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HIGHER EDUCATION AND REGIONAL TRANSFORMATION: GEOSPATIAL INSIGHTS INTO URBAN GROWTH AROUND UITM BERTAM

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Abstract:

This study examines land use and land cover (LULC) transformation surrounding Universiti Teknologi MARA Cawangan Pulau Pinang (UiTMCPP) Bertam Campus within the broader regional development of North Seberang Perai, Penang. Using Geographic Information System (GIS) and remote sensing techniques, multi-temporal Landsat images from 1999, 2009 and 2019 were analysed to identify land use and land cover changes within 5 km and 10 km radii surrounding the campus. Results indicate substantial growth in developed land, increasing from 7.25% to 37.60% within the 5 km radius and from 8.15% to 36.71% within the 10 km radius over twenty years. These

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changes were accompanied by reductions in several agricultural and vegetated land-cover classes. Supplementary visual comparison of Google Earth historical imagery from 2019 and 2026 further showed continued land transformation east and northeast of the campus. The findings indicate that the growth surrounding UiTMCPP Bertam Campus occurred within a broader regional transformation involving educational, residential, commercial, healthcare, and infrastructure development. The findings suggest that higher education institutions may function as one of several development anchors within a rapidly transforming regional environment. However, the observed reduction in agricultural and vegetated land highlights the importance of integrating sustainable land management considerations into future regional planning.

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Keyword:

GIS, Higher Education, Land Use Land Cover Change, Urban Transformation

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Introduction

Malaysia has experienced rapid urbanisation over the past few decades. The urbanisation rate increased from 70.08% in 2009 to 74.21% in 2015 and reached 76.61% in 2019 (Statista, 2020). Malaysia is also considered one of the most urbanised countries in East Asia (World Bank Group, 2015). Penang is among the highly urbanised states in Malaysia, with an urbanisation level of 90.8% (Woo & Khoo, 2020).

Despite being the second smallest state in Malaysia in terms of land area, Penang has a high population density. The Population and Housing Census 2010 reported a population density of 1,490 persons per square kilometre, which was the second highest after Kuala Lumpur (Malaysia, 2010). The increasing population and urbanisation have resulted in greater demand for housing, commercial areas, educational institutions and healthcare facilities. Consequently, changes in land use have continued to occur in many parts of Penang (Woo & Khoo, 2020).

Higher education institutions are among the developments that can influence their surrounding areas. Apart from providing education, universities may contribute to the local economy, infrastructure and human capital development. Previous studies have reported the role of universities in human capital development and innovation within cities and regions (Perry & Wiewel, 2015; Samat et al., 2019). Development associated with educational institutions may also occur together with changes in population, land use, infrastructure and social activities (Woo & Khoo, 2020).

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Universiti Teknologi MARA Cawangan Pulau Pinang (UiTMCPP) Bertam Campus is the second campus of UiTMCPP. Phase 1 of the campus, covering approximately 13.2 hectares, was completed in May 2011. The campus started its operation in the same year and accommodated students from the Faculty of Health Sciences and Faculty of Pharmacy. The establishment of the campus took place during a period when the surrounding Bertam area was also undergoing development.

Since 2011, Bertam has continued to develop as one of the growth areas in North Seberang Perai. Residential and commercial development has increased, together with healthcare and educational facilities. This includes the development of Bandar Putra Bertam and Bertam Perdana, road infrastructure and other public facilities. The Penang State Structure Plan 2030 identifies Kepala Batas as one of the main urban centres in Penang (PLANMalaysia@Pulau Pinang, 2019). These developments have gradually changed parts of Bertam from an agricultural landscape to a more developed area.

UiTMCPP Bertam Campus is one of several developments occurring within this area. The presence of students and staff may create demand for housing, food, transportation and other services. However, development in Bertam is also related to residential, commercial, healthcare and infrastructure expansion. Therefore, the changes surrounding the campus should be considered within the wider development of Bertam rather than attributed to the university alone.

Although GIS and satellite imagery have been widely used to study urban growth, fewer studies have specifically examined land use changes surrounding higher education institutions. Othman et al. (2022) examined development surrounding the UiTMCPP Permatang Pauh Campus in Central Seberang Perai. However, less information is available for the Bertam area in North Seberang Perai. Bertam provides a different setting because agricultural land exists together with expanding residential, educational, healthcare and infrastructure development. Therefore, this study aims to assess land use and land cover (LULC) changes surrounding UiTMCPP Bertam Campus between 1999 and 2019 using Geographic Information System (GIS) and remote sensing techniques. The study also examines the changes surrounding the campus in relation to the broader development of Bertam.

Literature Review

North Seberang Perai is one of the three administrative districts on the mainland of Penang, Malaysia. It covers approximately 267 km² and had a population of 405,100 in 2019 (Woo & Khoo, 2020). Kepala Batas is the district capital, while other localities include Bertam, Penaga, Pinang Tunggal, Tasek Gelugor, Teluk Air Tawar and Mak Mandin. Agriculture remains an important land use in North Seberang Perai, particularly paddy cultivation.

Bertam has also developed as an area for education and healthcare. Several institutions are located within the area, including UiTM Cawangan Pulau Pinang Bertam Campus, Pusat Kanser Tun Abdullah Ahmad Badawi, Universiti Sains Malaysia (USM), Industrial Training Institute (ILP), Kepala Batas Community College and Kolej Kejururawatan Bertam. The presence of these institutions has added educational and healthcare activities to an area that was traditionally associated with agriculture.

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Universities can influence the areas surrounding them through activities beyond teaching and learning. They may create demand for housing, transportation, food and other services because of the presence of students and employees. Universities have also been described as anchor institutions because their activities can be linked to local and regional development (Fongwa, 2021; Garton, 2021). Perry and Wiewel (2015) also discussed the role of universities in urban development. However, the extent of development around a university depends on the local setting and other development taking place in the same area.

A local example can be seen in the study by Othman et al. (2022), which examined urban development surrounding the UiTM Cawangan Pulau Pinang Permatang Pauh Campus in Central Seberang Perai. Their study reported changes in developed areas surrounding the campus over time. This provides a useful comparison for the present study because UiTMCPP Bertam Campus is located in a different part of Seberang Perai, where agricultural land is still present together with increasing residential, educational and healthcare development.

Land use and land cover (LULC) analysis is commonly used to examine changes associated with urban growth. GIS and remote sensing allow land use changes to be mapped and compared over different periods (Al-Shalabi et al., 2013; Hegazy & Kaloop, 2015; Samat et al., 2020). Landsat imagery is suitable for this type of analysis because historical images are available over a long period, can be accessed freely and have a spatial resolution of 30 m (Borana et al., 2016).

Different classification methods can be used to identify land-cover classes from satellite images. Pixel-based methods such as Maximum Likelihood Classification (MLC) and Support Vector Machine (SVM) have been applied in previous LULC studies (Boori et al., 2015; Hegazy & Kaloop, 2015; Liu et al., 2020). These methods can separate the study area into different land-cover classes, such as agricultural land, vegetation, water bodies and developed areas. Comparison between different years can then show how the amount and distribution of these land-cover classes have changed.

Many studies have used GIS and remote sensing to examine urban growth. However, studies focusing on land use changes surrounding higher education institutions are still limited. In Seberang Perai, Othman et al. (2022) studied the UiTMCPP Permatang Pauh Campus, but less attention has been given to the Bertam area in North Seberang Perai. Bertam has a different development setting because agricultural land exists alongside educational and healthcare institutions, residential areas and expanding infrastructure. This study therefore examines LULC changes surrounding UiTMCPP Bertam Campus over a 20-year period to determine how the surrounding landscape has changed.

Methodology

The study was conducted within the surrounding area of Universiti Teknologi MARA Cawangan Pulau Pinang (UiTMCPP) Bertam Campus, which occupies a total land area of 100.4 hectares. Multi-temporal satellite images with a spatial resolution of 30 m were obtained from the United States Geological Survey (USGS) Earth Explorer. Three Landsat datasets representing different time periods were selected to evaluate land use and land cover (LULC) changes over a 20-year period: Landsat 7 Enhanced Thematic Mapper Plus (ETM+) for 1999, Landsat 5 Thematic Mapper (TM) for 2009, and Landsat 8 Operational Land Imager (OLI) for 2019 (Figure 1). The satellite images were downloaded in the World Geodetic System 1984

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(WGS84) coordinate system. Image preprocessing was carried out using ERDAS IMAGINE software. Individual spectral bands were first combined through a layer stacking process, followed by image enhancement, geometric correction, atmospheric correction, vectorisation, image classification, and information extraction. Atmospheric correction was performed using the Dark Object Subtraction (DOS) method to minimise atmospheric scattering effects by identifying the darkest pixel values within each image (Tollerud et al., 2020). This pre-processing step improved image quality and enhanced the accuracy of subsequent land use classification.



(a) **(b)** **(c)**

Figure 1. Landsat Imageries (a) 27 December 1999, (b) 14 December 2009 and (c) 25 February 2019.

Land use and land cover (LULC) classification was performed using the supervised Maximum Likelihood Classification (MLC) technique, which is widely used for Landsat image classification (Hegazy & Kaloop, 2015). The satellite images were subset according to the study area and classified into six land cover classes: water bodies, forest, vegetation, paddy fields, oil palm plantations, and developed areas. Classification was carried out separately within 5 km and 10 km buffer zones surrounding the UiTM Cawangan Pulau Pinang (UiTMCPP) Bertam Campus (Figure 2)

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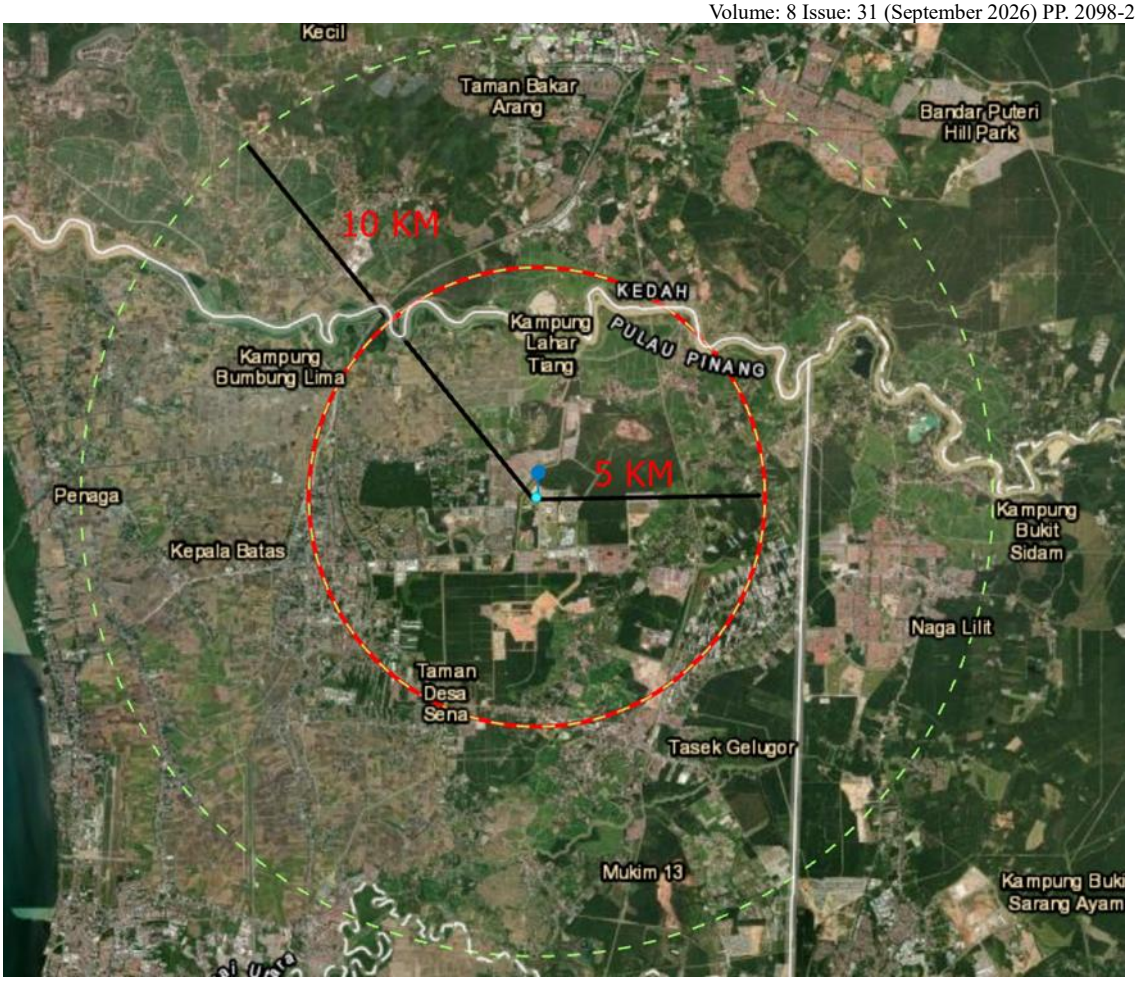


Figure 2. Zone in radius 5km and 10km from the UiTM Bertam Campus

The study areas were delineated using the Buffer tool in ArcMAP software, with radii of 5 km and 10 km from the campus boundary (Figure 2). The 5 km and 10 km buffer zones were chosen to assess the LULC changes at two spatial scales around the campus. The 5 km radius refers to the immediate vicinity of the campus and the 10 km radius indicates a larger regional context of land-use transformation. These buffers were used as analytical boundaries for spatial comparison and were not meant to represent fixed zones of influence of UiTMCPP Bertam Campus. For qualitative validation of the classified maps, approximately 30 reference points distributed across the study area were selected. The classified land-cover classes at these locations were compared with high-resolution Google Earth imagery and supported by field observations to assess the reliability of the classification.

While the main LULC analysis for the quantitative analysis of the 20-year study period was performed using Landsat satellite images for 1999, 2009, and 2019 to maintain the same temporal consistency, additional visual verification was carried out using the historical imagery from Google Earth for October 2019 and January 2026. The purpose of the use of the Google Earth imagery was to visually observe any recent changes that occurred in land cover and development in the vicinity of the study area after 2019. It was a qualitative visual comparison, which was not quantitatively classified.

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Results and Discussion

Land Use and Land Cover in UiTM Bertam Campus, Pulau Pinang

A classification scheme for further analysis of the land use and land cover (LULC) image was established, based on the characteristics of the area (Table 1). The LULC is displayed within 20 years' period at ten years interval; the year 1999, 2009 and 2019. The LULC of the UiTM Bertam Campus consists of water bodies, forest, vegetation, paddy field, palm oil and developed area. The selection image's classes are depending on the existing of LULC surrounding UiTM Bertam Campus, Pulau Pinang.

Table 1. Detail Classification Scheme Used for Supervised Classification

Code	Land Cover Type	Description
1	Water Bodies	River, permanent open water, lakes and reservoirs
2	Forest	Area covered with trees and undergrowth
3	Vegetation	Agriculture, shrub lands, etc.
4	Paddy Field	Area covered with paddy
5	Palm Oil	Area covered with palm oil trees
6	Developed Area	Temporary and permanent buildings, houses, villages and artificial infrastructures

Land-use Land Cover UiTM Bertam, Pulau Pinang in Five (5) Kilometer Radius

The LULC classification results are then summarized for the years 1999, 2009 and 2019 (Table 2) of UiTM Bertam Campus with an offset of 5km. The LULC is displayed within 20 years' period at 10 years interval; year 1999, 2009 and 2019. As shown in Table 2, the LULC of UiTM Bertam Campus consists of water bodies, forest, vegetation, paddy field, palm oil and developed area. Considerable changes in land use were observed throughout the 20-year study period.

UiTMCPP Bertam Campus is bounded within a developed area since it is located along the main road. Some vegetation and forest are shown in the upper and lower part of the image. A string of water bodies shown at the upper part of the image (Figure 2). As vegetation class has different hues and patterns, the sites were classified into three detail classes, e.g. palm oil and vegetation.

Within the 5 km radius the largest land-use category was oil palm. The area it occupied being 44.92% in 1999, 27.96% in 2009 and 27.62% in 2019. This shows a significant decrease in the extent of oil palm over the 20-year period of the study. In 1999 the smallest land-use category was forest, with an area of 534.87 ha. In 2009 vegetation covered 788.31 ha and this declined to 298.17 ha by 2019. According to Table 2, the amount of developed land increased considerably from 7.25% in 1999 to 17.74% in 2009 and to 37.60% in 2019, while the forest area reduced from 4.74% to 3.87% between 1999 and 2019. However, in 2009 the forest class was incorrectly classified in a number of areas around UiTMCPP Bertam because of the mixed-pixel problem in the Landsat image (Wentz et al., 2014). The changes in land-use cover types during the study period are shown in Figure 3.

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The relative changes in the LULC classes are given in Table 3. Between 1999 and 2019, the area of developed land increased by 3,423.06 ha (30.35 per cent), which was the greatest increase among all the LULC classes. On the other hand, oil palm decreased by 1,950.66 ha (17.30 per cent), vegetation by 802.17 ha (7.11 per cent), and water bodies by 379.80 ha (3.37 per cent). Forest and paddy fields both increased between 1999 and 2009 before falling between 2009 and 2019. Taken as a whole, the findings show that there has been considerable expansion of developed land together with reductions in oil palm, vegetation and the other land-cover classes within the 5 km radius.

The large increase in developed areas coupled with the decrease in oil palm plantation and other agricultural land shows a significant land transformation within the 5 km radius. These changes have been accompanied by the establishment and growth of UiTMCPP Bertam Campus and wider residential, commercial, healthcare and infrastructure development in Bertam.

Table 2. Summary of Land Use/Land Cover area for year 1999, 2009 and 2019 (5km)

Land Use Class	1999 Area (ha)	%	2009 Area (ha)	%	2019 Area (ha)	%
Water Bodies	1373.85	12.18	1151.19	10.21	994.05	8.81
Forest	534.87	4.74	1492.65	13.24	436.32	3.87
Vegetation	1100.34	9.76	788.31	6.99	298.17	2.64
Paddy Field	2384.82	21.15	2691.63	23.87	2192.94	19.45
Palm Oil	5065.74	44.92	3152.79	27.96	3115.08	27.62
Developed Area	817.38	7.25	2000.43	17.74	4240.44	37.60
Total	11277.00		11277.00		11277.00	

Table 3. Summary of relative changes of LULC area from year 1999 to 2019 (5km)

Relative Changes	1999 – 2009 Area (ha)	%	2009 – 2019 Area (ha)	%	1999 – 2019 Area (ha)	%
Water Bodies	-222.66	-1.97	-157.14	-1.39	-379.80	-3.37
Forest	957.78	8.49	-1056.33	-9.37	-98.55	-0.87
Vegetation	-312.03	-2.77	-490.14	-4.35	-802.17	-7.11
Paddy Field	306.81	2.72	-498.69	-4.42	-191.88	-1.70
Palm Oil	-1912.95	-16.96	-37.71	-0.33	-1950.66	-17.30
Developed Area	1183.05	10.49	2240.01	19.86	3423.06	30.35

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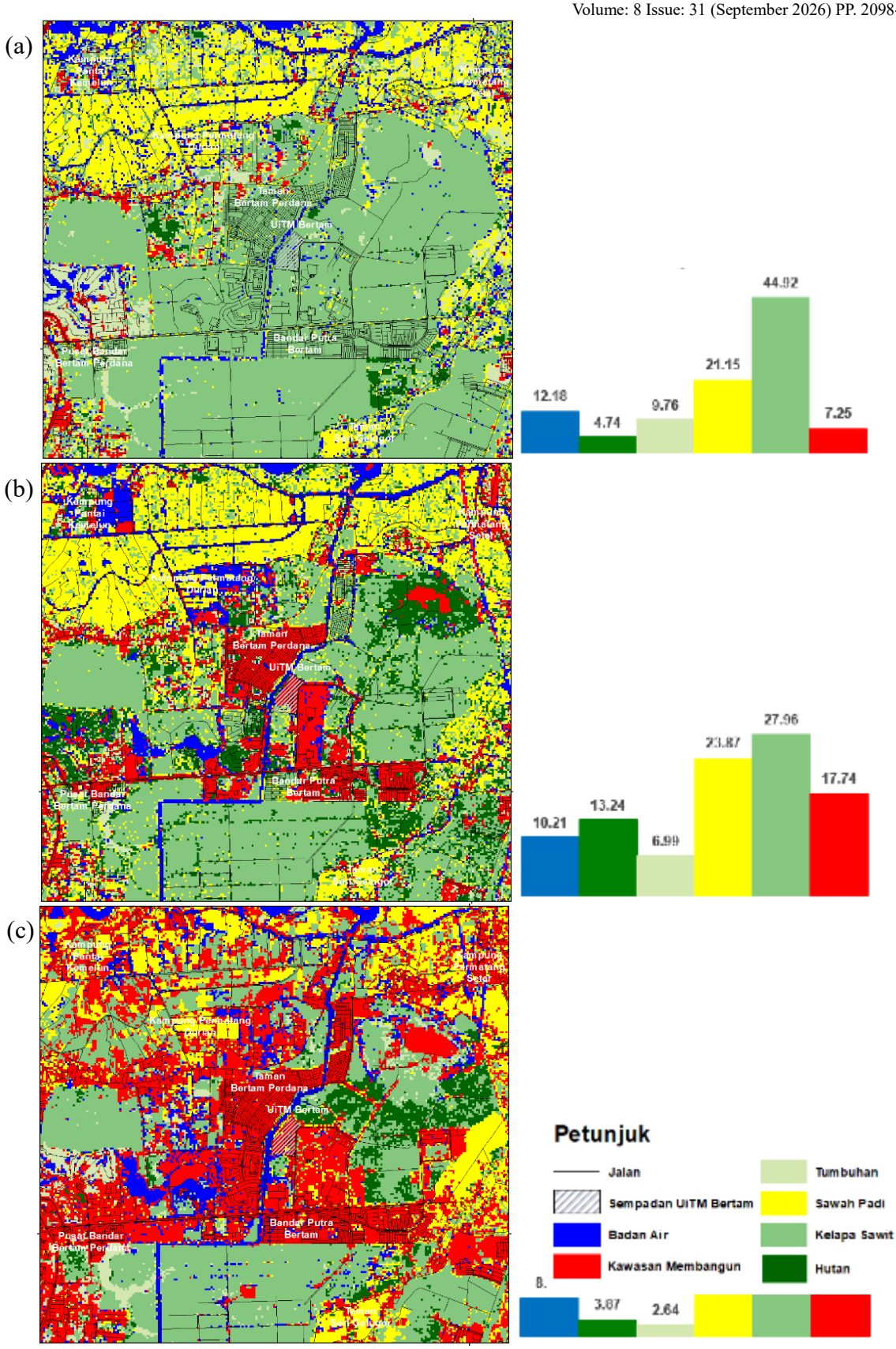


Figure 3. Land Use/Land Cover Map of 3 Consecutive Years (a) 1999 (b) 2009 and (c) 2019 for 5km Radius.b. Land-use Land Cover UiTM Bertam Campus, Pulau Pinang in Ten (10) Kilometer Radius

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Table 4 shows the changes in land use and land cover within a 10 km radius of the UiTMCPP Bertam Campus. The land use and land cover categories include water bodies, forest, vegetation, paddy fields, oil palm and developed areas. In both 1999 and 2009, paddy fields were the most extensive land-use category, making up 24.22% and 26.87% of the study area respectively. In 2019, paddy fields covered 24.92% of the study area. The amount of vegetation fell from 10.56% in 1999 to 5.95% in 2009 and then to 4.48% in 2019. There was also a clear increase in forest area between 1999 and 2009, a trend which might be linked to the pixel misclassification found in satellite imagery. Overall, during the 20-year period of the study water bodies, oil palm and vegetation all declined, whereas developed land increased considerably (Figure 4).

The amount of developed land rose from 3,486.78 ha (8.15%) in 1999 to 15,705.10 ha (36.71%) in 2019, which means that there was an increase of 12,218.32 ha during the 20-year period under study. On the other hand, oil palm area declined from 15,475.20 ha (36.17%) to 8,416.80 ha (19.67%), and vegetation decreased from 4,519.53 ha (10.56%) to 1,917.81 ha (4.48%).

Table 4. Summary of Land Use/Land Cover area for year 1999, 2009 and 2019 (10km)

Land Use Class	1999		2009		2019	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Water Bodies	4733.19	11.06	3829.41	8.95	3503.88	8.19
Forest	4208.85	9.84	6976.80	16.31	2579.31	6.03
Vegetation	4519.53	10.56	2545.47	5.95	1917.81	4.48
Paddy Field	10361.50	24.22	11497.00	26.87	10662.20	24.92
Palm Oil	15475.20	36.17	10035.80	23.46	8416.80	19.67
Developed Area	3486.78	8.15	7900.56	18.47	15705.10	36.71
Total	42785.05		42785.05		42785.05	

The area of developed land increased significantly during the study period within the 10 km radius while several agricultural and vegetated land-cover classes decreased. This pattern demonstrates a significant growth of the urban area in the broader Bertam region. The growth of developed land was in line with the establishment and development of UiTMCPP Bertam Campus, and other residential, commercial, healthcare, educational and infrastructure development in North Seberang Perai. Hence, the land-use change observed cannot be solely attributed to the presence of UiTMCPP Bertam Campus but should be seen as part of the larger regional development of Bertam.

Developed Area for year 1999, 2009 and 2019

Bertam has experienced considerable physical and socioeconomic development associated with increasing urbanisation and economic activities. The expansion of residential, commercial, educational, and healthcare facilities has contributed to changes in the surrounding built environment and increased demand for supporting infrastructure and services.

Table 5 shows the ratio between the developed area and the UiTMCPP Bertam Campus area keeps increasing from 1999 to 2019 in both radii of 5 km and 10 km. This rising ratio indicates the significant expansion of developed land around the campus during the period of study. Nevertheless, the observed increase should not be viewed as a direct contribution of the campus

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to urban development, but rather development in Bertam took place in conjunction with other regional factors including residential, commercial, healthcare, educational and infrastructure expansions. Therefore, the ratio is a descriptive indication of the extent of development surrounding the campus, not evidence of a causal relation.

Table 5. Ratio of development per area of UiTM Bertam Campus for 5km and 10km radius (1999, 2009 & 2019)

Radius (km)	Years	Development Area (ha)	Area of UiTM (ha)	Ratio of Developed Area to Campus Area
5	1999 2009 2019	817 2000 4240	253.88	3.22 7.88 16.70
10	1999 2009 2019	3487 7901 15705	253.88	13.73 31.12 61.86

Urban Development Map for 1999 to 2019 shows a slight increase in a developed area in the UiTM Bertam Campus, Pulau Pinang (Figure 5). The early development of Bertam in 1999 is about 7.25% (817.38 ha) and an increase in 2009, approximately 17.74% (2000.43 ha). The development focuses on the main access and connection between other towns because it is located near the downtown area. The establishment of Bertam Campus likely contributed to and accelerated ongoing development trends in Bertam, alongside other regional growth drivers such as healthcare facilities, residential developments, transportation infrastructure, and economic expansion. Thus, the development in 2019 is increasing about 2461.50 ha (37.60%) for a 5 km radius in Bertam. Figure 6 shows the urban development map for the year 1999 to 2019. There is a slight increase of developed area from 8.15% (3486.78 ha) in 1999 to 18.47% (7900.56 ha) in 2009 due to that particular area's locality within 5km. Different locality factors support most development areas along the main road, providing access to the main area. Total area of developed area in 2019 is increasing about 15705.10 hectares (36.71%) for a 10 km radius in Bertam.

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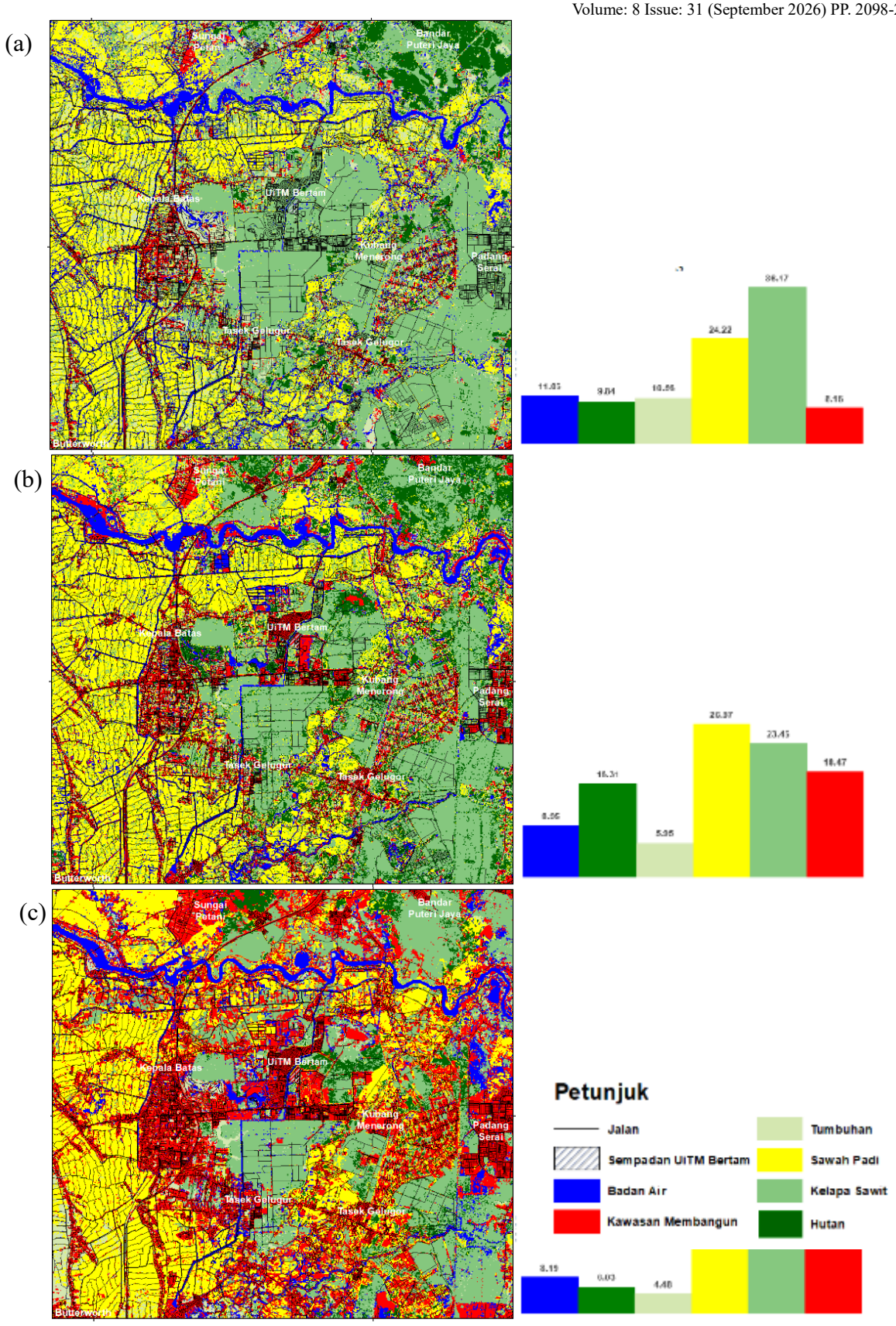


Figure 4. Land Use/Land Cover Map of 3 Consecutive Years (a) 1999 (b) 2009 and (c) 2019 for 10km Radius.

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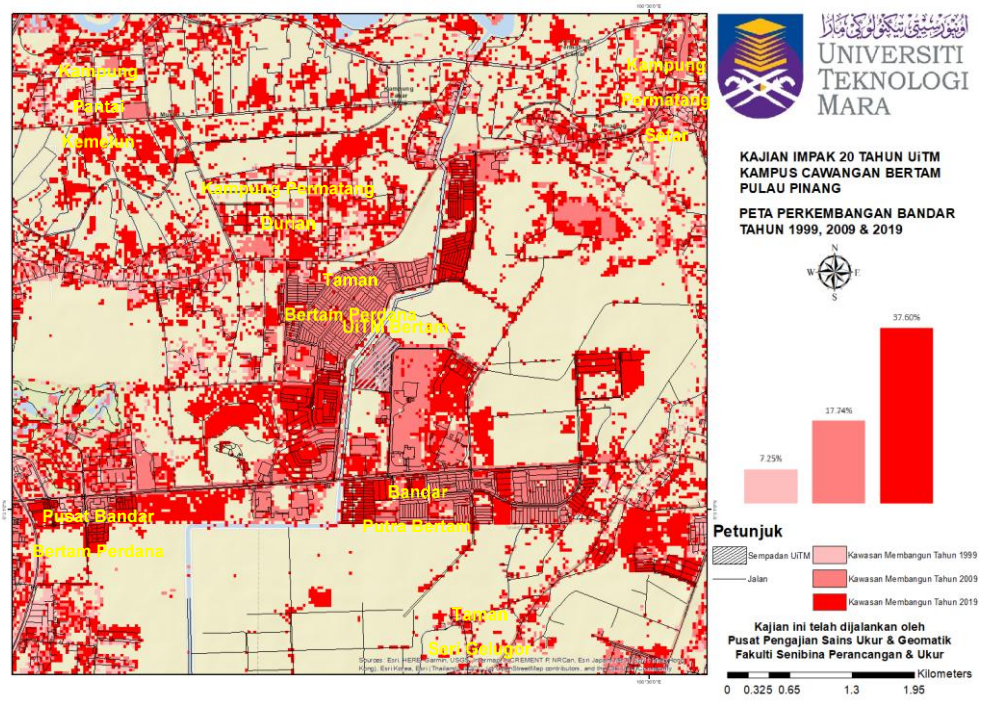


Figure 5. Urban Development Map Of Year 1999, 2009 & 2019 For 5km Radius From Uitm Bertam Campus, Pulau Pinang

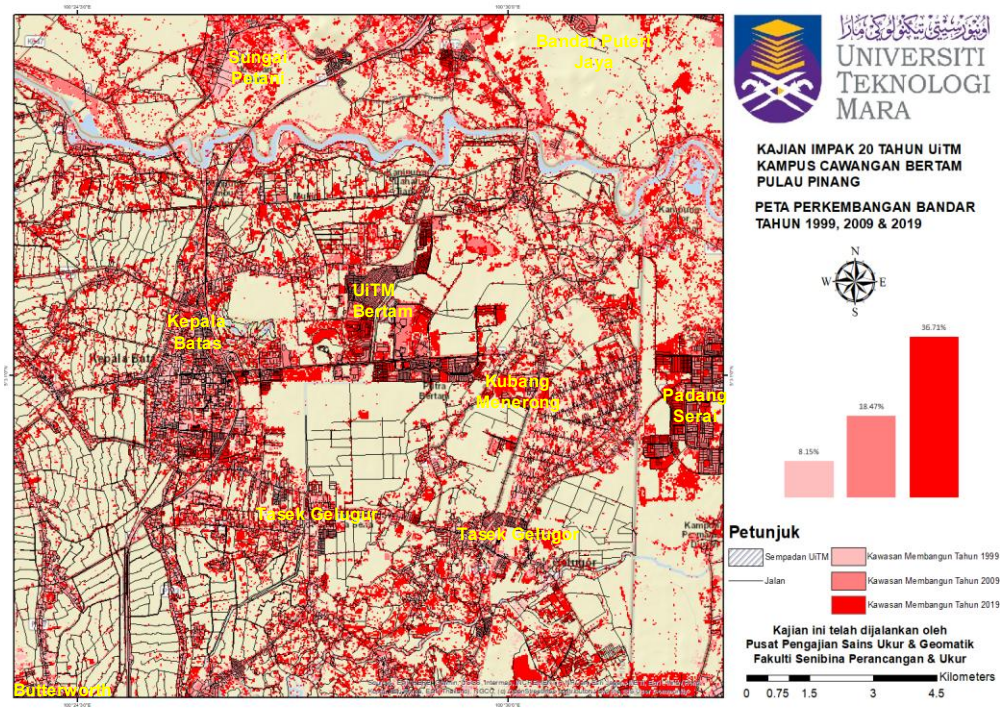


Figure 6. Urban Development Map Of Year 1999, 2009 & 2019 For 10km Radius From Uitm Bertam Campus, Pulau Pinang.

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Recent Development Trends in Bertam

Although the main GIS analysis of the study was done up to 2019, development in Bertam has continued. Google Earth images from October 2019 and January 2026 were visually compared to observe more recent changes surrounding UiTMCPP Bertam Campus. The comparison showed noticeable changes, particularly to the east and northeast of the campus (Figure 7). Some areas that were mainly covered by plantation and vegetation in 2019 had been cleared by 2026, together with the appearance of new roads and developed areas. This visual comparison suggests that land transformation around Bertam continued after the period covered by the Landsat analysis.

The changes observed after 2019 should not be associated with UiTMCPP Bertam Campus alone. Bertam has also experienced residential and commercial development, expansion of healthcare and educational facilities, and improvements in road infrastructure. These developments occurred within the same surrounding area and may have contributed to the continued transformation of the landscape. UiTMCPP Bertam Campus is therefore considered as one of several developments present within the changing Bertam area.

The continued conversion of agricultural and vegetated land is also important from a planning perspective. As development continues, consideration should be given to the management of the remaining agricultural and green areas. This is relevant to the broader aim of balancing urban and economic development with sustainable land management (United Nations, 2025).



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Figure 7. Visual Comparison Of Land Transformation Surrounding Uitmcpp Bertam Campus Between October 2019 (A) And January 2026 (B) Using Google Earth Historical Imagery. Substantial Changes Are Visible East And Northeast Of The Campus.

There are several limitations to this study. First, there was no control area without a large higher education institution in the original study design. Hence, the specific contribution of UiTMCPP Bertam Campus cannot be separated from the broader issues of regional urbanization and other development factors. Future studies might include comparable sites to better distinguish between university-related development and general trends in regional development. Furthermore, the classification was qualitatively validated with reference points, Google Earth imagery and field observations, but no formal accuracy assessment was available for the original analysis.

Conclusion

The findings provide useful spatial information on the pattern of land-use transformation around UiTMCPP Bertam Campus from a planning perspective. The observed expansion of the developed areas and the reduction of the agricultural and vegetated lands could help the local authorities and planners to identify the areas under development pressure and to plan future infrastructure, with regards to the conservation of the existing agricultural and green areas. The findings also provide baseline information for future planning of campus expansion, transportation and services, environmental management, and coordination among higher education institutions, local authorities and surrounding communities.

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