not diminish between 1982-2012, however. According to the study, farmland expansion played a major role in continuing to maintain agricultural levels. Agricultural expansion effects the regions natural biodiversity by repurposing formerly natural land. The island of Java is composed of significant amounts of lush, green natural forest. Consequently, due to the continued development of Jakarta, nearly 80% of total forest loss in Kali Bekasi, Ciliwung, and Cisadane catchments was due to farmland expansion. Farmland continues to be relocated further from development in former forested areas. As previously noted, this deforestation is not without ramification. Yet, while expansion of peri-urban

agriculture has consequences, it has also been found that peri-urban agriculture has been shown to increase water retention, water infiltration, and help groundwater recharge (Pribadi et al 2018).

### **Contextualizing Jakarta's History**

Although trends of peri-urbanization found in Jakarta are common globally, specific geographic and regional contexts are important to discuss. In addition to geography, the history of land use, law, and government have been instrumental in developing patterns of peri-urbanization in Jakarta.

The nation of Indonesia is comprised of thousands of islands. Java, home to the nation's capital, is both the largest island geographically, as well as the most heavily populated. Jakarta sits along the northern coast of Java, against the Java sea, at very low elevations. The city averages 8 meters above sea level, however, many neighborhoods face extreme flood events yearly. Furthermore, some regions of the city are below sea level, inciting extreme concern for nearby residents. Jakarta is further exposed with 13 major rivers meandering through the region. Historically, past and present governments have attempted to canalize and control the river systems, yet, challenges persist, and initiatives continue to lag behind. This is crucial for understanding the path urban development has taken. Jakarta's growth is limited by physical geographic constraints, due to the Java sea in the north and a mountainous volcanic zone to the south.

In addition to unique environmental obstacles facing Jakarta, the history of urban policy in Jakarta continues to shape development. Jakarta's historic urban planning decisions remain strongly connected with modern day challenges and persistent issues. After independence, the Central Planning Bureau (CPB) was established in 1947 within the Department of Public Works

and Traffic (Silver 2013). This laid the foundation for planning initiatives as an independent nation. However, by 1954, still no legal foundation had been established for a physical regional plan in Jakarta. This lack of framework or plan gave private real estate developers significant freedom in project choices and implementation. One of the first satellite cities built outside of Jakarta's urban core, was Kebayoran Baru, which today is found in South Jakarta due to the annexation of 1950. Plans for this development were established soon after independence, before the CPB was established. However, this development is reported to have had a history of breaking regulations (Silver 2013). For example, surrounding the development to the south a greenbelt was originally planned. Planners warned that the region was at severely at risk due to annual flooding. However, the protected greenbelt did not remain development free. Unregulated development occurred, and unsurprisingly, experiences intense annual flood events. Many of the homes in this development were built for government officials, or for service workers of government officials. This supports the Herlambang et al (2018) findings of historic elite networks present within real estate development dealings. Another important factor regarding this early development, was the forced mass displacement which occurred to clear lands for the Kebayoran Baru real estate development project. Ten thousand local fruit farmers were displaced, beginning a cycle of agricultural displacement which continues today. Furthermore, displaced farmers were stripped of their right for negotiation. Dutch government officials (shortly before independence) set the amount for land compensation without allowing those removed from the land to negotiate fair prices (Silver 2013).

Jakarta's boundaries have been expanding for many years. After the Kebayoran Baru development was built, originally outside of the Jakarta city limits, the annexation of 1950 changed the city limit boundaries. This annexation doubled the size of Jakarta to include the

Kebayoran Baru development. After independence, the first master plan of Jakarta was established in 1950, under the name Jakarta Raya. The early concept was inspired by garden city schemes and was designed in concentric zones. As discussed, plans for Jakarta Raya included a green beltway surrounding the city, free from development, with ring highways crossing through town (Silver 2003). Grandiose ideas have been a part of Jakarta's history since inception, in addition to planning changes and unregulated growth.

Building on the Jakarta Raya plan, in 1959 a more detailed plan, the Outline Plan, was established highlighting housing and infrastructure challenges. Although this early master plan highlighted the need for improved access to housing, it identified that housing projects should be addressed by the private sector. Similarly, another lasting feature of the plan, officials hoped to focus residential development around Tangerang, Bogor, and Bekasi, in the peri-urban region. The 1959 Outline Plan called for northern coastal zones to be conserved for recreational use. While the plan laid out idealistic goals, the plan wildly under predicted the percent of growth the city would experience. Between 1952 – 1965 the plan assumed there would be 4% growth each year, however, during this time the city grew by about 25%. Between 1948 - 1961 population increased by 1.8 million, to 2.9 million (Silver 2013). Along historic lines of intense growth and urbanization, kampung removals have and continue to occur.

Today Jakarta continues to experience high growth rates. Currently, in 2018, the population for the city of Jakarta is approximately 10 million, and the metropolitan zone is estimated to contain 32 million residents (BPS Provinsi DKI Jakarta). More residents in this region live in the periphery than in the city center, pressuring infrastructure in the region and increasing social divides (Firman 2004). According to a more recent article,

in 2014, the population of Jabodetabek was nearly 30 million people; the region had an annual growth rate of 3.6% between 2000 and 2010. Indonesia currently has 12 cities with at least 1 million people, six of which are located in Jabodetabek (Jakarta, Bekasi, Tangerang, South Tangerang, Depok, and Bogor), which indicates the primacy of the Jakarta region. (Firman et al 2017)

However, while regional growth rates indicate largescale population gains, between 2000-2010, population in the peri-urban region grew twice as quickly as in the city center (Firman et al 2017).

### ***Data Sources***

For this research project, the primary source of data used was remote sensing imagery. The imagery used in this analysis was collected through multiple NASA Landsat Missions between 1995 and 2015. Landsat Imagery is a widely accessible, medium spatial resolution imagery, which has been collecting data, through various satellites and sensors since 1972, and continues today. Due to the time period selected by this study, it was required that imagery be sourced from two Landsat missions. Landsat-5 imagery was not available for the most up to date time period analyzed, therefore Landsat-8 imagery was also utilized.

As discussed above, this study utilized imagery collected from two types of Landsat sensors, including: Landsat TM, and Landsat ETM+. The Landsat TM sensor is on board the Landsat-5 Mission satellite, providing the majority of the data in this study, for the years 1995-2005. The second sensor provided imagery for the 2015 analysis; the ETM+ sensor is found on board the Landsat Mission-8 satellite. Both the Landsat-5 and Landsat-8 missions, with the TM and ETM+ sensors, have a spatial resolution of 30m, an improvement from earlier models.

Furthermore, it is important to note that comparison across different sensor types does have limitations (Jenson 2007).

The majority of data utilized for this analysis was downloaded from the United States Geological Survey (USGS) Earth Explorer Website (<https://earthexplorer.usgs.gov/>). The Jakarta Metropolitan region was selected using map coordinates in the search criteria section. After selecting the appropriate site, imagery from the summer of 1995, 2005, and 2015 were chosen. Imagery was selected for clarity, with the least amount of atmospheric noise. Visible below in Table 1, specific imagery acquisition details are listed for each image downloaded from the USGS Earth Explorer website.

After imagery was chosen from the USGS Earth Explorer website, surface reflectance products, of the chosen images, were downloaded from USGS website (<https://espa.cr.usgs.gov/ordering/new/>). From the chosen imagery, selected and viewed in USGS Earth Explorer, the Landsat ID was listed on the surface reflectance product download page. After each Landsat ID was listed and submitted, the surface reflected products were then emailed after a short period of time.

**Table 1** Remote Sensed Imagery acquisition data for analysis replication.

Year	Path	Row	Landsat Mission	Date
1995	122	64	5	August 24, 1995
	122	65	5	August 24, 1995
2005	122	64	5	July 2, 2005
	122	65	5	July 2, 2005
2015	122	64	8	August 31, 2015
	122	65	8	August 31, 2015

Courtesy of the U.S. Geological Survey

In addition to data for the remote sensing analysis, this study references new town development data provided by Herlambang et al (2018). New town development data was provided in spreadsheet form, specifying the year projects were built, developer information, and location.

### ***Data Analysis***

Utilizing NASA Landsat Imagery for land use land cover classifications has been advocated by many researchers as a reliable methodology for documenting land use change in a variety of contexts (Shaw and Das 2018). This study utilizes NASA Landsat Imagery between 1995-2015, in 10-year time increments, conducting an unsupervised minimum distance classification.

Using remote sensing software, ENVI, a variety of procedures were conducted for each time period studied. After the imagery was downloaded, each time period and tile file contained multiple bands (number depending on the Landsat sensor the image was derived from). To begin, each tile and time period was loaded into ENVI, and the bands were stacked using the layer stacking tool. Next, due to the Jakarta metropolitan region location bordering between two Landsat tiles, in order to encompass the entire study site, the newly stacked tiles were joined together using the mosaic tool. Once each year was stacked and mosaicked, the imagery was clipped to select a smaller, appropriate region using the metropolitan boundaries. Next, land use training data was created, identifying land type for each time period. Training data consisted of shallow water, deep water, urban land, dry/fallow land, and vegetation. This land use training data was then used in the unsupervised minimum distance classification conducted to obtain land use land cover classification maps for this study.

After conducting the land use land cover classification for this study, a random sampling accuracy assessment was conducted for the 2005 and 2015 classifications. This assessment was designed to overcome a number of challenges in accuracy for the unsupervised method described above. Firstly, in regions such as the United States, organizations readily update and share land use data, which can be used to test the accuracy of remote sensing classifications. However, the study site for this research lacked readily available ground truth data. Secondly, using Landsat imagery, which has a medium spatial resolution of 30m requires a degree of generalization. Each pixel in the imagery represents 30m x 30m on the ground, but is given one single value in the imagery. Medium resolution data requires a generalization, using the most common value, or land use, found in a 30m x 30m region, generalizing the reality of mixed land use found in peri-urban Jakarta. Using this data for classifications therefore generalizes regions more so than higher resolution imagery. In order to overcome this challenge, random sampling comparing classification results to high resolution imagery was crucial.

The random sampling accuracy test was conducted by using QGIS to generate 50 random points within the Jakarta metropolitan boundaries. The location of each random point was then compared to the 2005 and 2015 classifications, as well as to the respective year's high resolution imagery available on Google Earth Pro. This accuracy assessment could not be conducted for the 1995 results due to the lack of high resolution data available on Google Earth Pro for this time frame.

With increasing urbanization in Jakarta's peri-urban zone, clear patterns are evident when looking at regional development on the metropolitan wide scale. Remote sensing analysis conducted documenting land use type, shows patterns which align with findings of past

literature. Urban land use has spread rapidly, in identifiable patterns, causing extreme loss to natural vegetation.

Accuracy assessment tests conducted for 2005 and 2015 resulted with levels above 90 percent accurate. In 2005, through accuracy assessment sampling, using land use classifications and Google Earth Pro high resolution imagery, resulted in 96 percent accurate findings. Furthermore, in 2015 the accuracy assessment test resulted in 91 percent accurate findings.

In addition to confirming that the results from the above land use classifications are worthwhile, the process of random sampling also confirmed an important story regarding agriculture. While useful, classifying land use can also be imprecise and flawed. Regarding agriculture specifically, different crops will appear with varying signatures in the remote sensed imagery. Depending on the crop type, rotation, and season, agricultural fields can identify as water, dry/fallow land, or vegetation. Through sampling, this study found that agricultural lands were identified in each of these categories. For this reason, using a land use classification is difficult to accurately identify changes in land use specifically documenting changes to agricultural lands. However, losses in vegetation do indicate shifts in agricultural lands, which corroborate with claims that agricultural lands are shifting further from development to avoid closure (Pribadi et al 2018). While the number of agricultural lands have not diminished due to relocation (Pribadi et al 2018), encroaching urbanization continues to cause agriculture to move further away from development. Agriculture being relocated beyond the rural urban divide could indicate another cause of vegetation loss.

### *Challenges/Limitations*

While performing this study there were many challenges and limitations faced.

Utilizing a geographic, data driven methodology, such as an remote sensing or GIS analysis, in regions outside of the United States and Western Europe can be challenging for numerous reasons. Working in Indonesia, there were barriers to data access, including user challenges when searching and utilizing data found in languages other than English.

While NASA provides free access to imagery sourced globally, high resolution data is not as readily available. The data utilized in this study contains 30m spatial resolution, which forces large regions to be generalized into one specific land type, causing error. Furthermore, aside from government organizations such as NASA, many private companies have also released satellites and sell high resolution, high quality imagery. Yet, purchasing imagery can be extremely costly, further complicated by the large land area analyzed in this study. In the United States, projects have been conducted which provide free GIS and high resolution data, however, outside of the United States and Western Europe, acquiring access to data is more difficult.

In addition to challenges acquiring high-resolution remote sensing imagery, access to ground truth data for the Jakarta metropolitan region, for each time period, was also challenging. In order to overcome this limitation, I used an unsupervised classification method, selecting various land types by hand. Even with the accuracy assessment conducted, without more complete ground truth data for comparison, the results of this study are limited.

Aside from available data challenges, it is also important to note common error present in all remote sensing analysis. In tropical regions especially, however present globally, weather patterns cause image noise. Noise, a form of distortion, causes information gaps in the imagery. In regions such as Jakarta, where many months are extremely cloudy, finding clear imagery, not obstructed by noise, is difficult. Imagery used in this study was the best Landsat imagery available during the chosen timeframe. However, due to lack of clear imagery, this study

compares land use between remote sensed imagery captured in different months. Land use may appear differently depending on the season, causing some misinterpretations in results.

The accuracy assessment designed for this study faced limitations and generalizations as well. Importantly, as previously mentioned, the spatial resolution of imagery used to create the land use classifications resulted in a generalized result of land use. When comparing a random point between the land use classification and to actual ground data, the accuracy assessment took into account if the random point was located in vegetation surrounded by heavy development or another result which would factor heavily into the land use classification results. The accuracy assessment in this study used a small sampling number, only 50 random points for the entire region, due to the work load for checking land use in each map and time frame. In another study, given more resources, additional samples should be analyzed.

For the reasons listed above, this analysis and findings of this study are limited. Future analysis will be needed to build upon the results of this study.

### **Land Use Change in the Jakarta Metropolitan Region Between 1995-2015**

For this study, I analyzed Landsat Imagery in 1995, 2005, and 2015 of the greater Jakarta metropolitan region to concretely map spatial changes over time. For each land use land cover classification map represented, land use categories consist of: urban land; dry/fallow land; vegetation; shallow water bodies; and deep water bodies. Urban land is represented in pink, dry fallow land is represented in yellow, vegetation is represented in green, shallow water is light blue, and deep water bodies are represented in dark blue.

Land use land cover classification maps clearly show that regional planning has not occurred routinely or evenly throughout the region. Prior to 1995, development in the periphery

was minor, focusing heavily in the west. However, by 2005, development had shifted dramatically to the east in Bekasi. Bekasi is home to many industrial parks in the peri-urban region, offering employment opportunities for many Jakarta City residents, peri-urban residents, and foreigners as well. Many commute to this region daily for employment. Over a quarter of industrial estates operating in Jakarta are located in Bekasi, many in the automotive industry, which services growing middle class clientele in Jakarta (Firman et al 2017). Expansion of urban land use shown to the east, are the outcome of the industrial park development, and after 2005, integrated industrial and new town development in the Bekasi region. More recently, developments have moved south to Bogor, notably as the Trump Corporation begins construction on a large luxury property (Stevenson and Paddock 2018).

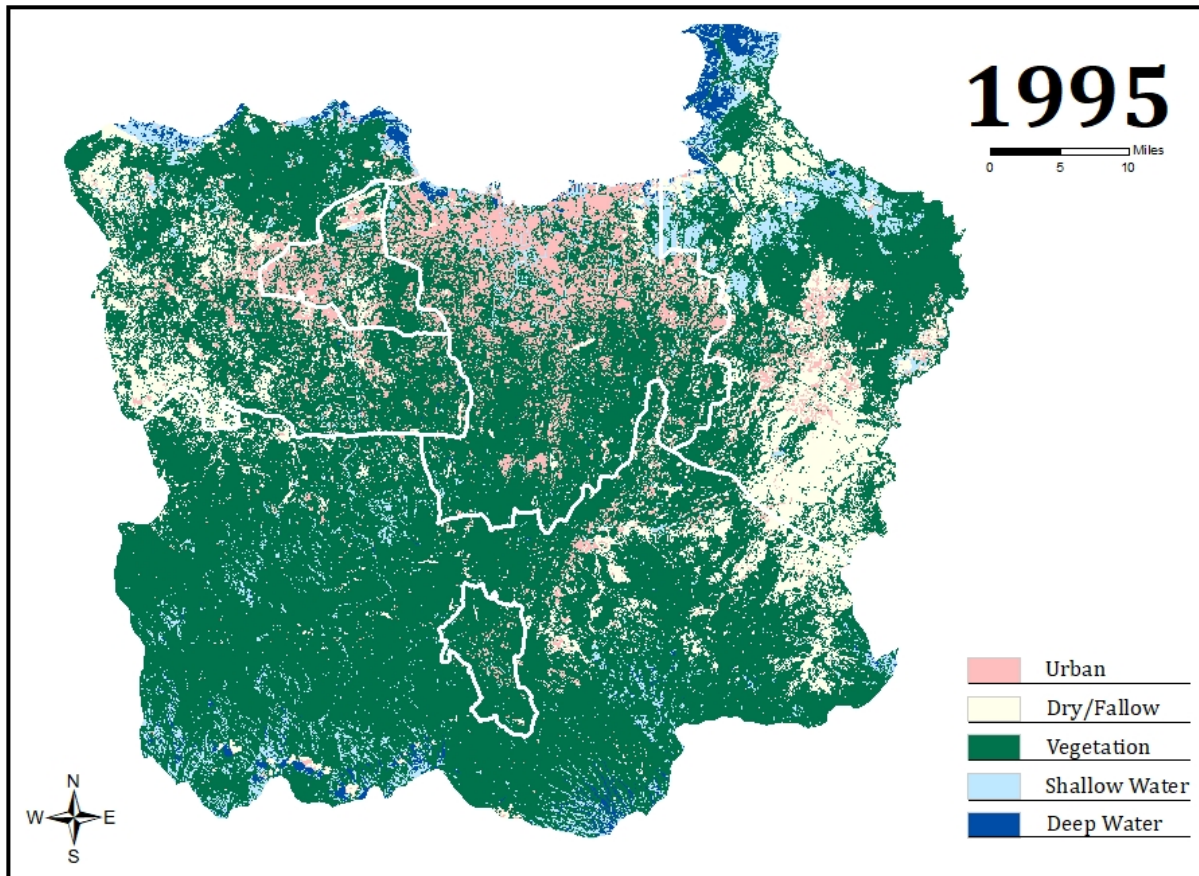
Importantly however, the land use land cover classifications created in this study highlight the spatiality of planning trends which supports and extends findings of existing scholarship. It is well documented that large new town developments began in the late 1980s/early 1990s, with notable names such as BSD City and other projects (Herlambang et al 2018; Firman et al 2017). However, the regional land use land cover classification maps provide more detail regarding transition between land use type and varying relationships between types of land. Visible in the following figures, urban land is often surrounded by dry/fallow classified zones. In each time period these zones continue to migrate, but the pattern of urban land in relation to dry/fallow land remains. This is a strong indication of a popular land holding technique utilized in Jakarta, called land banking. Land banking, or the practice of developers securing the rights to large swaths of land without immediately beginning development projects, are evident in the spatial patterns of land use. Many developers prior to the Asian Financial Crisis commonly used this practice. Holding the land through land banking efforts helped to

guarantee adequate profit margins as land became more valuable. Impacts to local residents directly and indirectly affected by these practices is largely undocumented however (Silver 2013).

To begin, figure 2 shows the regional land use patterns in the Jakarta metropolitan region in 1995. In the 1995 land use land cover classification, urban development is clustered in a small, central region along the Java coast. Broadly, figure 2 highlights early peri-urbanization beginning in Tangerang. By this time, west of Jakarta, Tangerang had experienced significant urban development compared to other peri-urban zones. Bogor has very limited urban settlement as this time. Yet, looking to the east of DKI Jakarta, it is clear that development is beginning to form along the Jakarta-Cikampek Toll Road cutting through Bekasi to Purwakarta on the eastern periphery. However, south of the DKI Jakarta region, Depok and Bogor lack significant amounts of urban land use. In 1995, the region is heavily characterized by its prevalence of vegetation, and agriculture to the north west (visible through high concentrations of water).

By 2005, visible in figure 3, urban development has intensified east of Jakarta in Bekasi, and slightly spread south into Depok. Large increases in shallow water bodies, both to the north east and north west of the 2005 land classification map are representative of crop rotation and rice patty prevalence. The prevalence of water in the region skew land use land type classification results due to the high presence of water required for rice patty agriculture, which fluctuates due to annual crop rotation, season, and weather pattern. In addition to increased water content in agricultural zones, it appears that dry and fallow land decreased between 1995 and 2005.

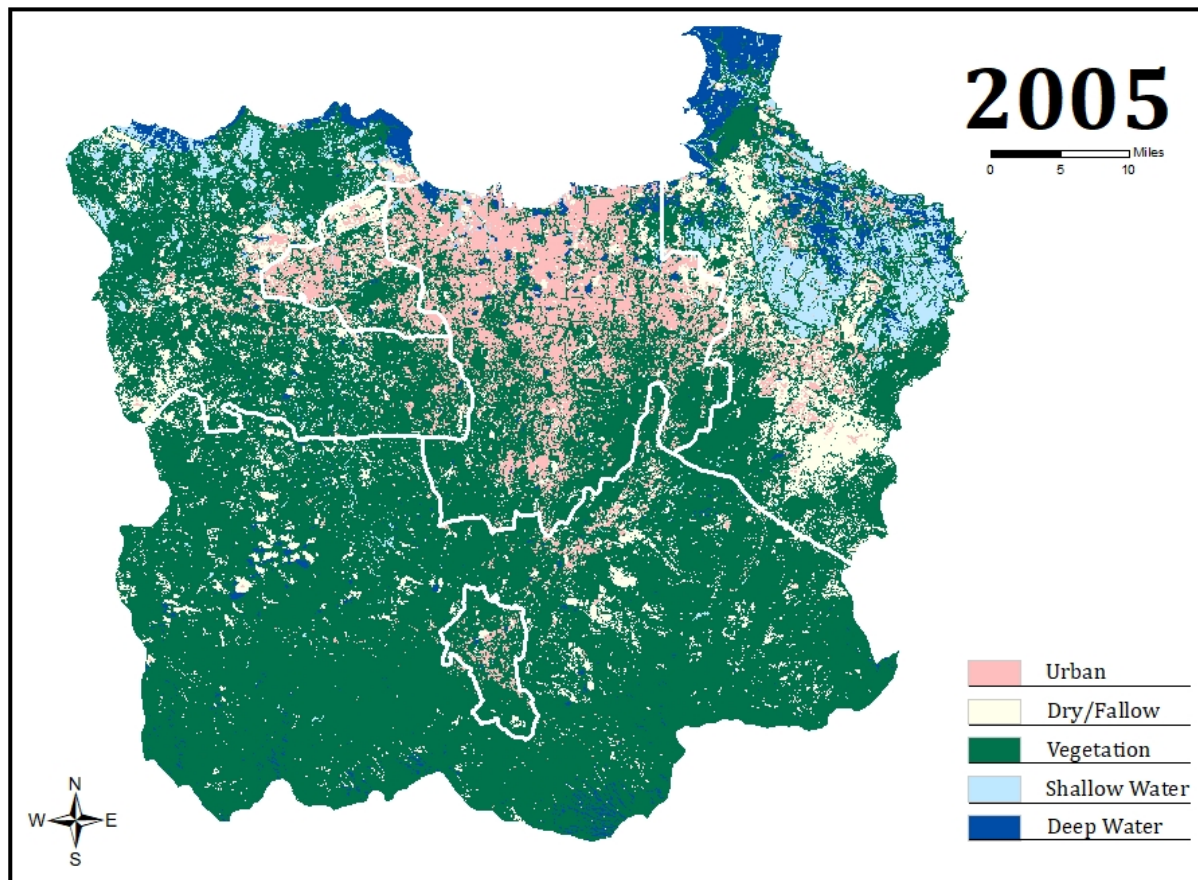
**Figure 2** Jakarta Metropolitan Regional Land Use/Land Type Classification for 1995.



Landsat-5 imagery courtesy of the U.S. Geological Survey.

Regions which appear dry in 1995, and lush by 2005, are an indication of a wetter season. Furthermore, dry/fallow land in 2005, is highly concentrated in Bekasi surrounding urban land use types. However, due to the Asian Financial Crisis, and departure of foreign investment (Herlambang et al 2018), between 1995- 2005, urban growth was minimal.

**Figure 3** Jakarta Metropolitan Regional Land Use/Land Type Classification for 2005.



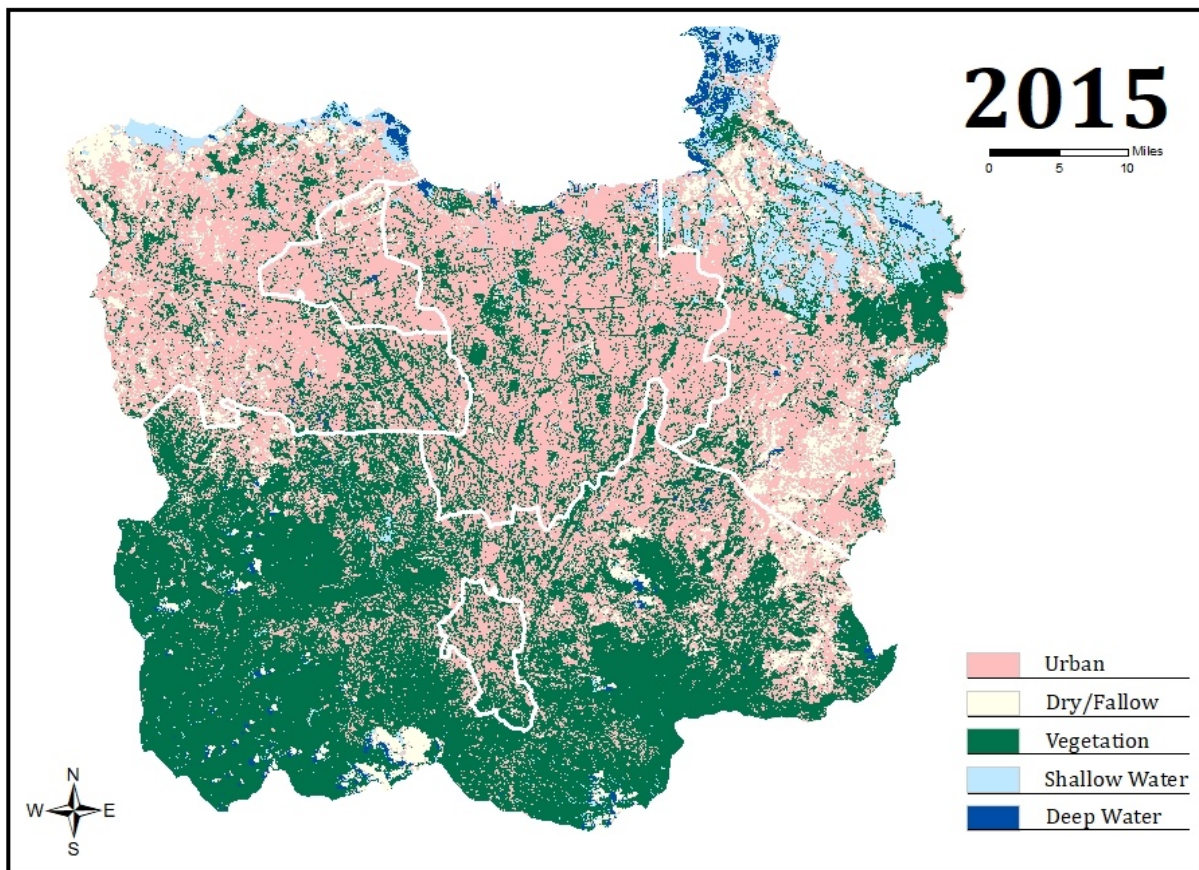
Landsat-5 imagery courtesy of the U.S. Geological Survey.

Since the resurgence of real estate activity in Jakarta after 2005, development has been particularly vigorous towards the eastern and southern periphery. Two current large scale developments underway, the Meikarta new town project in Bekasi, and the Trump Organization luxury hotel project in Bogor follow this spatial pattern. Meikarta is being constructed in Bekasi, and the Trump Organization project is being built in Bogor. Furthermore, Jakarta's historic relation with foreign investors (Herlambang et al 2018) continues with the Trump Organization project, recently partnering with the Metallurgical Corporation of China (Stevenson and Paddock 2018). Despite continued growth amongst all social classes, large luxury development projects

continue to displace local low income residents. Looking forward, land use land type classification maps can be used to predict future battle grounds of displacement and inevitable relocation. Anecdotally, Depok has been cited as a common relocation zone for displaced informal residents, as very few planned developments are located in the Depok region.

Lastly, figure 4, shows the 2015 land use land cover classification. This shows Jakarta's regional land use in the last time period analyzed by this study. The 2015 map exhibits dramatic urban growth, however, as mentioned above, due to spatial resolution of the original Landsat imagery analyzed, urban growth which increasingly weaves between agriculture and vegetation, is characterized as uniformly urban.

**Figure 4** Jakarta Metropolitan Regional Land Use/Land Type Classification for 2015.



Landsat-8 imagery courtesy of the U.S. Geological Survey.

By 2015, urban development has largely spread throughout the region. Depok and Bogor witnessed extensively urban land use growth after 2005. However, visible to the east and west, urban land use has largely densified. Regions which had previously had urban land, by 2015 show a more uniform urban space, with less varying land type present. Dry/fallow land continues to be located near urban land use, but has significantly decreased by 2015. Furthermore, vegetation, while previously surrounding the Jakarta metropolitan area, by 2015 is only located south of the growing metropolis. After 2005, vegetation sharply declined, as urban land use became more prevalent.

While urban sprawl has occurred, a significant factor of peri-urbanization in Jakarta is densification of urban spaces, more so than urban sprawl. Figure 5 shows the complex patterns of development occurring in Jakarta's peri-urban region. Large swaths of land are not purchased and swiftly built upon, rather slowly land is claimed by developers, amidst agricultural plots and kampung settlements. The images below show one area in western Tangerang, first in 2001, then in 2015. In 2001, the most common settlement, amongst the agricultural plots and vegetation are kampung settlements. To the north and east only a few planned developments are visible. However, by 2015, there is a densification in kampung settlements, as well as significant increases to planned developments. In 2015, agricultural plots are still visible, however, no longer dominant. In the southwest corner of the image in 2001, land is being cleared, and by 2015 it is developed. To understand regional change in Jakarta, it is essential to view the land classifications in figure 2 in the light of the complexity of development densification in figure 5. In figure 4, between 2005 and 2015, urban growth throughout the region exploded. However, the findings of figure 5 suggest that an important factor of this urbanization is massive densification and often small, incremental land conversions.

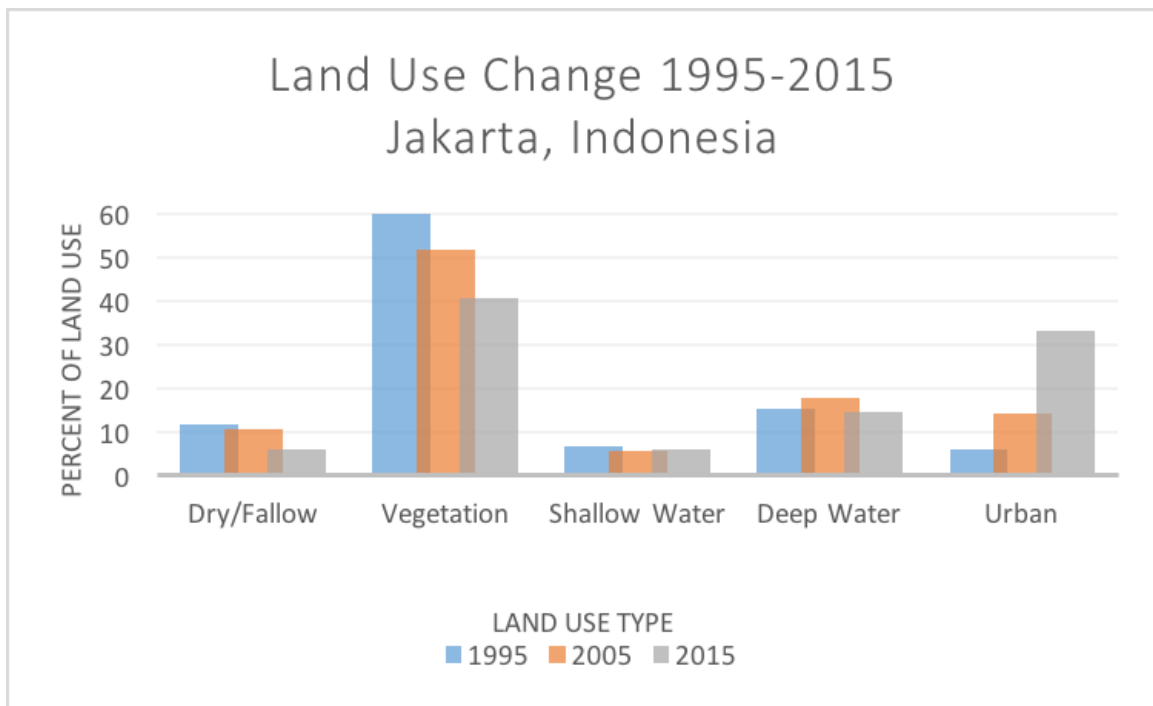
**Figure 5** Comparison of Google Earth imagery of a location in western Tangerang in 2001 and 2015 showing the complex pattern of weaving development.



Data source: Google Earth Pro

While each land classification map distinctly represents growth in urban land uses, table 2 clearly defines the numeric value of land use change by time period. Both water categories show slight changes, most likely due to seasonal variation and classification error. However, other land types show distinct patterns of change. While dry/fallow land, indicated in yellow on classification maps, is one of the smallest proportions of land use, it showed declines between 1995-2015. Furthermore, vegetation, nearly 60 percent of land use in 1995, dropped by nearly 20 percent during this twenty year timeframe. Apparent from land classification maps, urban land use made significant gains, increasing to over 30 percent.

**Table 2** Showing land use types identified in this research compared in different time periods.

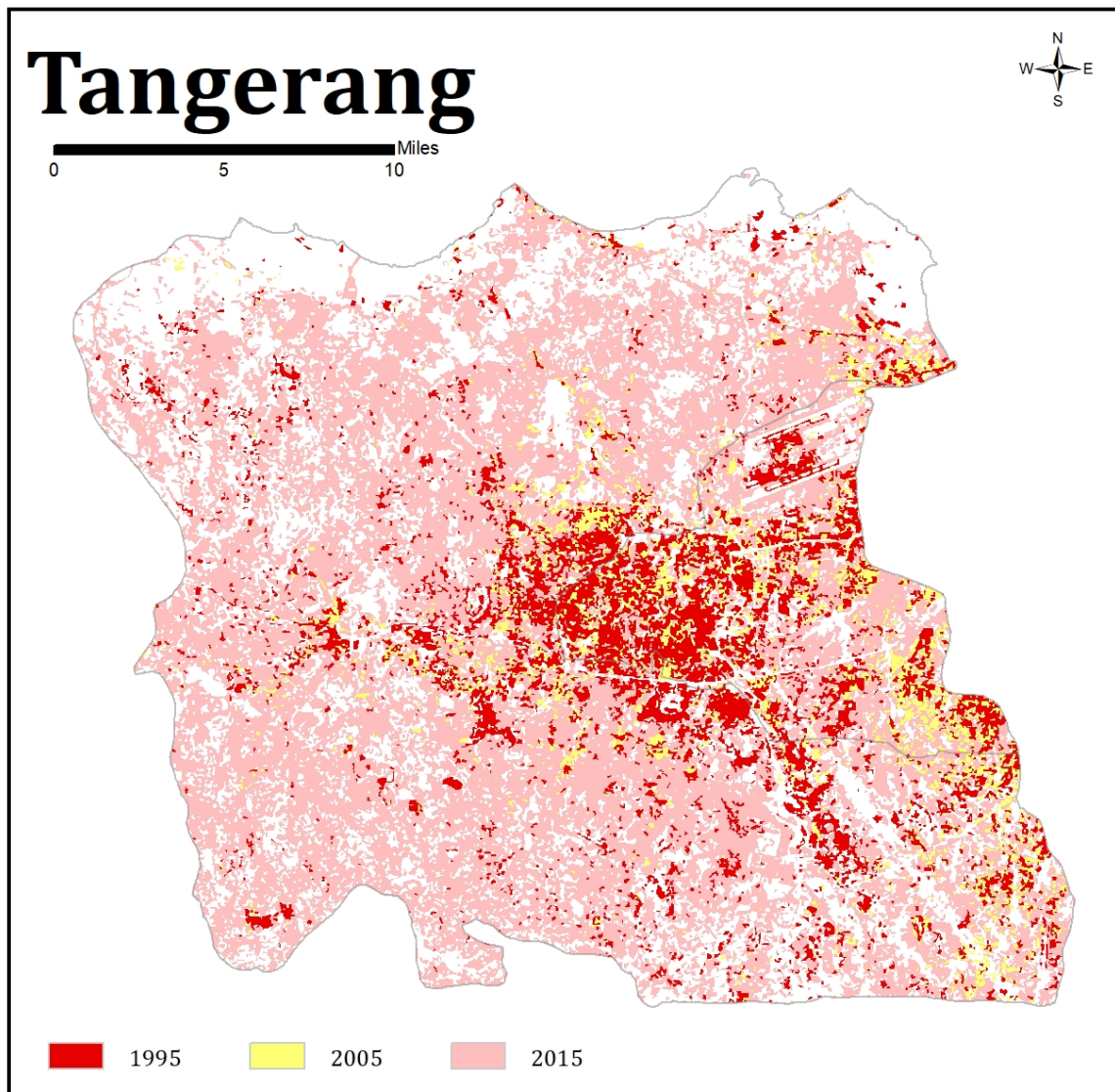


Data derived from analysis conducted on Landsat-5 and Landsat -8 imagery, courtesy of the U.S. Geological Survey.

## Variation in Urban Growth Patterns Within the Metropolitan Region

Many previous studies conducted regarding peri-urbanization in Jakarta, focus heavily on the peri-urban space as a singular zone, with little indication of regional differences (Firman et al 2017, Pribadi et al 2018). However, patterns of development in the peri-urban space have taken different form, at different times throughout the region. Figures 6-8 depict urban land use change in 1995, 2005, and 2015 by region.

*Figure 6* Urban growth compared over time on the western front of peri-urbanization.

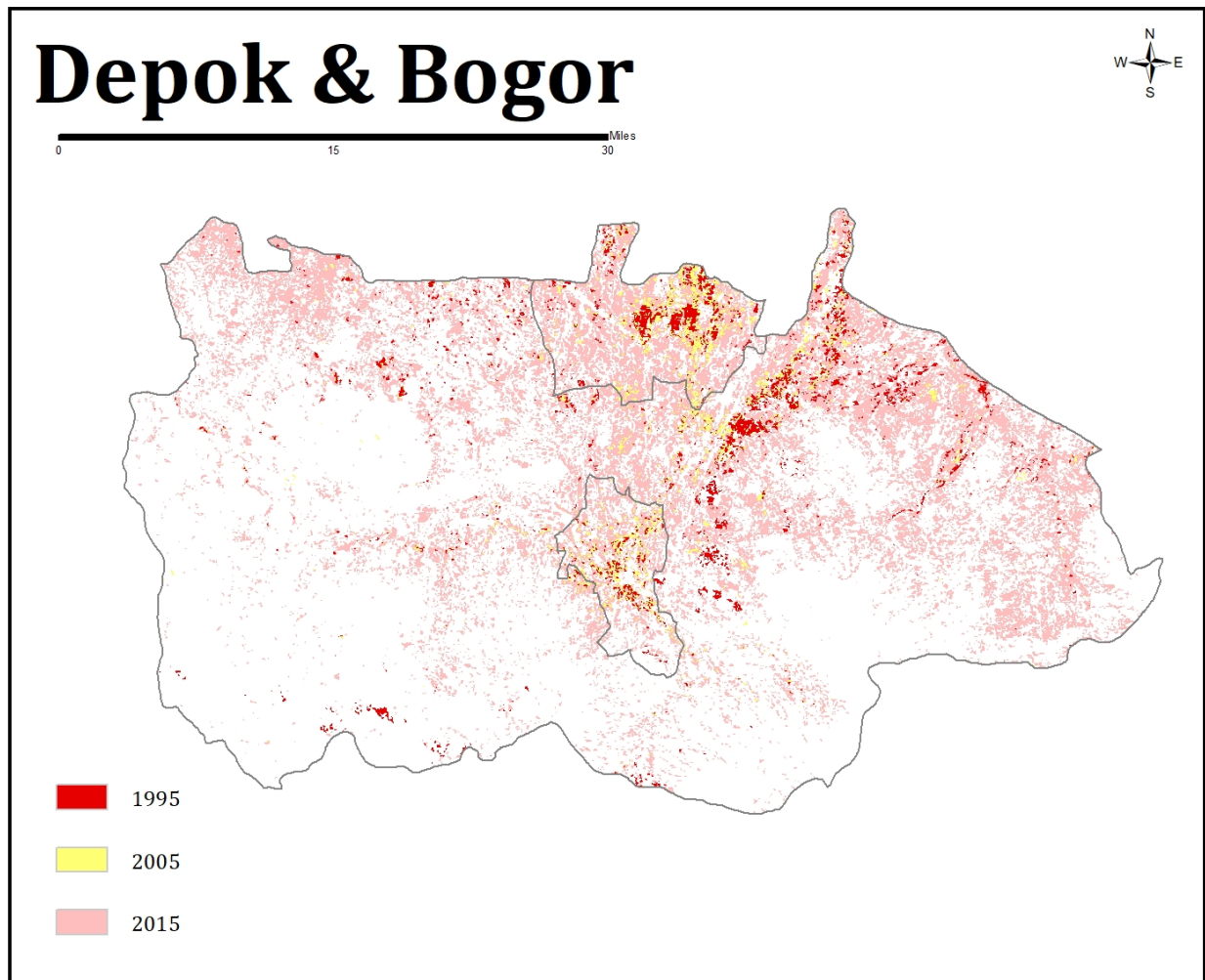


Data derived from Landsat-5 and Landsat-8 imagery, courtesy of the U.S. Geological Survey.

In figure 6, the region west of Jakarta City, Tangerang, is shown. By 1995, Tangerang led the peri-urbanization frontier, containing significant portions of overall new town developments built in Jakarta (Herlambang et al 2018; Firman et al 2017). While figure 6 shows large swaths of urbanization by 1995, between 1995-2005, few urban developments were added to the region, due to the reduced building activity around the financial crisis of 1997-98 (Herlambang et al 2018). Notably, one of the largest new town developments in Jakarta, BSD City, which began construction in 1989, is located in Tangerang. The project, known for its large scale goals, was projected to be built in three tiers, the first phase was completed in 2009, spanning 3700 acres. Development on BSD City, is planned to be completed in 2035, covering nearly 15,000 acres (Winarso et al 2015). However, BSD City is only one new town development located in Tangerang, several others, as well as other smaller gated communities, also continue to urbanize the region, evident in the widespread changes between 2005-2015.

South of Jakarta City, figure 7 shows urbanization over time in Depok and Bogor. By 1995, only a small portion of land was urbanized, following a corridor between eastern Depok to Bogor. Urbanization between 1995 and 2005 in this south zone was extremely minimal. However, by 2015, urbanization has spread throughout Bogor and Depok, connecting Bogor City to the metropolitan zones in Jakarta City, as well as Tangerang and Bekasi. Massive sprawl and densification of this region occurred after 2005, where previously very few urban land use was found. While many forms of privatized development exist, shifts in new town development signal larger regional development patterns. After 2005, Bogor, Depok, and Bekasi have been the site of numerous new town developments (Herlambang et al 2018).

*Figure 7* Urban growth compared over time on the southern front of peri-urbanization.

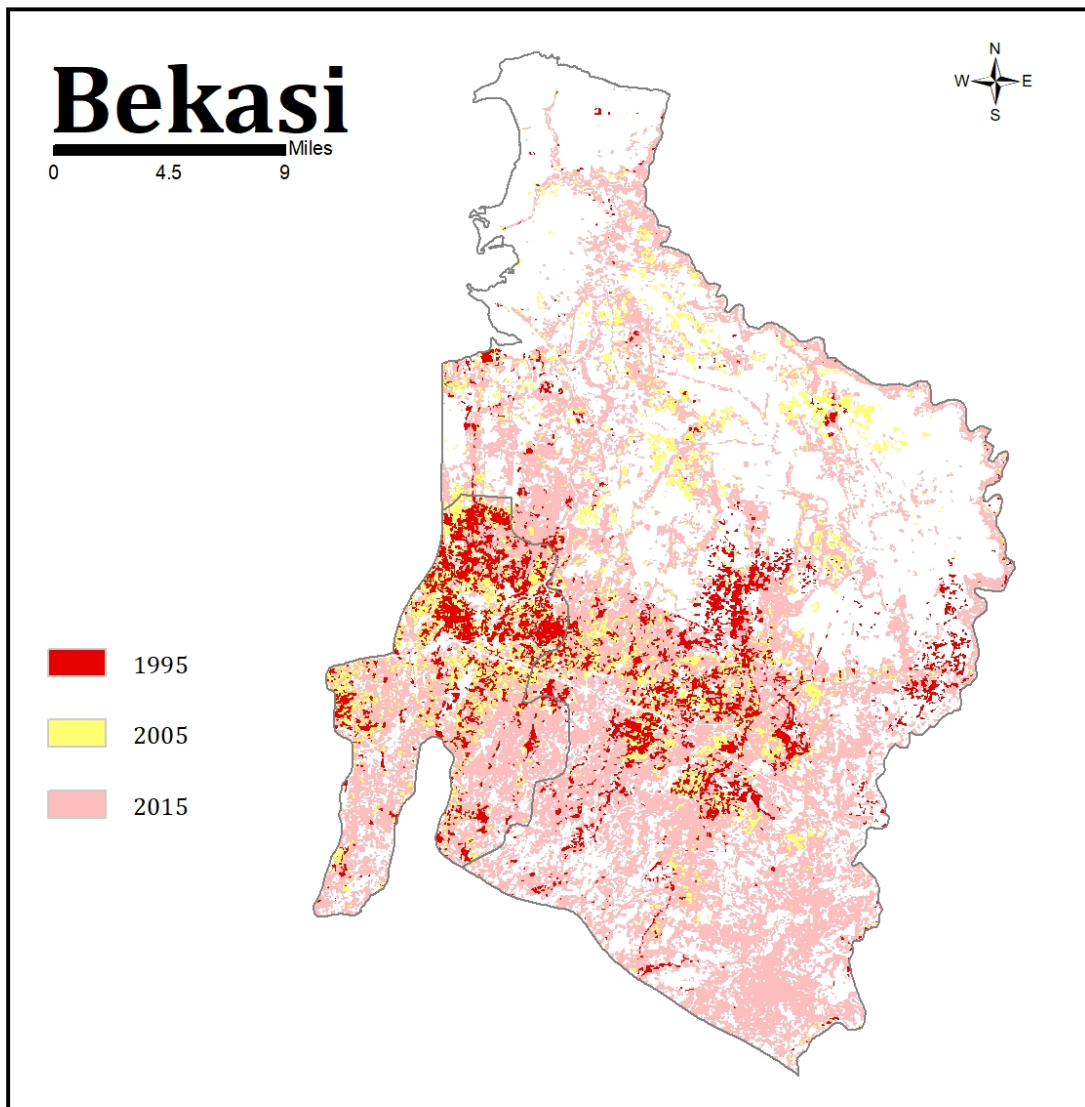


Data derived from Landsat-5 and Landsat-8 imagery, courtesy of the U.S. Geological Survey.

Urban expansion in Bekasi, shown in figure 8, focused to a large extent along the major transportation corridor to the east until 2005. Between 1995-2005, while development remained highly concentrated, new urban land was developed north of the transportation corridor. The north region of Bekasi remains a highly agriculture dense space. However, while regionally, throughout the metropolitan area, development halted between 1995-2005, Bekasi continued to gain urban land. Interestingly, urban expansion at this time occurred along in the northern Bekasi

agricultural zone, breaking the corridor pattern. Development in Bekasi continues, however, to center around a toll road project cutting through Bekasi, from Jakarta City to Purwakarta. After 2005, development does not continue to be focused north of the transportation corridor. Between 2005-2015, development magnifies south of the transportation corridor, with intense urban land densification.

**Figure 8** Urban growth compared over time on the eastern front of peri-urbanization.



Data derived from Landsat-5 and Landsat-8 imagery, courtesy of the U.S. Geological Survey.

## **Conclusion**

The goal of this study was to document land use change throughout peri-urban Jakarta, while also highlighting significant components and consequences of peri-urbanization. It was crucial to utilize and expand upon existing research on land use change and the development trajectory of the Jakarta metropolitan region to inform and contextualize the findings presented in this paper.

While insightful, this analysis contains limitations, and more work is necessary to continue building an accurate representation of land use change in Jakarta. To improve classification quality, higher resolution imagery and more accurate ground truth samples could provide more insight on regional change in a future analysis.

This study found that between the years 1995-2015 regional urban land use increased from 6 percent to 32 percent. In the same time period, vegetation decreased by 20 percent. However, land use change varied by region throughout the metropolitan area. Early development began to the west, in Tangerang, and slowly moved east after 1995. Depok and Bogor, south of Jakarta DKI, only recently experienced mass urban land conversion, after 2005. Each region developed at different paces, with different development types, creating unique peri-urban spaces. Residential zones have dominated Tangerang, and continue to densify, however, industrial developments characterize Bekasi.

Importantly, the findings of the land use land cover classifications presented in this analysis support findings of other peri-urban studies, in addition to existing scholarship conducted in Jakarta's metropolitan area. Other peri-urban studies using land use land cover classifications also saw massive reduction in vegetation, with significant increase in urban land use (Shaw and Das 2018). Furthermore, patterns of development described in existing Jakarta

literature (Herlambang et al 2018; Firman et al 2017; Winarso et al 2015) correspond to the remote sensing findings conducted in this study. However, the remote sensing analysis conducted extended current knowledge regarding peri-urbanization in Jakarta through detailed regional land use analysis.

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