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LAND USE MODEL FOR BUILDING BASED ON CARRYING CAPACITY OF CITY LAND (CASE STUDY: PALU CITY)

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ABSTRACT

This study aims to model the growth trend of the extent of land use for building based on the carrying capacity of land in Palu city which is known as Bay City in accordance with the prediction of time. Methods of research were carried out with the approach of spatial and quantitative methods. The results show that Palu city as Bay City has the characteristics of urban land that is quite specific to the protected area. There is still available land for building i.e.: ± 13.151,13 ha (34.74%) with a growth rate of land use for building in the future 2.72% per year, area of cultivation will be fully filled in the year 2056 with the capacity of 1.052.730 people. Carrying capacity of land in Palu city until the year 2056 has not exceeded the threshold, either by the land consumption per capita or by the level density.

Keywords: land use, building, carrying capacity.

ABSTRAK

Penelitian ini bertujuan untuk memodelkan tren luas penggunaan lahan untuk bangunan berdasarkan karakteristik daya dukung lahan di kota Palu sebagai kota teluk sesuai dengan prediksi waktu. Penelitian dilakukan dengan pendekatan metode spasial dan kuantitatif. Hasil penelitian menunjukkan bahwa kota Palu sebagai kota teluk memiliki karakteristik lahan kota yang cukup spesifik dengan kawasan lindung mencapai hampir setengah dari total luas wilayahnya. Masih tersedia lahan untuk bangunan seluas: ± 13.151,13 ha (34.74%) dengan tingkat pertumbuhan penggunaan lahan untuk bangunan di masa akan datang sebesar 2,72% per tahun, maka kawasan budidaya belum terbangun akan penuh pada tahun 2056 dengan kapasitas 1.052.730 orang. Daya dukung lahan di kota Palu sampai tahun 2056 belum melampaui ambang batas, baik menurut konsumsi lahan per kapita maupun tingkat kepadatannya.

Kata kunci: penggunaan lahan, bangunan, daya dukung.

INTRODUCTION

Indonesia as a developing country still faces major problems in the development of cities. The development of economic activities and population growth which keep increasing will be followed by the demand of land, especially land for building as a place that holds a variety of urban activities such as housing and offices [*Amar, et.al.* 2011].

As well as phenomena that occur in urban areas, then Palu as one of the cities in Indonesia which is used as the object of this study, are also having the same problems associated with the population growth parallel with the increasing of urban land use, especially land use for the building, but its condition is not as serious as other major cities so that the pattern of land use is still possible to set up and develop in accordance with the land

availability (supply) and utilization requirements (demand) in order not to exceed the carrying capacity of land.

The population growth rate of Palu city from year to year has increased significantly on the number of people. In the period 2000 – 2010, the percentage rate of the population growth is in the average of 2.26% per annum with 336.532 people at the end of 2010 (The SP2010 and Palu *BPS* 2011). Along with the increasing of the population number in Palu city, the demand/need for land has increased, particularly the land use for building, with an increasing number of building in the average of 1.89% per year in the period 2000-2010, where the number of buildings at the end of 2010 is ± 79.205 unit buildings with an extensive land use for building/yard and garden is ± 4.723,62 ha (12.48%), including urban infrastructure (primary survey, 2011).

Besides the issue of increasing population and building, Palu city as bay city, by nature, also has ecological boundaries problems in the form of land availability which is a limiting factor for the development of the bay urban space, because the state of land resources are fixed (cannot be moved). Therefore, the land availability will determine wide distribution of the carrying capacity of space for land use in the Bay City [*Amar, et.al.* 2011)

Land use for building and ground which keep increasing, especially in the area of Palu, will cause problems later on. This is because of its limited land area, while the demand of land for building and yard always increases with the increasing population and urban activities, which at the certain times, the land in Palu city will be full of buildings.

THE METHODS

This study was conducted in Palu city towards population, families, hotel guests, buildings, extensive grounds/buildings and extensive areas/regions. The research data were in the form of primary data and secondary data which were categorized into two groups: spatial data and a spatial data. The research data were obtained through technique of survey, document noting and recording, mapping and satellite photo image digitization.

This study was carried out by using the approach and methods of quantitative spatial methods through several analytical techniques such as mapping analysis, namely an overlay technique and image analysis with the help of the *GIS* program to get the extensive availability of land, the regression analysis to see the growth trend of the extent of land use for building and the time limit of land available are capable of supporting the growth of the extent of land use for building, as well as analysis of the carrying capacity of land to see how much the capacity and the thresholds of the carrying capacity of land to the time limit of land availability for building.

RESULT AND DISCUSSION

Strategic Issues toward Regional Characteristics of Palu City

Due to having relevance to the issues and the objectives of the study conducted, discussion of strategic issues toward regional characteristic of Palu City is limited only to the physical and demographic characteristics as pointed out previously. Based on the above picture of the regional characteristic, it can be formulated that strategic issues taken into consideration in the structuring and developing of the Palu city in the future are as follows:

a. As the city bay which has graben shape, Palu has an ecological boundaries, namely the eastern part extending from north to south is bounded by the extreme mountains topography, while the western part extending from north to south is bounded by a line beach of Palu Bay.

This condition certainly gives a significant influence on the pattern of land use, where the availability of land for the cultivation area is only about 51.07% (± 19331.45 Ha) and the protected area is approximately 48.93% (± 18529.38 ha) of the total area of land in Palu city (see Table 1 and Figure 1).

Table 1. Slope Classification of Palu City

Slope (%)	Class	Width (Ha)	(%)	Remarks
-	0	-	-	Waters
0 - <8	1	20,875.733	56.26	Flat
8 - <15	2	6,694.817	18.04	Sloping
15 - <25	3	5,157.395	13.90	Rather Steep
25 - <40	4	3,734.662	10.07	Steep
≥40	5	642.474	1.73	Very steep
Total		37,105.081	100.00	

Source: Analysis Result of Delineation of Topographic Map, Palu City

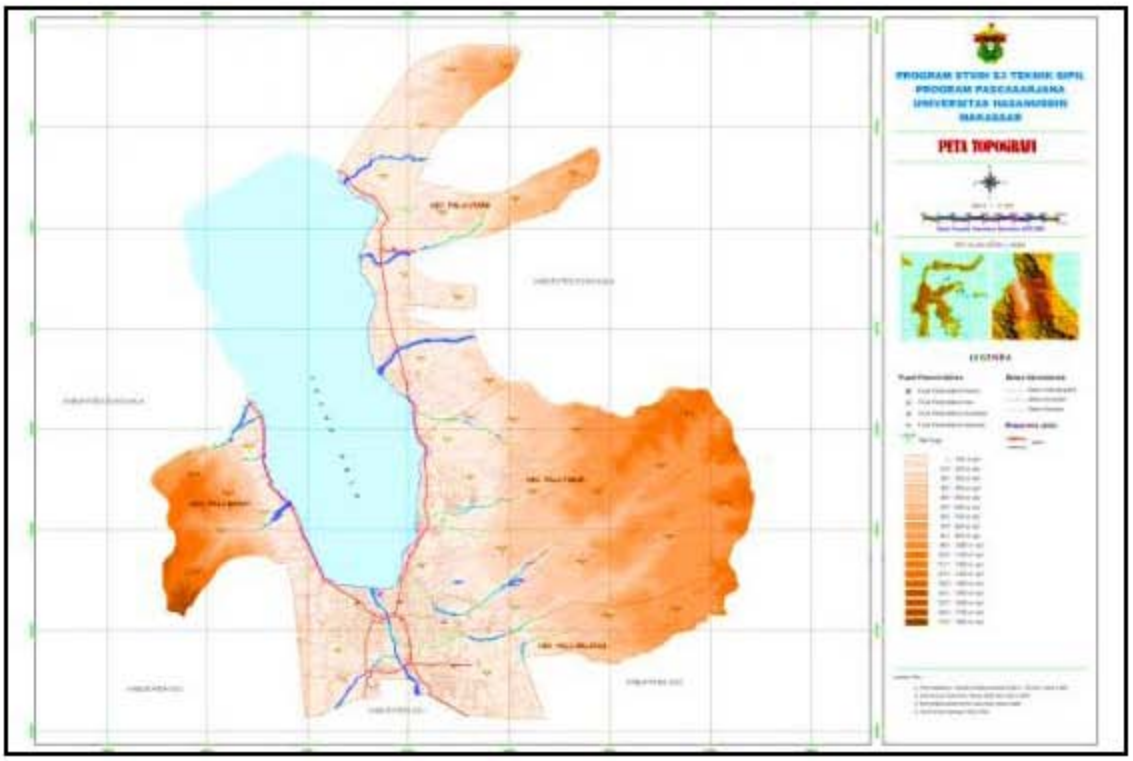


Figure 1. Map of Topographic of Palu City

b. As the Bay City which has valley shape and surrounded by the mountains, it makes Palu relatively crossed by the rivers and creeks which terminate into Palu bay, so that this condition can be used as a surface water source which is considerably potential for the needs of living things and activities of urban areas.

c. As a city that has three natural forces, namely mountains, rivers, and bay coasts, it makes of Palu as one of the exotic natural tourism cities becoming potential and prospective for the development as a tourist destination. It is through the planning of tourism

infrastructure and the provision of tourist accommodate on with the consideration to the carrying capacity and environmental quality (see Figure 2).

d. Asone of the cities passed by the fault line (Palu-Koro Fault) [*Bellier, O. et al*. 2001]; Palu city has relatively big potential seismic and tsunami. This condition would be a serious concerning managing land use and technical feasibility of building to suit their quirements of zone and construction (see Figure 3).

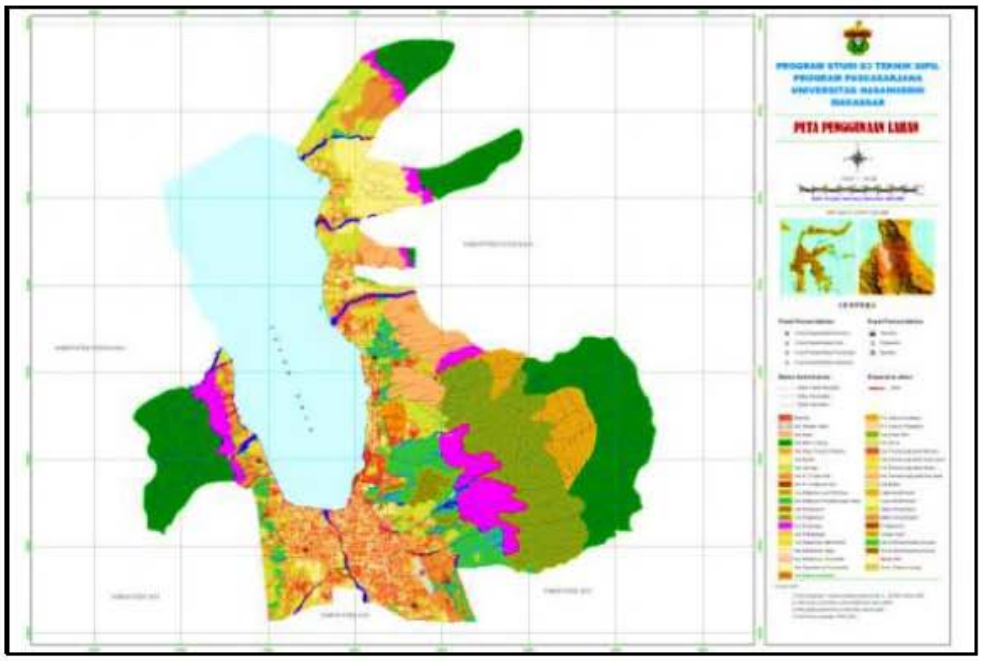


Figure 2. Map of Land Use of Palu in 2010

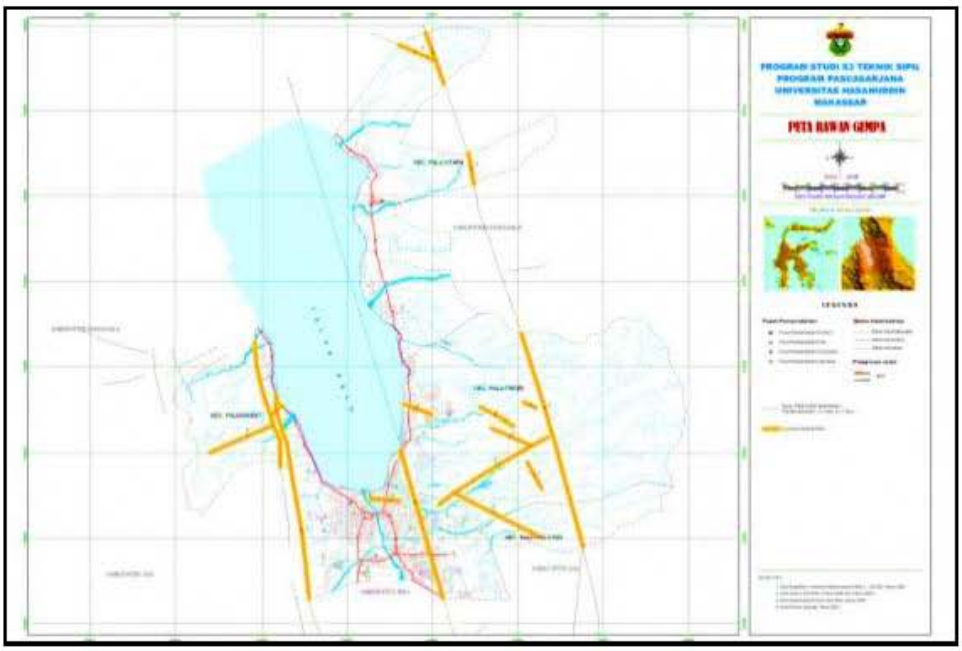


Figure 3.Map of Earthquake Prone of Palu City

e. As one of the cities located on the equator line, precisely located in the south line of the equator at coordinates 0^0,36"- 0^0,57" South Latitude (LS) and 119^0,45"- 120^0,01" East Longitude (BT), Palu city is a city that has the lowest rainfall categories when compared to other cities in Indonesia. In facing global climate change, this condition should be really paid attention when the opposite conditions occur, especially in anticipating the flood through the provision of land for green open spaces as the response to mitigation/disaster and environmental destruction.

f. As the capital of Central Sulawesi Province and the newly developing city, Palu will be the one of the alternative cities that is visited and inhabited if it is linked to public service and administration, and also business and creative opportunities. Characteristics of population growth in Palu city are dominated by migrants (migration/urbanization), namely 82.32%, while natural growth (births minus deaths) is only 17.68%. This condition triggers a high growth of population for the last 30 years with a growth rate above 2.0% so it can be classified as the population explosion and also will have an impact on increasing to the demand for land.

Land Availability for Building

Spatially, the availability of land use for building to Palu area is ± 37.860,83 ha (see Figure 4). It can be done through an approach of overlay analysis technique to the base maps and thematic maps, which is derived both from the Bakosurtanal and *RTRW* Palu and from the results of digitization and classification of land use in image processing analysis. Based on spatial data processing, then it is obtained a map of the distribution and availability of land for building in Palu city, as shown on the map in Figure 5.

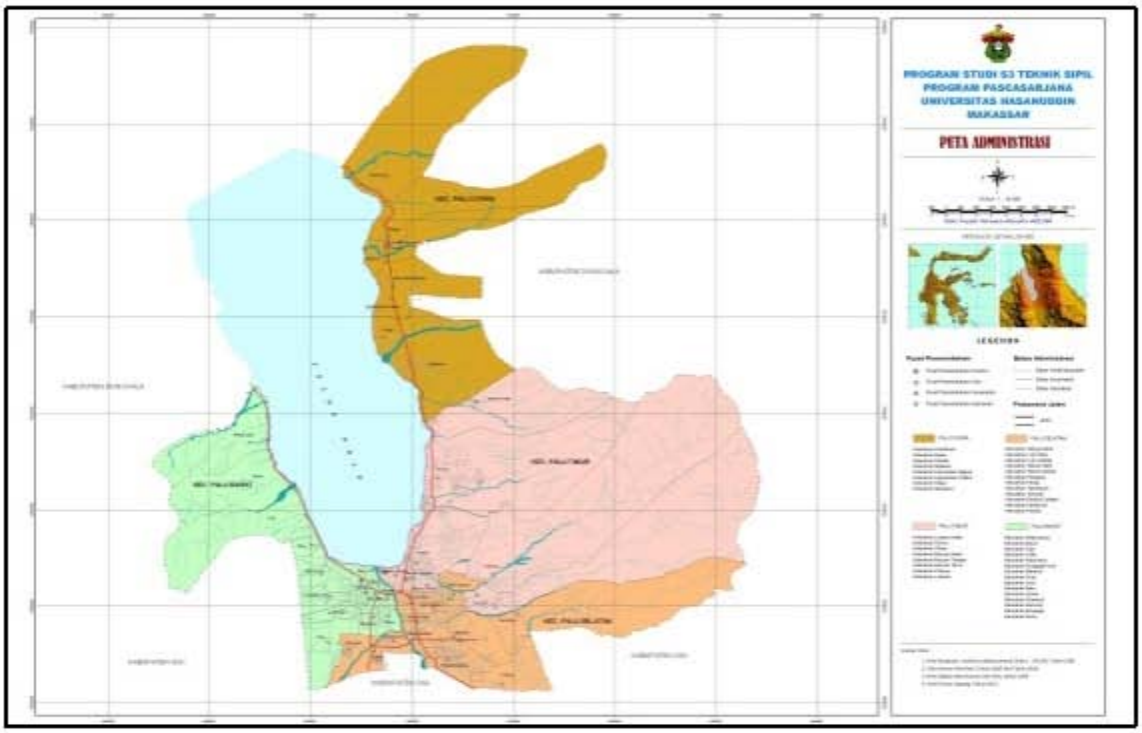
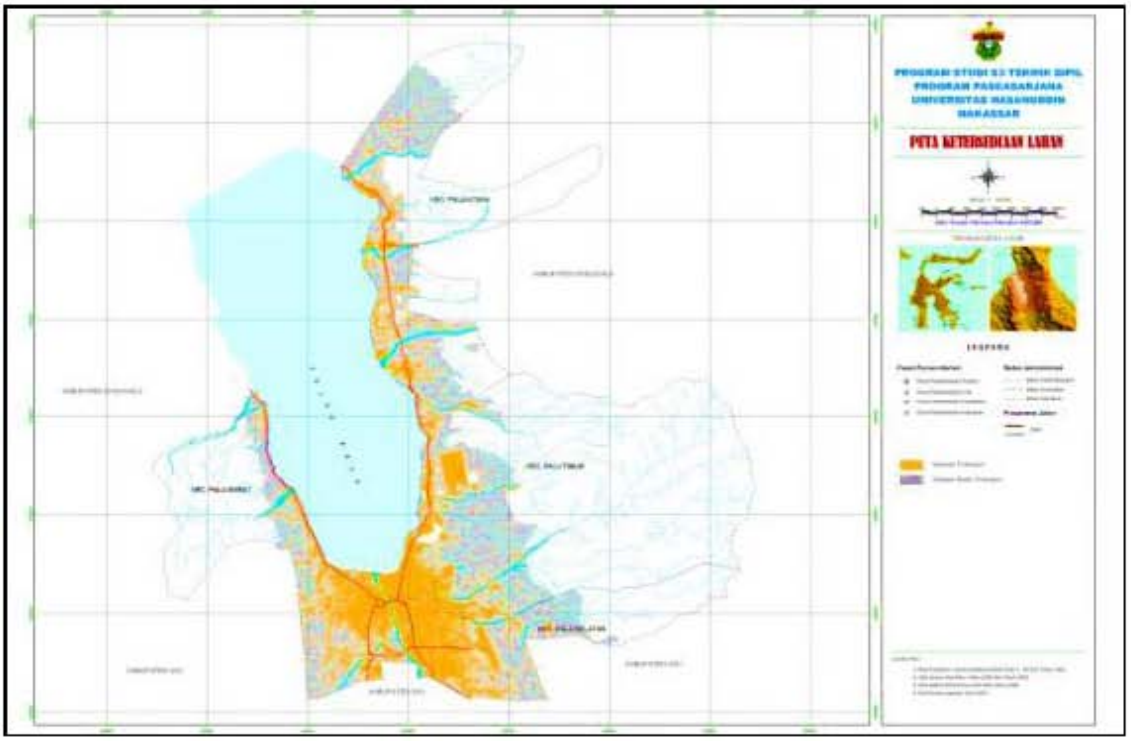


Figure 4. Map of Administration and Area of Palu City



Picture 5. Map of Land Availability for Building in Palu City

Furthermore, land use maps quantitatively obtained from spatial data processing can also be tabulated and grouped by type and area of each land use area, including: protected area (K_L) is ± 18529.38 Ha; developed cultivation area (K_{BT}) is ± 4180.25 Ha; urban infrastructure area (K_{PK}) is ± 543.27 ha; and strategic area of city (K_{SK}) is ± 1456.80 Ha, so the extensive availability of land for building can be calculated in accordance with the needs of mathematical model equation:

$$L_{EF} = L_W - (\sum K_L + \sum K_{BT} + \sum K_{PK} + \sum K_{SK})$$

The analysis shows that there are± 13.151,13 Haof land classified as land for cultivation activities, including the establishment of building. It is the biophysical land, especially from slope and topography aspects which are suitable to be used and developed as land for various cultivation activities [*Amar, et al.* 2012].

Relation Model of the Extent of land use for Timing Building for Future Time

The Equation of the Number of Land Users for Building in Palu

The equation of the population number and the number of families is classified on the total number, while the equations of the number of hotel guests consists of star hotel guests and non-star hotel guests and other accommodations. The equations obtained from regression method are changed from period to A.D. calendar/ year.

a. The Equation of the Population Number of Palu
   $P_{jpk} = 261.996,9824\ e^{0,0244\ (t\ -\ 1999)}$
   $R^2 = 0,9749$
b. The Equation of the Population Number of Central Sulawesi Province
   $P_{jpp} = 2.136.910,1758\ e^{0,0192\ (t\ -\ 1999)}$
   $R^2 = 0,9998$
c. The Equation of The Number of Families of Palu
   $P_{jkt} = 54.667,0217\ e^{0,0306\ (t\ -\ 1999)}$
   $R^2 = 0,9306$

d. The Equation of the Number of Star Hotel Guests
P_{thbb}= 6.443,8697 (t – 1999)^{0,5589}
R^2= 0,6705

e. The Equation of the Number of Non-Star Hotel Guests and Other Accommodations
P_{thnb}= 11.400,7213 (t – 1999) ^{0,9920}
R^2= 0,8295

f. The Equation of the Number of Restaurants and Restaurant Seats in Palu
P_{krm}= 2.135,6250 e $^{0,1184\ (t\ -\ 2001)}$
R^2= 0,4826

The Extent of Land Use by One User for Building

Overall, the extensive land use by one user for building in Palu city can be seen in Table 2.

Table 2. The extensive land use by one user for building in Palu

No.	Type of Land Use	Equation Symbol	Land User	Width by User (m^2)
1.	Housings	L_{Lrmh}	Per 1 Household	203,000
2.	Education Facilities*)	L_{Lddk}	Per 1 Person	5,980
3.	Health Facilities	L_{Lkes}	Per 1 Person	1,413
4.	Worship Facilities	L_{Libd}	Per 1 Person	2,000
5.	Economic Facilities	L_{Leko}		
	a. Trade		Per 1 Person	1,530
	b. Work space/room		Per 1 Person	1,270
	c. Restaurant		Per 1 Restaurant Seat	3,200
6.	Government Facilities/Public Services	L_{Lplu}		
	a. City Level		Per 1 Person	2,270
	b. Province Level		Per 1 Person	0,760
7.	Environmental Infrastructure	L_{prling}	Per 1 Person	21,000
8.	Parks, Playgrounds/Sports Fields, CemeteriesandGreen Lines	L_{Lrtb}	Per 1 Person	19,000
9.	Tourist Accommodation Facilities	T_{Lbg2}	Per 1 Hotel Guest	4,130

Source : Analysis Result of Researcher, 2011

**) dosen not include an area of higher education facilities*

The Equation of the Extent of Land Use for Building

The equation of the extent of land use for building is the multiplication of the extent of land use by one user with the equation of the number of users. The extent of land use by one user from year to year is fixed. The equation of the number of users and the extent of land use by one user is already obtained in the previous stage.

a. The Equation of The extent of land use for Settlement

1) Land Use for Housings:
$L_{Lrmh} = L_{LRrt} \times P_{lrt}$
L_{Lrmh}= 1.109,7405,41 e$^{0,0306\ (t\ -\ 1999)}$ Ha

2) Land Use for Educational Facilities:
$L_{Lddk} = L_{Lddk1} \times P_{lpk} + K_{ppdk}$
L_{Lddk}= 156,6741954752 e$^{0,0244\ (t\ -\ 1999)}$ + 299,8 Ha

3) Land Use for Health Facilities:
$L_{Lkes} = L_{Lkes1} \times P_{lpk}$
L_{Lkes}= 37,02017361312 e$^{0,0244\ (t\ -\ 1999)}$ Ha

4) Land Use for the Worship Facilities:
$L_{Libd} = L_{lhkb} \times P_{lpk}$
L_{Libd}= 52,39939648 e$^{0,0244\ (t\ -\ 1999)}$ Ha

5) Land Use for Economic Facilities:
$L_{Leko} = (L_{pt} \times P_{lpk}) + (L_{rh} \times P_{lpk}) + (L_{rm} \times P_{krm})$
L_{Leko}= 40,0855383072 e$^{0,0244\ (t\ -\ 1999)}$ Ha + 33,2736167648 e$^{0,0244\ (t\ -\ 1999)}$ Ha + 0,6834 e $^{0,1184\ (t\ -\ 2001)}$ Ha

6) Land Use for Government Facilities and Public Services:
$L_{Lplu} = (L_{splu1} \times P_{lpk}) + (L_{splu2} \times P_{lpg})$

L_{Lplu}= 59,473315005 $e^{0,0244\ (t - 1999)}$ Ha + 162,405173361 $e^{0,0192\ (t - 1999)}$ Ha

7) Land Use for Environmental Infrastructure:

$L_{Lpling} = L_{prling} \times P_{lpk}$

L_{prling}= 550,19366304 $e^{0,0244\ (t - 1999)}$ Ha

8) Land Use for Parks, Playgrounds / Sports Fields, Cemeteries and Green Lines:

$L_{Lrtb} = L_{tbrt} \times P_{lpk}$

L_{Lrtb}= 497,79426656 $e^{0,0244\ (t - 1999)}$ Ha

9) Total Area of Land Use for Settlement in Palu(T_{Lbg1}) :

$T_{Lbg1} = L_{Lrmh} + L_{Lddk} + L_{Lkes} + L_{Libd} + L_{Lekb} + L_{Lplu} + L_{Lpling} + L_{Lrtb}$

T_{Lbg1}= (1.109,740541 $e^{0,0306\ (t - 1999)}$) + (1.426,91416524512 $e^{0,0244\ (t - 1999)}$) + (0,6834 $e^{0,1184\ (t - 2001)}$) + (162,405173361 $e^{0,0192\ (t - 1999)}$) Ha + 299,8 Ha

b. The Equation of the Area of Land Use for Tourist Accommodation Facilities

1) The use for star hotel:

$L_{Lhbb} = L_{L1hbnb} \times P_{thbb}$

L_{Lhbb}= 2,6613181861 $(t - 1999)^{0,5589}$ Ha

2) The use for non-star hotel and other accommodations:

$L_{Lhnb} = L_{L1hbnb} \times P_{thnb}$

L_{Lhnb}= 4,7084978969 $(t - 1999)^{0,9920}$ Ha

3) Total area of land use for the entire tourist accommodation facilities (T_{Lbg2}) :

$T_{Lbg2} = L_{Lsaw} = L_{Lhbb} + L_{Lhnb}$

T_{Lbg2}= {2,6613181861 $(t - 1999)^{0,5589}$} Ha + {4,7084978969 $(t - 1999)^{0,9920}$} Ha

c. Total Area of Land Use for Building in Palu

Total area of land use for building in Palu city is the accumulation of total land use for settlement and tourist accommodation facilities by using the following equation:

$T_{Lbg} = T_{Lbg1} + T_{Lbg2}$

T_{Lbg}= [{(1.109,7405,41 $e^{0,0306\ (t - 1999)}$) + (1.426,91416524512 $e^{0,0244\ (t - 1999)}$) + (0,6834 $e^{0,1184\ (t - 2001)}$) +(162,4051733608 $e^{0,0192\ (t - 1999)}$) + 299,8} + {(2,6613181861 $(t - 1999)^{0,5589}$)} + {4,7084978969 $(t - 1999)^{0,9920}$)}] Ha

The Growth of Land Use for Building

The equation of the total area of land use for settlement and tourist accommodation facilities in Palu city is based on 5-year period of the extent of land use from 2015 to 2100 resulting from equation (18). Based on this equation, the extent of land use for building is 4.531,8520 Ha for the year 2015 (period 1), and 43.218,9591 Ha for the year 2100 (period 18). The growth rate of land use for building is calculated based on the discreate growth method of land use for building as follows:

$P_t = P_0 (1 + r)^t$

r = the average of the increasing proportion of land use every year.

$43.218,9591 = 4.531,8520 (1 + r)^{84}$

$(1 + r)^{84} = 9,53671$ → 84 log (1 + r) = log 9,53671

log (1 + r) = 0,0116595 → 1 + r= 1,02721→r = 0,02721= 2,72%.

The growth rate of land use for building in Palu city is 2.72% per year.

Figure 6. Shows graph showing the relationship between the extent of land use for building and the extent of available land in undeveloped cultivation area in Palu city.

Time Limit of Land Availability which is Capable of Supporting the Growth Area of Land Use for Building

The calculation of the time limit is completed by assuming the growth average of land use for building in Palu city is fixed at2, 72% per year.

a. The time limit for the settlement area in Palu city is able to support the growth of land use for building under the direction of the type and the extent of land use .± 12.493,57 Hauntil the year 2055.

b. The time limit for the tourist accommodation facilities in Palu city is able to support the growth of land use for building under the direction of the type and the extent of land use ± 263, 02 Ha until the year 2052.

The time limit for the undeveloped cultivation areas in Palu city is capable of supporting the growth of land use for the building under the direction of the type and the extent of land use ± 13.151,13 Ha until the year 2056. Figure 7. shows map of land use for building in Palu city in year 2056.

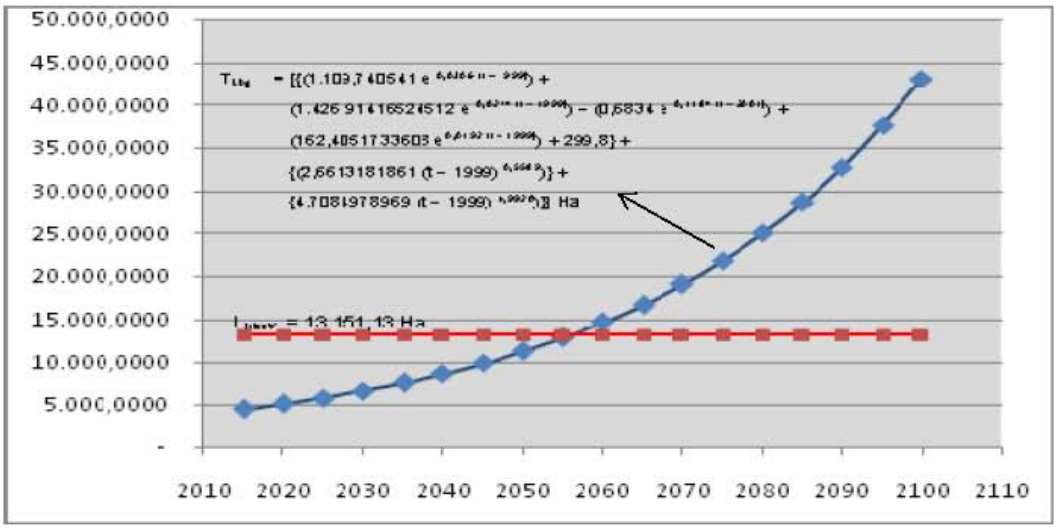


Figure 6.Graph showing the relationship between the extent of land use for building and the extent of available land in undeveloped cultivation area in Palu city

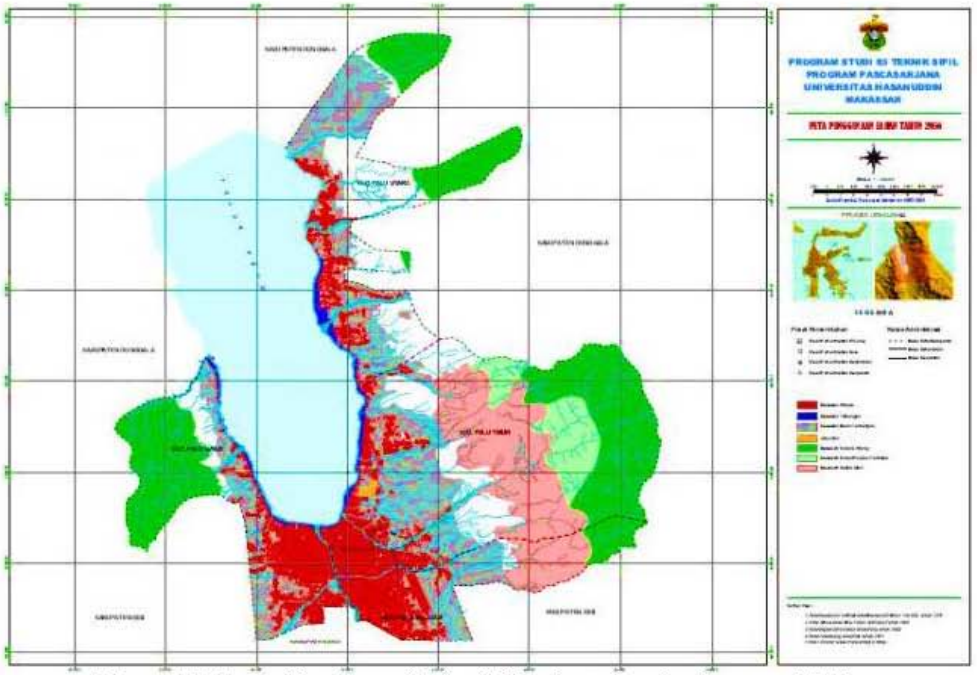


Figure 7.Map of land use for building in Palu city in year 2056

Source : Analysis Result of Researcher, 2011

The Carrying Capacity of Land for Building which is Capable of Accommodating the Population Growth of Palu

a. The land capacity for settlement area in accordance with the time limit until the year 2055 with the land availability of ±12.493, 57 Ha is 1.027.354 people and the household capacity in settlement area of ±6.188, 0816 Ha is 303.345 households.
b. The capacity for tourist accommodation in accordance with the time limit until the year 2052 with the land availability of ±263, 02 Ha is 59.273 star hotel guests, as well as the capacity for non-star hotels and other accommodations in tourist accommodation facilities area of ±263.02 Ha is 585 362 non-star hotel guests and other accommodations.
c. The capacity for the undeveloped cultivation area in accordance with the time limit until the year 2056 with the land availability of ±13.151, 13 Ha is 1.052.730 people.
d. The carrying capacity threshold of land in Palu city based on the land consumption per capita is: ±13.151, 13 Ha/1.052.730 people = 0, 01249241 Ha/Person.

   Based on the standard of land consumption of urban per capita, the calculation result is not yet exceeded the threshold with a ratio of 1: 0, 2. For that matter, the land consumption per capita for 1.052.730 people should be ± 0,061 Ha/person.

   While the carrying capacity threshold of land according to the population density is: 1.052.730 people/ ± 13151.13 Ha =80 people/Ha.

   Based on the classification of the population density of urban settlement, the calculation result is still relatively low.

Efforts in dealing with the Land Use for Building

Based on the equation model for the extent of land use for building and the calculation of the carrying capacity of land in Palu city as bay city, then it is required some efforts to be able to support the growth of the extensive of land use for building longer in accordance with the carrying capacity, among others: a) improving efficiency of the extent of land use for building by one user; b) controlling population growth; c) increasing the extent of land for building, and d) developing multi-stories building.

CONCLUSION

a. Palu has regional characteristic which is quite specific and its protected area attains almost half of the total land area ±18.529, 38 Ha (48.94%) and the rest is cultivated area ± 19.331,45 Ha (51.06%).
b. The extent of land use for building in Palu in future has increased with the growth rate 2.72% per year.
c. The time limit for the settlement area is capable of supporting the growth of land use for building ± 12.493,57 Ha until the year 2055 with a capacity of 1.027,354 people and 303. 345 households. The time limit for the tourist accommodation is capable of supporting the growth of land use for the building ± 263, 02 Ha until the year 2052 with a capacity of 59.273 star-hotel guests and 585.362 non-star hotel guests and other accommodations. At the same time, the time limit for undeveloped cultivation area is capable of supporting the growth of land use for building ± 13.151,13 Ha until the year 2056 with a capacity of 1.052.730 people.
d. The carrying capacity value of land in Palu city, both by the consumption or the demand for land per capita and the

population density is not exceeded the threshold, even it is far beyond the environmental carrying capacity thresholds.

e. Efforts needed to support the growth of the extent of land use for building in Palu city becoming longer are: to do the efficiency for the extent of land use for building by one user; to control the population growth; to increase the extent of land for building; and to develop multi-stories building.

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