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RESEARCH ARTICLE

Peri-urbanization Dynamics: Changes in Demographic and Land-use Pattern

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Abstract Recent peri-urbanization, primarily characterized by declining agricultural land and a growing population, is a primary driver of peri-urban dynamics. Uncontrolled and excessive rural-urban transition leads to detrimental socio-cultural, environmental deterioration, and economic uncertainty due to the emergence of urban-oriented activities and needs. These adverse consequences involve complex processes predominantly associated to demographic and land-use change. This study investigates the trends of demographic and land-use changes in the peri-urban area and evaluates the interrelationships between these two factors. We utilize the multi-decade population and land-use transformations from 1990 to 2020 in the peri-urban area of Denpasar City – one of the most metropolitan areas in Indonesia. The results reveal that the peri-urban areas encountered unprecedented population growth and urban sprawl. According to preliminary findings, the inner peri-urban area has experienced more significant population and land-use changes than the outer peri-urban area. However, not every demographic trend positively impacts peri-urban land-use change. This explains why land-use is becoming increasingly distinct from household demographic dynamics, particularly population growth, population density, and the number of males and non-productive ages. The reliant relationship between these variables implies land-use conversion in peri-urban areas. The outcomes urge each executive decision-maker to thoroughly review demographic and land-use change patterns in developing exclusive regional cross-border policies to sustain market and long-term peri-urban resource values.

1. Introduction

Urban areas in developing countries, particularly in Southeast Asia, have expanded progressively . Southeast Asia is experiencing rapid urbanization, with 294 million people living in urban areas. Despite the fact that there are numerous metropolitan cities, urbanization in Southeast Asia remains to expand massively. United Nations (2019) noted that in 2010, 73% of the urban population in the region resided in small towns (under 500,000 people) and middle-sized towns (500,000 to one million people). The pattern is predicted to remain substantially consistent through 2030, when over two-thirds of the region's urban population will be resident in small and middle-sized towns (61% and 5.5%, respectively). The emergence of small and middle-sized towns, due to metropolitan expansion, is home to 22% of the population in Southeast Asia.

The development of urban areas exhibits an exceptionally dynamic. Urbanization is a prominent expression of the dynamics of urban development. Urbanization boosts economic performance but harms the environment. The two most significant negative consequences of urbanization are uncontrolled population growth and excessive urban sprawl. Uncontrolled growth tends to increase urban land prices, increase pressure on fragile ecosystems, and lead to the irreversible degradation of heritage assets Excessive urban sprawl is indicated by increased land conversion both within and beyond a city's administrative boundaries . In turn, this phenomenon contributes to peri-urbanization.

Peri-urbanization is typically a peri-urban phenomenon in terms of its scope, geographic distribution, implications, and contribution to physical and social transformation processes, and it works gradually . One of the outcomes of peri-urbanization is the emergence of 'peri-urban areas,' which are semi-urban settlements outside of metropolitan areas. Peri-urbanization is a geographic process in rural areas surrounding rapidly growing urban areas. This process has accelerated rural areas' physical, social, and economic transition into more urban . Rapid peri-urbanization is defined by cities' immense growth and extension to their peripheries, particularly in developing countries. Despite numerous advantages, peri-urbanization has disrupted the natural balance of agricultural and non-agricultural land-uses by changing the rural landscape, resulting in a miserable deterioration . Thus, peri-urbanization is an inevitable process that triggers demographic and spatial changes in peri-urban areas.

Demographic change is acquiring prominence in debates about development and regional planning, as it is considered a determining factor in the future development of peri-urban areas . Nonetheless, long-range records on the relationship between demographic trends and land-use changes remain scarce . Migration – the most potent factor in population growth - might become a more influential demographic trend that shapes population size and the transformation of

population structure . The process of migration is related to the existence of larger possibilities in the destination area, primarily related to factors that promise improvements in the living standard and social well-being of the residents. . Population growth and migration, along with a lack of public policies, are contributing to various socio-environmental issues in peri-urban areas, for example, slums in areas at risk along with job insecurity , constant prevalent diseases such as dengue fever and pandemics such as coronavirus disease .

Changes in land-use are commonly prevalent in peri-urban areas to accommodate the growth and functioning of the metropolitan regions . As cities expand, agricultural land or natural land from the rural-urban interface (i.e., peri-urban areas) changed to housing, business, or manufacturing properties . Peri-urban land conversion creates several challenges for peri-urban landscape management, which includes the loss of farmland , an erosion in native biodiversity , and ecosystem depletion . Furthermore, the loss of natural vegetation around cities diminishes public access to leisure activities and green spaces, potentially harming both mental and physical well-being .

The peri-urban area experienced spatial transformation, transitioning from rural to urban characteristics . According to Simon (2008), peri-urban interface are increasingly attracting middle- and upper-class residents who want to live in areas similar to cities but located in a rural environment. According to Allen (2003), the peri-urban areas is a 'mixed mosaic' of environmental and productive ecosystems interacting with prevalent socioeconomic differences . This spatial phenomenon is the peri-urban area's defining characteristic. Peri-urban transformation can be categorized into two types based on spatial distribution: land-use and demographic changes.

Mortoja et al. (2020) divide peri-urban areas into two categories: inner and outer peri-urban. The inner peri-urban area is located within the city administration. Comparatively, the outer peri-urban area extends for a considerable distance into the surrounding rural landscape. The inner peri-urban area is challenging to identify due to the variances and sporadic pattern of peri-urban land-use. Similarly, determining peri-urban outer boundaries is difficult because peri-urbanization terminates and follows the undeniable rural landscape. However, this approach to peri-urban area segmentation may reveal comprehensive spatial differentiation of demographic changes and land-use in peri-urban areas. Demographic changes and land-use are not constant in peri-urban areas over time and space . This lends credence to the notion that inner and outer peri-urban areas have the potential to be spatially distinct.

Numerous works have attempted to quantify and discuss the causes and consequences of peri-urbanization . Despite numerous studies on land-use change in peri-urban areas, research on peri-urbanization dynamics still needs to be completed. More work is required to understand demographic trends in peri-urban areas and more profound studies that examine the relationship between demographics and land-use change. There needs to be a more quantitative analysis of the relationship between demography and land-use change at the peri-urban scale. Previous studies used demographic trends limited to population size and density . Our research craves to fill this gap by investigating the trends of demographic and land-use changes in the peri-urban area and evaluates the interrelationships between these two factors using multiple demographic variables and a long-term study period. Such an analysis can enhance peri-urban sustainability model development by integrating demographic and land-use change trends and providing a quantitative validation basis for the model.

2. Methods

Study Area

The peri-urban area of Denpasar City was chosen as the study areas as itis one of the most metropolises cities in Indonesia. Denpasar City has the status of the provincial capital, is located in the southern part of the island of Bali. Based on our prior knowledge of the peri-urban levels of the study area, two distinct zones were identified: (1) inner peri-urban areas, which are sub-districts that are within or on the inner edge of the city's administrative boundary; and (2) outer peri-urban areas, which are villages that directly border or are on the outer edge of the city's administrative boundary. This study focuses on peri-urban areas that exhibit a mixture of urban space and rural land without one side highly dominating the other. Therefore, the primary criteria for selecting study areas are peri-urban areas, both inner and outer, with a proportion of rural or urban land-use of at least 25% or greater than 75% (Figure 1).

Land-use and demographic database

Peri-urban land-use change analyses through a spatial approach require two specific datasets. First, administrative maps are used to determine the unit of analysis (sub-district and village) for the study area. Second, land-use maps of 1990, 2000, 2010, and 2020 are used to assess land change in a multitemporal manner. Both data were obtained from Indonesia government agencies at the district or city level (https://tanahair.indonesia.go.id/portal-web). The spatial data is stored in vector format (shapefile), which will be processed using a Geographic Information System (GIS). On the other hand, we obtained 1990 to 2020 population data for every sub-zones from the Statistics Bureau . These data were re-tabulated to scale from the demographic trends analysis, resulting in the total population number, growth, and percentage.

Data analyses

The study utilized spatial and quantitative analysis. The spatial analysis via GIS consists of three stages: input, processing, and output. In the first stage (input), data is entered into the system using ArcGIS software. These data include administrative maps and land-use maps. At this stage, the area coordinates are adjusted if they are not appropriate, and then the attribute table adjustments are made, especially in relation to determining the land-use class to be studied. After the spatial data and attributes match, the next step is to process. In the processing stage, spatial analysis is carried out using the overlay intersect method on 1990, 2000, 2010, and 2020 land-use maps. Moreover, the change detection technique determines land changes over time. Change detection techniques are based on comparing land-use polygons derived distinctly for each period. They imply a spatial overlay of each polygon and search for their intersections. Furthermore, the results of the analysis will proceed to the presentation stage. The third stage is output. At this stage, the presentation of the final results of the data that has been analysed is carried out. Information is presented as land-use change maps from 1990, 2000, 2010, and 2020. By overlaying the 1990 land-use maps with 2000, 2010, and 2020 land-use maps, it is possible

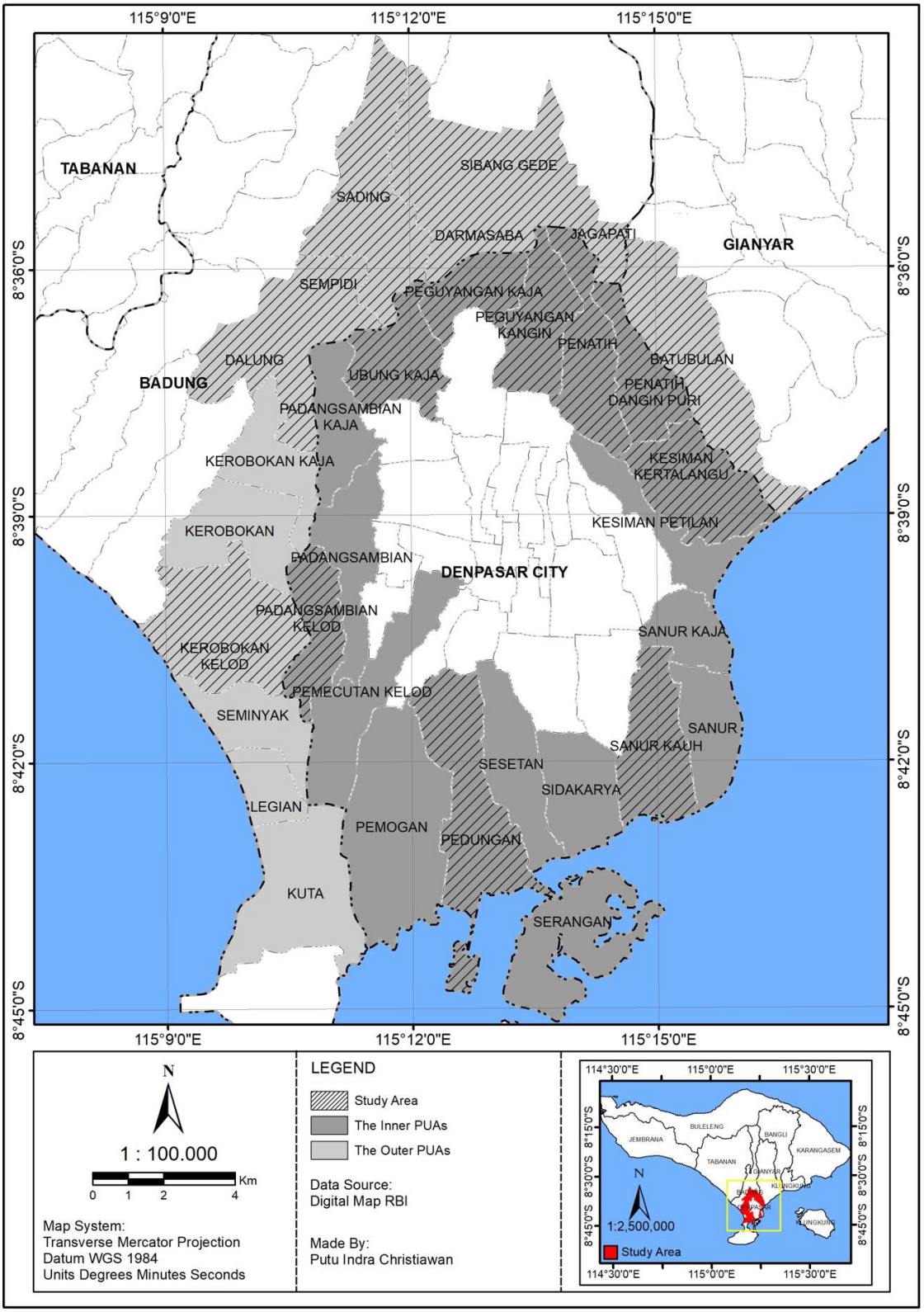

Figure 1. Map of the Study Area

to determine which areas have changed, and what land-use has changed.

For the statistical analysis, descriptive statistics are obtained using percentages, frequencies, averages, standard deviations, and crosstab techniques. Descriptive statistics summarize the frequency of indicators in demographic trends, including population size, population density, age-based population structure, and gender-based population composition. Meanwhile, Crosstab is used to categorize independent variables based on percentile groups. In addition, the Mann-Kendall test and Sen's slope estimator are used to examine the land-use and demographic change trends using time series analyses. The Mann-Kendall test identifies an upward or downward trend in land-use and demographic variables from 1990, 2000, 2010, and 2020. Simultaneously, Sen's slope estimator determines the slope magnitude. Both are used as tests because they do not require the data to meet normality assumptions and are unaffected by data outliers and single data errors in the data series (Meals et al., 2011). The demographic and land-use change in all peri-urban regions

is analysed using two sample t-test) (McDonald, 2009). This was performed to assess whether or not there is a statistically significant difference between the two groups, inner and outer peri-urban areas, in the demographic and land-cover change. Demographic and land-use variables were subjected to a Pearson bivariate correlation analysis (as the data were predominantly Gaussian distributed). A particular interest for statistical analysis in this study is the land-use variable used in the ''developed" class, namely areas characterized mainly by changes in land-use to settlement classes. This was done for all peri-urban areas, as well as for the inner and outer peri-urban areas. In the end, we employed multiple regression analysis to discover the extent to which each demographic variable can be attributed to the divergence in development change. The objective of this study was to investigate whether the concurrent formation of each demographic variable would allow us to reveal the dynamics of land-use change and examine whether both types of peri-urban areas behave differently concerning development.

3. Result and Discussion

Peri-urban expansion and land-use change

Land-use change is frequently linked to urban areas as they undergo expansion to accommodate the increasing population . As urban areas extend, peri-urban natural lands are transformed into housing, businesses, and manufacturing facilities . This section illustrates the trends, rates, and transitions of peri-urban land-use change in inner and outer peri-urban areas of Denpasar City. Denpasar City and its hinterland experienced a massive upward trend in peri-urban expansion. From 1990 to 2000, it raised at approximately 13.15%, following an increase of 15.19% from 2000 to 2010, and nearly doubled from 2010 to 2020 at 43.26%. The rates of the built-up area have increased exponentially in Denpasar City's peri-urban areas. From 1990 to 2020, the expansion has reached 86,72% of the total area.

The results of land-use trends for each peri-urban area are illustrated in Figure 2. The spatial analysis confirmed that in 1990, 2000, and 2010, agriculture tended to be the largest land-use class covering the peri-urban areas, both the inner and outer peri-urban areas. Conversely, in 2020, the settlement covered most peri-urban areas, mainly in the inner part. The cartographic results depict a substantial change in various peri-urban areas with diverse trajectories. The research reveals frequent changes involving an increase in peri-urban expansion with urban characteristics, which transform the natural landscape into settlement areas. The fascinating fact is that agriculture remains the most extensive land-use in the outer peri-urban areas. However, from the available trends, it will be displaced by the settlement in the near future. The most pronounced land-use changes in Denpasar City peri-urban areas between 1990 and 2020 were the rapid decrease in agricultural class and associated increase in settlement (built/up) class. The spatial analysis confirmed that the 2010-2020 period is the most massive decrease of agricultural classes, both in the inner and outer peri-urban areas (-34,04% and -19,23%, respectively). Conversely, settlement classes experienced a significant increase in the last decades, mainly in the inner peri-urban with 8,50 km2 or 51,28%.

Moreover, Figure 2 illustrates the cumulative gains and losses transition rate for each analyzed period in the three land-use classes in the study area. During 1990–2000, in the inner peri-urban areas, the settlement classes increased at an annual rate of 16,22% or 2,05 km2, of which 7,51% occurred over agricultural land. In the outer peri-urban areas, the settlement class only rose 10,06% or 1,26 km2, whereas the agricultural class gained significance at an annual rate of 17,78% or 4,84 km2. During the first decades, the water bodies' classes were profoundly lost in the outer peri-urban areas. Over 2000–2010, the rate of peri-urban expansion in the inner peri-urban areas decreased to 12.83%. However, the extent of the new urban cover was comparable to the preceding period, and those new settlement areas were sourced both from agricultural lands and water bodies.

Conversely, the urban expansion rate started to elevate in the outer peri-urban areas to 17,71% from 2000–2010. The new settlement in these areas was entirely from agricultural lands. In the next period of 2010–2020, the urban expansion rate doubled to 51,28% in the inner peri-urban areas and 35,09% in the outer parts. The escalation of new built-up areas in the inner peri-urban areas is sourced from agricultural lands (34,04%) and mostly from water bodies (51,27%). Meanwhile, all the newly built-up areas in the outer peri-urban areas were originally agricultural lands. Thus, changes in land-use from 1990 to 2020 in Denpasar City's peri-urban areas experienced a transition from rural to more urban characteristics. Farmland was adjacent to the urban area in 1990, and their areas gradually converted into settlements in the following decades. Assessment of land-use change by detecting trends from 1990 to 2020 was also carried out using a non-parametric approach using the Mann-Kendall test and Sen's slope estimator. The Mann-Kendall test detects trends in a land-use change in Denpasar City peri-urban areas at a 95% confidence level (Table 1).

The trend of the land-use change consists of agricultural land, settlement and water bodies in both inner and outer peri-urban areas. The agricultural land shows a significant decrease trend at a rate -0,43 km^2 in total total, but the trend more significant in the inner than the outer peri-urban areas. Moreover, in all peri-urban areas, settlement shows a statistically significant increasing trend. The rate of change was 0,31 km^2 for inner peri-urban areas, 0,27 km^2 for outer and 0,58 km^2 for entire peri-urban areas. Similar with agricultural trend, water bodies tend to decrease significantly, but the trend more significant in the outer (-0,10 km^2) than the inner peri-urban areas (-0,03 km^2). The result for sen's slope shows that the slope magnitude corresponds to the result of the Mann-kendall value, which shows a decreasing trend for both agricultural and water bodies, while the settlement area was found to be increasing all significance (Figure 3).

This study revealed that natural land was significantly converted into built-up areas in the last decades, especially in the inner peri-urban areas. One plausible cause is the considerable economic growth in the inner peri-urban areas. As part of the city's administrative boundaries, the inner peri-urban areas play a crucial role in facilitating economic growth. In Denpasar City's inner peri-urban areas, enterprise, industry, trade, hotel, and restaurant establishments dominate the economic landscape . This area is attractive to business districts due to its high accessibility and complete amenities. The study by Carson and Carson (2021), which examined large-scale infrastructure projects in the hinterland area, also revealed that the increase in services and industries in the inner peri-urban areas corresponds to the emergence of new economic centers. Similarly, in China (Shenzhen and Shanghai), economic levels were immensely related to changes in city land cover .

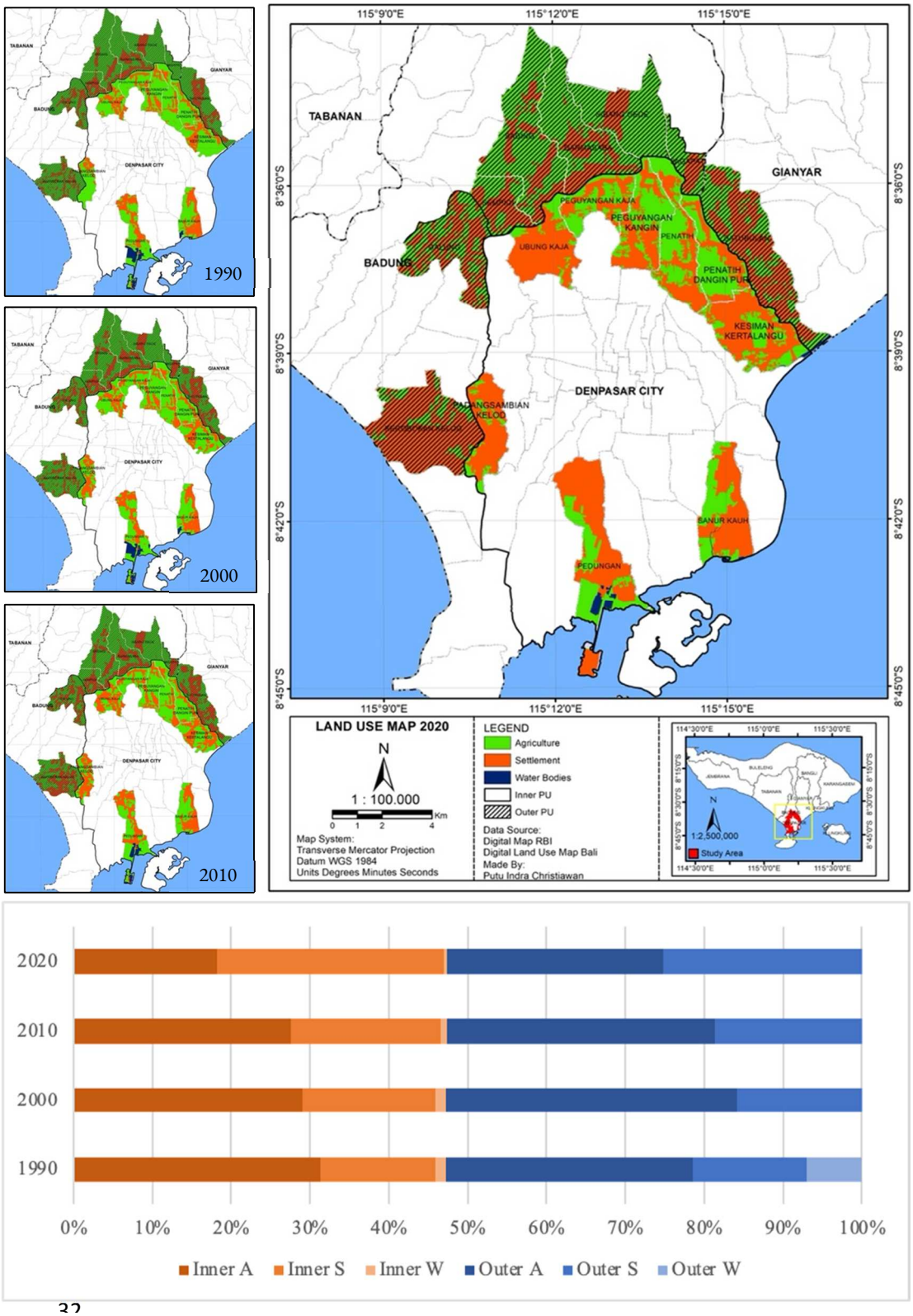

Figure 2. Land-use change in the Denpasar City's peri-urban areas 1990–2020, by land-use class (agriculture, settlement and water bodies)

Consequently, many of the farming community's rice fields have been "surrounded" by developed land. This condition encourages farmers to sell their farmland or convert it to an urban business district. Carson et al. (2022) discovered that the main reasons inner peri-urban communities sold their land were the difficulty of obtaining quality irrigation and the high cost of farming. Farmers are less able to survive as a result of their declining productivity, particularly when it comes to meeting the escalating, periodic, and complex needs of urban life, including monthly costs for electricity, water, gas, and other facilities and various tertiary needs, such as transportation, communication equipment, and other modern conveniences .

On the other hand, transformation in the outer peri-urban areas occurred due to the high land demand for housing, and land prices are relatively more affordable than in urban areas. Urban residents move to peri-urban areas, which are located outside the city's administrative boundaries, due to

Table 1. The mann-kendall trend and sen's slope values of land-use change (1990-2020)

Indices	Inner PUAs				Outer PUAs				Total PUAs			
	MK	p-value	Trend	Sen's Slope	MK	p-value	Trend	Sen's Slope	MK	p-value	Trend	Sen's Slope
Agri-cultural	-2,91	0,01	Significant decrease	-0,29	-1,33	0,03	Non-significant decrease	-0,17	-1,66	0,03	Significant decrease	-0,43
Settle-ment	2,47	0,02	Significant increase	0,31	1,70	0,02	Significant increase	0,27	2,91	0,02	Significant increase	0,58
Water Bodies	-0,91	0,04	Non-significant decrease	-0,03	-1,87	0,03	Significant decrease	-0,10	-1,90	0,03	Significant decrease	-0,14

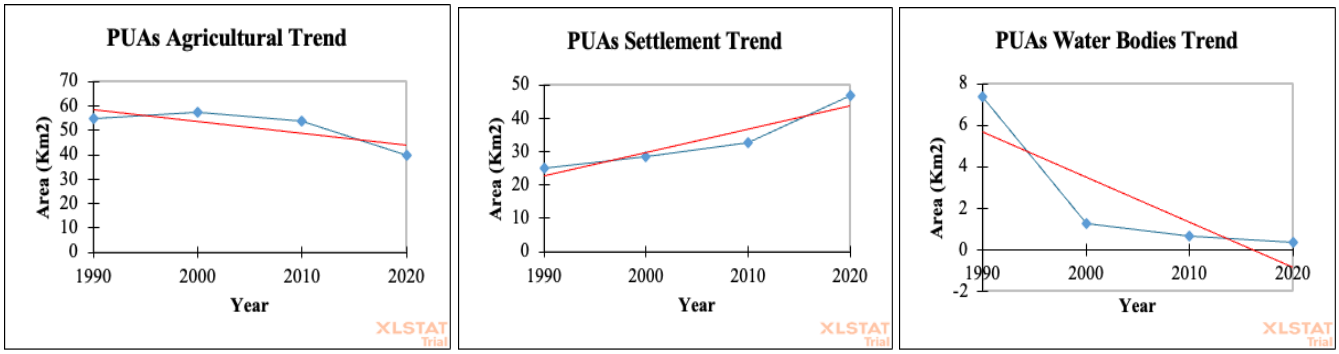

Figure 3. Trend of land-use change trends from 1990 to 2020 in Denpasar City peri-urban area

a lack of available land and dense environmental conditions with commercial buildings. A similar conclusion was reached by Appiah et al. (2014), who found that the rapid pace of peri-urbanization led to an upsurge in demand for housing, tourism (hotels and guest houses), and business land-uses at the expense of agricultural land-uses. The findings of this work, in line with previous research, indicate an increase in peri-urban lifestyles in Canada as city dwellers continue to migrate to the urban periphery in pursuit of less expensive expenditures .

The construction of roads accelerates the transformation of land-use in the outer peri-urban areas. Roads are vital transportation infrastructure for peri-urban communities to sell agricultural products outside the village. Pienaar (2014) stated that the development of better road infrastructure not only creates opportunities for farming communities but also facilitates urban residents and various city functions to enter and change the spatial appearance of peri-urban areas. In other words, the existence of the road will encourage development close to the road, as agricultural land nearby will be the first to change function.

The existence of roads as a condition of accessibility creates numerous business opportunities in peri-urban areas. One of the most profitable business opportunities is a housing development that meets the needs of urban residents who choose to live outside the city. In line with the construction of settlements, various commercial enterprises will crowd the residential area directly. According to Ustaoglu and Aydınoglu (2019), the need for land for commercial trading was contented by sacrificing agricultural land. Urban economics is believed to be more financially beneficial than remaining in the agricultural sector, considering that the conversion of farmland increases the cost of locating, storing, and purchasing food.

Peri-urban demographic trends

Peri-urbanization is a complex process of the rural population transitioning into more urban. Due to the widespread nature of the process, many people currently reside in peri-urban areas . This section discusses the trends and growth of population size, composition, and population density of peri-urban demographic change in the inner and outer peri-urban areas of Denpasar City. The demographic trends for each peri-urban area are illustrated in Figure 4.

The population sizes in the inner and outer peri-urban areas are quite different. The inner peri-urban areas have a larger population than the outer peri-urban areas. However, from 1990 to 2020, both population sizes steadily increased. The population growth rate in the inner peri-urban areas was minimal in the first decade (1990–2000), at 3.32%, but rocketed in the second decade (2000–2010), reaching 46.8%, before slowing to 5.67% in the last decade (2010–2020). Meanwhile, the population growth rate in the outer peri-urban areas consistently increased by 1.41% in the first decade (1990–2000), increased to 12.69% during the second decade (2000–2010), and accelerated to 15.58% in the last decade (2010–2020). Overall, the number of people living in the peri-urban area of Denpasar City has steadily grown over the past decades. Population growth in inner peri-urban areas peaked between 2000 and 2010. In contrast, the outer peri-urban areas continued to experience population growth over the following decades. The fascinating fact is that population size in the outer peri-urban areas showed more remarkable growth than in the inner peri-urban areas in the last decades.

The growth of the population based on sex has a different story. The female growth rate outpaced the male. In the inner peri-urban areas, female growth rate already dominated in the first decades (1990–2000) with 3,35%, rocketed in the second decade (2000–2010) with 44,59%, and slowed down in the last

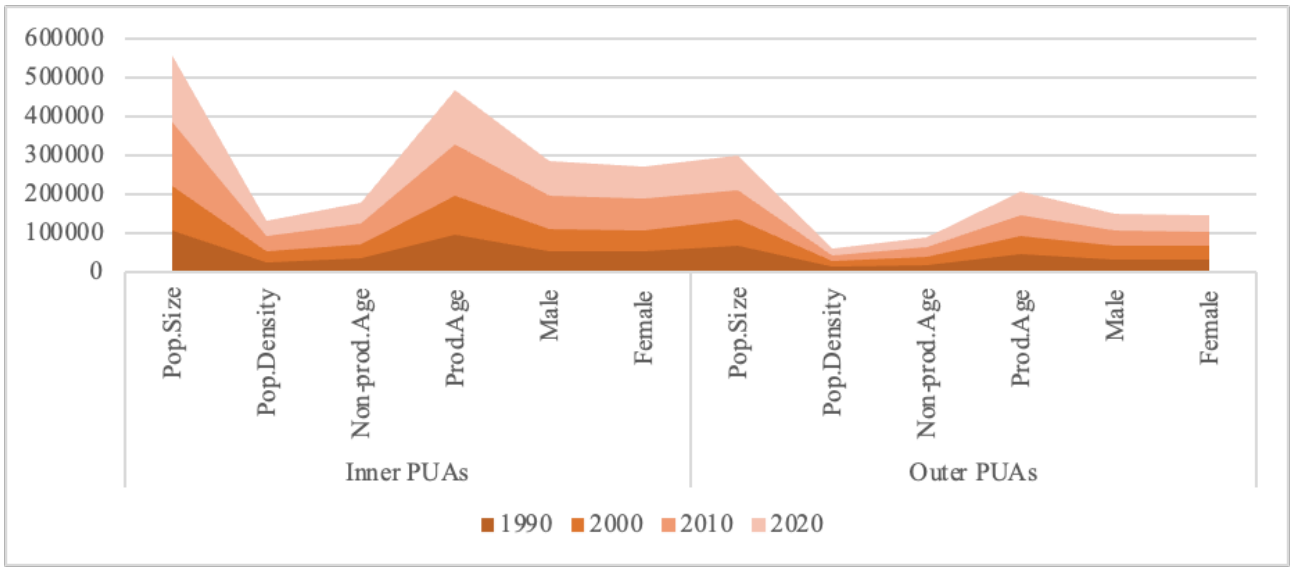

Figure 4. Denpasar city's peri-urban areas demographic trends

decade (2010–2020) with 5,84%. Male growth rates showed different trends. The male growth rate relatively fluctuates, at a minimum, in the first decades within 3,29%, declining in the second decades at 0,49% and rising in the last decades at 5,49%. In the outer peri-urban areas, the female growth rate consistently increased by 1,36% in the first decade (1990–2000), scaled up to 12,73% in the second decade (2000–2010), and expanded to 15,64% in the last decade (2010–2020). The male growth in the outer peri-urban areas also fluctuates, from 1,46% in the first decade, decreasing to 0,13% in the second decade, and rising to 15,51% in the last decade. Thus, females in peri-urban areas, has steadily risen over the decades. The rise of females in the inner peri-urban areas peaked between 2000 and 2010, whereas the number in the outer peri-urban areas continued to rise in the following decades. Males in the inner and outer peri-urban areas fluctuated but appeared to rise in recent decades.

The population density in the inner and outer peri-urban areas differs significantly. The inner peri-urban areas are denser than the outer peri-urban areas. However, both population densities steadily rose from 1990 to 2020. In the inner peri-urban areas, the population density growth was minimal in the first decades (1990–2000) at 3,32%, but it rocketed in the second decade (2000–2010) at 47,77% and slowed down in the last decade (2010–2020) at 5,57%. Meanwhile, the population density growth in the outer peri-urban areas consistently increased by 2,10% in the first decade (1990–2000), scaled up to 8,71% in the second decade (2000–2010), and expanded to 14,42% in the last decade (2010–2020). To sum up, the population density in peri-urban areas steadily rises over decades. Population density growth in the inner peri-urban areas peaked from 2000 to 2010. In contrast, the population density in the outer peri-urban areas continued to increase in the following decades and showed higher density in the last decade.

The trend in demographic change from 1990 to 2020 as recorded by the Mann-Kendall test is summarised in Table 2. The trend of the population growth shows a significantly increasing trend at a rate of 3075 person in total, but the trend more significant in the inner than the outer peri-urban areas. Population density also shows a significantly increasing trend at a rate 701 person per km^2 in total, but the trend more significant in the inner than the outer peri-urban areas. In all peri-urban areas, non-productive age change shows no trend observed. Conversely, productive age shows a significantly increasing trend at a rate 2025 person per km^2 in total, but the trend more significant in the inner than the outer peri-urban areas. Male population also shows a significantly increasing trend at a rate 1602 person per km^2 in total, but the trend more significant in the inner than the outer peri-urban areas. In all peri-urban areas, female population shows a statistically significant increasing trend. The rate of change was 1177 person for inner peri-urban areas, 391 person for outer and 1472 person for entire peri-urban areas. The result for sen's slope shows that the slope magnitude corresponds to the result of the Mann-kendall value, which shows a increasing trend for most of the demographic indices, and only the change of non-productive age people was found with no trend.

Furthermore, Sen's slope test shows that population growth has the highest demographic trend value of 30753,5. The positive trend value in peri-urban areas indicates an increasing annual population growth trend. The significant increase indicates that peri-urban areas will become more populous than urban or rural areas. The overall Sen's slope estimator for all demographic trends in peri-urban areas is illustrated in Figure 5.

Growth in population is inevitable in peri-urban areas. The results indicated that the population of Denpasar's peri-urban areas elevated continuously. The evidence shows that the inner peri-urban areas have a larger population, but the outer peri-urban areas have a more stable population growth trend. This finding is parallels with previous studies suggesting that the population of peri-urban areas has increased significantly . Moreover, numerous studies even have discovered that the population growth rate in peri-urban areas is higher than in urban areas . This fact implies that the peri-urban area will become the next population growth epicenter. The population growth trend in peri-urban areas is shaped by increasing living standards . The increases in longevity and life expectancy are associated with population aging. The decreases in mortality have contributed to a trend in which the number of elderly and their proportion of the total population increase . These trends are also followed by a rapid rise in in-migration , both of productive age and pensioners, who target peri-urban areas as

Table 2. The mann-kendall trend and sen's slope values of demographic change (1990-2020)

Indices	Inner PUAs				Outer PUAs				Total PUAs			
	MK	p-value	Trend	Sen's Slope	MK	p-value	Trend	Sen's Slope	MK	p-value	Trend	Sen's Slope
Pop. Growth	1,96	0,03	Significant increase	2478	1,5	0,03	Non-significant increase	788	2,91	0,01	Significant increase	3075
Pop. Density	2,3	0,02	Significant increase	604	1,47	0,04	Non-significant increase	121	1,98	0,03	Significant increase	701
Non-Prod. Age	1,68	0,45	No trends	757	1,1	0,72	No trends	206	2,47	0,08	No trends	963
Prod. Age	1,98	0,03	Significant increase	1616	1,4	0,03	Non-significant increase	458	2,96	0,01	Significant increase	2025
Male	1,7	0,04	Significant increase	1301	1,38	0,03	Non-significant increase	396	2,5	0,02	Significant increase	1602
Female	1,8	0,04	Significant increase	1177	1,7	0,03	Significant increase	391	2,96	0,01	Significant increase	1472

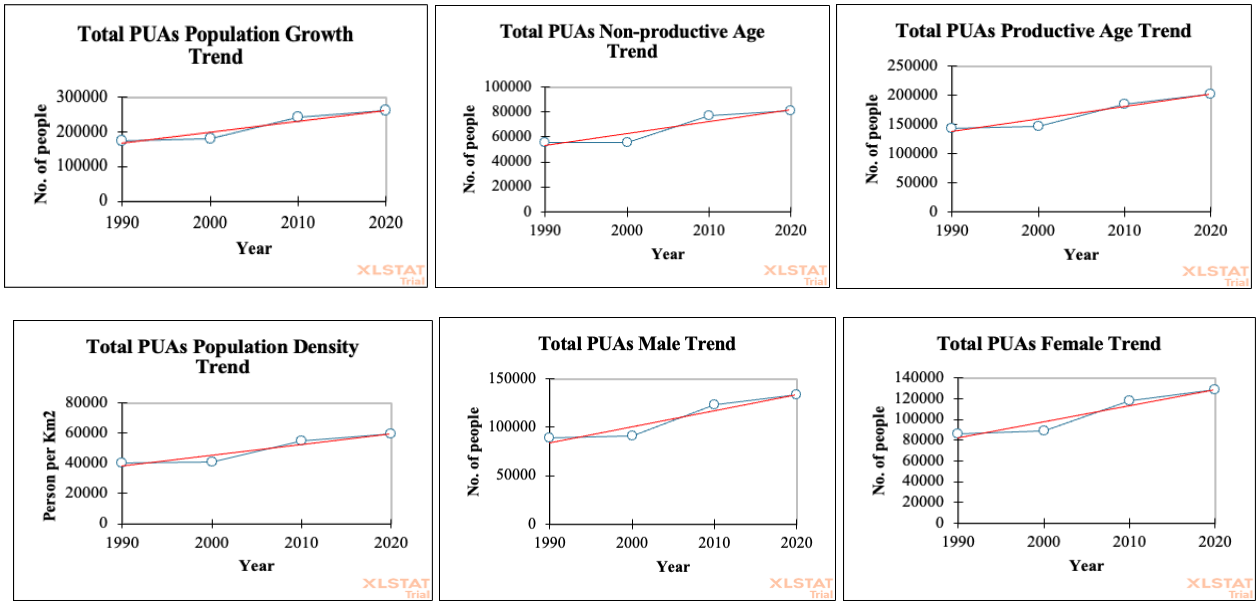

Figure 5. Sen's slope test for demographic trends in Denpasar city's peri-urban areas

places to live and work. These factors significantly contributed to peri-urban population growth. The ongoing population growth will continue to blur distinctions between rural and urban areas. The findings show that the rate of population growth trend is substantially more stable in outer peri-urban areas. This indicates that the area will grow more ethno-racially diverse and integrated . This slow but steady trend will accelerate the demographic change of outer peri-urban areas toward urban nature faster than inner peri-urban areas. When peri-urban areas turn into urban, rural areas close to the outer peri-urban areas will initiate a new peri-urbanization process.

Spatial differentiation on inner and outer peri-urban areas

The inner peri-urban areas express a significantly higher expansion of peri-urbanization than the outer peri-urban areas. The parametric t-test reveals an essential difference in development between the two groups (n = 17, p 0.05 for all) as seen in Table 3.

The p-values of Levene's test of each indice are greater than the α level. We assumed that the variances of the two groups are equal. The p-values (2-tailed) of the two-sample t-test in most indices are all less than the α level, thus there is a difference between among those indices. However, the p-values (2-tailed) of the two-sample t-test in settlement and non-productive age are greater than the α level. As predicted, we found that peri-urban areas fell between inner and outer peri-urban areas in terms of peri-urbanization and discovered that the peri-urban category is distinctive concerning the nature of demographic change, primarily based on gender (both male and female changes), population density, population growth, and productive age changes.

Pairwise correlations between land-use change and demographic trends

Pearson's correlation matrix demonstrates a weak but significant correlation between most population and land-use variables. Population growth and male population correlate

Table 3. The outcome of two sample t-test

	Levene's Test for Equality of Variances		t-test for Equality of Means				
	F	Sig.	t	df	Sig. (2-tailed)	95% Confidence Interval of the Difference	
						Lower	Upper
Settlement CHG (km^2)	3.015	.103	.312	15	.759	-119.991	161.213
Pop. Growth (person)	.620	.443	1.893	15	.048	-573.553	9.668.525
Pop. Density CHG (person)	3.021	.103	2.531	15	.023	208.409	2.431.953
Non-Prod. Age CHG (person)	4.648	.078	.081	15	.936	-2.252.214	2.430.242
Prod. Age CHG (person)	.059	.811	2.129	15	.050	-6.007	9.785.701
Male CHG(person)	3.048	.103	2.850	15	.012	738.792	5.118.847
Female CHG (person)	4.969	.078	2.746	15	.015	557.687	4.426.980

Table 4. Pearson's correlation coefficients r between statistical land-use and demographic data

		Settlement CHG (%)	Pop. Growth (%)	Pop. Density CHG (%)	Non-Prod. Age CHG (%)	Prod. Age CHG (%)	Male CHG (%)	Female CHG (%)
Settlement CHG (km^2)	R	1						
	Sig.							
Pop. Growth (person)	R	.825**	1					
	Sig.	.000						
Pop. Density CHG (person)	R	.756**	.988**	1				
	Sig.	.000	.000					
Non-Prod. Age CHG (person)	R	.688**	.861**	.875**	1			
	Sig.	.002	.000	.000				
Prod. Age CHG (person)	R	-.336	.214	.068	.105	1		
	Sig.	.188	.409	.796	.688			
Male CHG (person)	R	.807**	.979**	.983**	.868**	.117	1	
	Sig.	.000	.000	.000	.000	.655		
Female CHG (person)	R	.545*	.942**	.883**	.779**	.504*	.871**	1
	Sig.	.024	.000	.000	.000	.039	.000	

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

notably strongly with total settlement change on a percentage basis. Population growth is the most strongly correlated to settlement change on a percentage basis (R = 0.825). Table 4 summarizes the Pearson correlation coefficients r that were obtained.

What statistical relationships exist between demographic trends and land-use changes? The land-use variables did not correlate with all of the demographic variables in peri-urban areas (at $p < 0.05$). However, some correlations between demographic and land-use variables were discovered. The strongest correlation observed was between population size (R = 0.825) and male change (R = 0.807) trend ($p < 0.01$). Significant but weaker correlations were found between the change in population density (R = 0.756) and the non-productive age change (R = 0.688) trend ($p < 0.01$).

Multiple regression analysis demonstrates an improvement in the ability to describe peri-urbanization determinants. The combination of demographic variables can explain the settlement change in peri-urban areas. The F-test value is 12.634, with a significant level of 0.000. This significant value is below 0.05, which indicates that demographic variables simultaneously significantly affect land-use change variables at a significant level of 5%. Furthermore, multiple regression results also confirm that some demographic variables are predicted to have a stronger influence on settlement changes than other trends (Table 5).

Table 5 demonstrates that some demographic trends have a negative effect on settlement change. Notably, if the productive age population and female variables have risen, then the trend of settlement change will decline (0.696 and 2.042, respectively). On the other hand, the increase in population growth, density, non-productive age, and male populations will elevate the settlement change. The partial regression test (t-test) results also show that not all demographic variables significantly affect settlement change. The change in the productive age population and the female rate did not significantly affect the settlement change. Meanwhile, the most potent effect is determined by male change and non-productive age growth ($p < 0.01$). Significant but weaker effects were found between population size and change in population density ($p < 0.05$). This signal clearly reveals that population growth and density are not stand-alone factors in determining land-use change in peri-urban areas.

As stated previously, demographic trends influenced peri-urban land-use change, as indicated by a dramatic rise in settlement expansion within the inner and outer peri-urban areas. Consequently, these relationships generated a physical and socio-economic dynamic in peri-urban areas.

Table 5. Partial regression analysis of demographic variables and settlement change

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	21.251	30.662		.693	.504
	Pop. Growth	8.195	1.837	3.217	4.461	.001
	Pop. Density CHG	6.792	2.023	2.421	3.358	.005
	Non-Prod. Age	1.574	.346	.731	4.547	.000
	Prod. Age	-.696	.271	-.413	-2.564	.022
	Male CHG	3.545	.697	1.372	5.086	.000
	Female CHG	-2.042	.848	-.650	-2.408	.030

a. Dependent Variable: Settlement Change (%)

Regarding the physical environment, the rapid growth of housing and modern facilities has inevitably raised the impervious surface area, with a high heat capacity . Moreover, the rapid expansion and leading population concentration in the peri-urban areas caused a human-driven transformation of land-use, such as the substitution of agricultural land with impermeable materials and the filling of small reservoirs for construction, as well as the deterioration of rural villages for the establishment of industrial zones. These correlations culminated in substantial changes to the surface energy balance and heat flux, particularly an increase in sensible heat flux due to the depletion of reservoirs and green spaces in peri-urban areas.

Moreover, the population growth rate also has an impact on economic activity , particularly on community livelihoods. Changes in natural land-use to become an urban built-up area in peri-urban areas can, directly and indirectly, affect human landscapes. It directly pulled the community into urban jobs and indirectly pushed them to sell their land. Recent rapid peri-urbanization in Denpasar City creates challenges for the peri-urban community, notably in pursuing a sustainable livelihood. Therefore, the conversion processes of land-use and population shift are significant drivers of peri-urban livelihood changes and dynamics. This complementary relationship has been the subject of rural-urban linkages, which concluded that it is difficult for such a relationship to sustain.

Yao and Jiang (2021) discovered that the benefits for rural communities were not commensurate with those for urban communities. This rural-urban disparity is one of the causes of the decline in the number of farmers in the outer peri-urban areas. Subsequently, it leads to a decrease in agricultural land. Østby (2016) and Hoogerbrugge and Burger (2022) discovered that some rural communities pursued employment in urban areas, while others, even while residing in villages, transformed the appearance of their work to imitate urban jobs. It concluded that the imbalanced backwash and spread effects caused rural-urban connections to be brief. This condition gradually transformed agricultural land into residential land in the subsequent period. Carrilho and Trindade (2022) noted that most settlements in the outer peri-urban areas consist of informal settlements, ranging from substandard to luxurious.

4. Conclusion

The peri-urban areas of Denpasar City experienced significant peri-urbanization throughout the study, as evidenced by a sharp increase in the settlement area, resulting in the loss of cropland and water bodies. The peri-urban land-use changes correlate with demographic trends, as evidenced by a substantial rise in population size and density, and are dominated by the productive age group, in which the male-to-female ratio is relatively balanced. Moreover, an in-depth comprehension of the findings suggests that each executive decision-making scenario should address the fundamental processes, structures, and patterns of land conversion and the response to peri-urbanization. Therefore, policymakers and developers could comprehensively review the ecological, social, and economic implications of various regional development contexts as well as establish an empirical framework for enhancing sustainable peri-urban planning and regulations to mitigate adverse outcomes and enforce the adaptability of peri-urbanization. This research also designed and implemented a dynamic peri-urban development approach to present robust data to obtain a better understanding of long-term land-use changes and population growth associated with the peri-urbanization of Indonesian metropolitan areas, as well as relationships between physical-demographic characteristics. Further research could examine the effects of migration patterns, housing and public services provision, and people's livelihoods on the spatial values associated with settings.

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