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Author: Oloan Sitorus, Sukmo Pinuji, Westi Utami,
Arif Suhattanto, Ferdy Nugraha, et al.
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LAND CONSOLIDATION MODELING TO MAINTAIN FOOD SECURITY IN BADUNG AND GIANYAR DISTRICTS OF BALI PROVINCE

Rochmat Martanto[1], Yendi Sufyandi[1],
Sri Kistiyah[1], Eko Suharto[1], Sri Ngabekti[2], Bambang Sulistyo[3]
[1]Sekolah Tinggi Pertanahan Nasional, Jl. Tata Bumi 5, Yogyakarta
[2]Semarang State University, Jl. Taman Siswa, Gunungpati, Semarang
[3]Universitas Bengkulu, Jl.W.R. Supratman, Kandang Limun, Muara Bangka Hulu,
Kota Bengkulu, Bengkulu

Abstract

Conversion of agricultural to non-agricultural land use causes a decline in food security. Population density, land productivity, and social welfare are assumed as the factors causing this conversion. This research is aimed not only to know the influence of population density to land use conversion, but also the limit of food self-supporting happened in Badung and Gianyar Districts. Research used correlational method by taking samples from the survey of data in 2005 – 2015, and the population is all sub districts located in Badung and Gianyar districts where the land use conversion took place from year of 2005 up to 2015. Result of analysis using multiply regression shows that population density and social welfare influence the conversion of agricultural to non-agricultural land use. To analyze the limit of food security used variable of population increase, and conversion used exponential equality. The result of analysis shows that limit of food self-supporting in Badung and Gianyar districts will happen in 12,41 years future or year of 2027 with the size of agricultural land is 15,289.41 ha. Agriculture land consolidation takes place in the sub-districts of Abiansemal, Payangan, Petang, Sukowati, Tampaksiring, and Tegallalang. In the meanwhile, urban land consolidation is in the sub-districts of Blahbatuh, Gianyar, Kuta Utara, and Mengwi. This research can be used as agriculture land consolidation modeling for food security in other areas.
Keywords: land use conversion, food security limit, land consolidation.

1. Introduction

The land is one of the natural resources that have a strategic role in the development of food supply (Oktalina et al. 2016). Economic growth, population density, and the declining number of farmers are the factor that affects land-use conversion from agricultural to non-agricultural in urban and rural areas (Hidayat 2008). The land-use conversion is mainly influenced by the rapid construction development of settlements, city centers, education area, and government central (Dewi 2013). Also, the high rate population growth with its socio-economic status is one of the driving factors of increasing needs of land areas (Ruswandi, et al. 2007).

Developing countries experience the highest rates of agricultural land conversion comparing with developed countries. The literature review has shown that some of the causes of the transformation of farmland including population growth, economic growth, housing construction, infrastructure development, speculative activity (buying and selling) of farmland (Govindaprasad and Manikandan 2014). As mentioned by Barati et al. (2015), the land-use conversion has caused some challenges in agricultural development and human life. In general, due to construction, the available land in urban and rural areas has become more limited. It raises issues of urban and rural land, including an uncontrollable increase in the conversion of land use from agricultural to non-agricultural due to the conflict of various interests (Sari et al. 2010). Instead of infrastructure development, staple food plantation such as paddy field is also dominating the land-use in most areas in Indonesia. The availability of land-use for rice field represents the food availability and food security in those particular areas. The debate on effective land-use either for infrastructure or agriculture has always been to be a serious problem (Bardhan and Tewari 2010). In modern life, the new building and infrastructure are necessary to build the civilized community; whereas the sustainability in food security also plays a crucial role to support a human being. Therefore, it is difficult to choose one of them, all of decision and policy by the stakeholders must cover all aspects in balance.

However, the fact shows that Indonesia experienced the rice deficit at 90 million ton in 2015. The further investigation in the field indicates that agricultural land has converted to the non-agricultural. In Bali Province, Indonesia, particularly in the administrative region such as Denpasar and Badung has been experiencing a land-use conversion at 0.34% (9,679 ha out of 563,666 ha) within 5 years (As-Syakur 2011). Also, the agricultural land has shrunk by 15,280 ha or 7.89% in Bandung Regency in the period of 7 years (1992-1999). The broad decline in farmland was followed by a decrease in rice production of 194,196 tons or at 24% (Ruswandi et al. 2007). Agricultural land conversion occurred in Gunungpati District (the suburb of Semarang) Central Java occurs due to population activities such as education and market along the main road (Dewi 2013). Land-use conversions do not only happen in Bandung, Semarang, and Bali; it also occurs in Ngawi where rice field area developments are likely to continue declining in line with the population growth and socio-economic activities. The paddy fields turned into houses and buildings (Hidayat 2008). The land-use conversion also happens in the other parts of the world; for example, a land-use conversion in Florida USA dominated the agricultural land and savannah which are located in rural areas due to rapid population growth (Ndez et al. 2012). Likewise, an analysis of the conversion of agricultural to non-agricultural land using the remote sensing in Qazvin Province, Northwestern Iran shows that within 20 years, 3.03% conversion of agricultural land into infrastructure mainly in the urban areas has occurred. Besides, in the countryside, the land has been converted into the local salt industry.

The rapid population growth is the primary factor of land-use conversion problems. The population density increases each year which is followed by the decrease of land area. The definition of population density is the total population divided by the area. The land-use conversion occurs as a result of the growth rates and population growth due to the expansion of unplanned residential areas (Mallupattu and Reddy 2013). However, those problems do not directly trigger the conversion of land use from agricultural to non-agricultural land for the needs of the population. The conversion of land-use can be determined by using satellite imagery. Landsat Satellite Imagery was launched in 1972 under the name Landsat-1, whereas now it is upgraded to the series of Landsat-8 (Sitanggang 2010; Suwargana 2013).

In this study, we focused on the land-use conversion problems in Badung Regency and Gianyar Regency, Central Java. This study aimed to analyze the factors of population density to estimate the land-use conversion rate and food security limits in Ngawi. It is to guide government to set the policy to suppress the land-use conversion in regards to increasing food security in Badung Regency and Gianyar Regency

2. Research Methods

2.1. Research area

The study area was all the districts in Badung Regency and Gianyar Regency, Bali Province. A sample survey was conducted on March-August 2017 to collect population density data from Central Bureau of Statistics of Badung Regency and Gianyar Regency.

2.2. Data collection

Data were collected using satellite imagery Landsat-7 and Landsat-8. To determine the land-use conversion in 2005 and 2015, satellite imagery Landsat-7 and Landsat-8 were employed, respectively. Landsat-8 was launched in 2011 from Vandenberg Air Force Base California, with the glider Atlas-V-401. Landsat-8 is designed on approaching circular orbit near sun circle with an altitude 705 km, inclination 98.2º, period 99 minutes, coverage time 16 days. It brings sensor images Operational Land Imager (OLI) like Landsat-7. Landsat-7 was launched in April 1999. Landsat satellite imagery has near-infrared channels 1, and 7 channels appear reflective, with a spatial resolution of 30 m.

2.3. Data analysis

The land-use conversion and population density were used to calculate food security status and food security limits in Badung Regency and Gianyar Regency. The research applied a correlational analysis. The deciding factor of influence (relationship) conversion of agricultural land use to non-agriculture to population density was analyzed using partial correlation (Telussa et al. 2013). The partial correlation analysis formula is as follows:

$$t = \frac{r \cdot \sqrt{n-k}}{\sqrt{1 - r^2}} \quad \text{...} \ (1)$$

$$r = \frac{n\sum XY - (\sum X)(\sum Y)}{\sqrt{\{n\sum X^2 - (\sum X)^2\}\{n\sum Y^2 - (\sum Y)^2\}}}$$

n = Number of data

X = Independent variable

Y = Dependent variable

r = Partial correlation coefficient

n = Number of respondent

k = Number of variable

$t_{count} < t_{table}$, then there is no significant relationship.

$t_{count} > t_{table}$, then there is a significant relationship.

Next, data was analyzed by SPSS 16 for Windows. The impact of the land-use conversion of paddy field on the level of food security (rice) can be calculated with the needs of food (rice) per capita per year. For example, rice consumption by the average Indonesians reached 139.15 kg/capita/year in 2010 (Rikumahu et al. 2013). Therefore, to get the number of rice demands of Ngawi population is as follows:

Rice demands = ∑ population x 139.15 kg/capita/year ....(2)

It is necessary to know the yield loss on drying using drying to calculate the needs of dry milled grain rice (post-harvest). Post-harvest handling of rice is very strategic efforts to support increased productivity of paddy into rice. Contribution to the post-harvest handling of paddy rice production increase can be reflected in a decrease in yield loss and target them quality grain/rice corresponding quality requirements. Postharvest handling of rice is the high loss of yield; it happens at the stage of harvesting, threshing, and drying. The yield or yield loss on drying using drying by sunlight 61.6% (Raharjo et al. 2012), therefore that the productivity of rice per year to rice is as follows.

The productivity of rice per year = productivity of rice x planting season per year x 61.6%...(3).

The availability of food (food security) due to the conversion of agricultural land (paddy) and population growth can be described as a two-way relationship (bilateral) between the conversion rate ofpaddy fields use and rate of population increase. It means that the rate of paddy fields conversion affecting the rate of population density and rate population density also affect the rate of land use conversion or both are mutually reinforcing in the process of the need for land. Therefore the limit of food security (rice) will form two (2) equation (function) exponential. While the exponential equation in land-use conversion rate (f_{X1}) and the population growth rate (f_{X2}) according to Panigoro, 2013 as follows.

$f_{x1} = ae^{bx}$ .... (4)

$f_{x2} = ae^{bx}$...(5)

From 2 equations, i.e. formula (1) and equation (2), there will be anintersection point (x; y), and that intersection point is a food security limit in the area. Matlab R2010a software was applied to get the intersection of two equations, equations of land-use conversion rate formula (4) and population growth rate formula (5).

2.4 Land Consolidation Modeling for Sustaining Food Security

Agriculture land consolidation is delineated through maps overlay. This kind of map is a result of several factors causing land use convertion. The references used are population density map, population welfare, and land productivity. Multiple regression test is done to identify the contribution of each variable to land use convertion. Calculation of partial test is applied to recognize the role and strength of each variable into built factor. The delineation of land consolidation through overlay technic is supported with scoring by using the following formula :

$$I = \frac{t_{\text{maks}} - t_{\text{min}}}{k} \quad \text{...(5)}$$

I = Class interval ;

t_{maks} = Total score of maximum value variables (high);

t_{min} = Total score of minimum value variables (low);

k = Class numbers made (3 classes) according to the last result of agriculture land consolidation, namely: agriculture land consolidation, urban land consolidation, and buffer (those two land zones) consolidation

Saaty in Martanto (2012) mentions that scoring on each attribute in a variable may use *Analilytycal Hierarchy Proses (AHP). AHP* explains how to abstractize the structure of a system to learn functional relation amongst components and come into effect on system as a whole. This system is arranged to unify rationally the man's perception having closed relation with certain problem through a procedure to come to a preference scale amongst various alternatives. This analysis is shown to make a model of problem having no structure. Commonly, it is determined to solve measured problem (quantitative), opinion-need problem (judgement), and complex situation or unframed, in the situation of limited statistic information and data, or even there's no at all. Therefore, this system is qualitative based on perception, experience or intuition. Basic concept of AHP is the use of pairwise comparison matrix to produce relative weight amongst criterias or alternatives. A criterium will be compared to other criteria in case of the importance on goal achievement above. AHP approach uses scale from 1 to 9. Scoring value of 1 shows equal importance. It means that attribute value with the same scale has value of 1, whereas, scoring value of 9 figures out the attribute case of absolutely important compared to other attributes.

Within AHP, the determination of policy priority is done by catching ma's perception rationally, and then convert the intangible factors into common rule in order to be able to compare. Suggested weight to make pairwise comparison matrix is;

score 1 : equal important;

score 3 : slightly more important;

score 5 : strongly more important;

score 7 : very strongly more important;

score 9 : extremely more important (*extreme*).

Beside value in scoring, each gap value can be used as well, viz 2, 4, 6, 8. Some those values illustrate the relation of importance amongst odd numbers mentioned.

To make it clear, overlay technic through scoring and data sources can be seen on Table 1.

Tabel 1. Scoring and data sources

No.	Variable	Assumption of calculation	Grouping of research result (atribut)	Score	Data sources
1	Population density	Population density per sub-district	Less densed	9	Grouping based on formula (5) from data of each sub-district
			Densed	5	
			Very Padat	1	
			Partly suitable (medium)	5	
			Not suitable	1	
2	Percentage of community welfare	Percentage per sub-district	High	9	Grouping based on formula (5) of each sub-district
			Medium	5	
			Low	1	
3	Land productivity	Average land productivity per sub-district on rice of sawahs	High	9	Grouping based on formula (5) of data per sub-district
			Medium	5	
			Low	1	

Notes: Score determination with AHP from Saaty in Martanto (2012)

On each variable score will be obtained score total later on. The score total is as the base to determine land consolidation. Land consolidation is delineated based on score total obtained from map as the result of overlaying certain factors. The classification is determined based on the result of calculating class interval according to formula (6) as in The Table 2.

Tabel 2. Grouping of agriculture land consolidation

No	Consolidation	Score total
1	Agriculture land	$\geq (t_{min} + 2I)$
2	Buffer zone	$\geq (t_{min} + I)$ - $< (t_{min} + 2I)$
3	Urban land	$< (t_{min} + I)$

Notes: Agricultural Land Consolidation based on formula (5)

Assumption built is that Badung and Gianyar regencies with the highest total score is land for agriculture (eternal sawahs) which has low population density, low welfare percentage, and low land productivity.

3. Results and Discussion

Landsat satellite imagery is effective and efficient for agricultural forecasting, energy exploration, ecosystem monitoring, natural resource management, mapping of land-use/land cover, and environmental monitoring. Landsat-7 satellite imagery and Landsat-8 with a spatial resolution of 30 m can be used for creating maps of land-use/land cover effectively (Suwargana 2013). In this study, the results are in the form of land-use conversion, population density, field data, and the results of delineation/digitalization of satellite imagery. Data of population density and land-use conversion are used for estimating food security status. Population density variable obtained from the population and rural areas as well as the potential of monographs/village community. These variables can affect the operation of the pressure on land, due to the high rate of growth and population growth due to the expansion of unplanned residential areas (Mallupattu and Reddy 2013; Govindaprasad and Manikandan 2014).After delineation through Landsat satellite imagery, we can see the conversion of agricultural land to non-agricultural landfrom 2005 until 2015. The conversion of land-use in 2005 and 2015 was occurred by way of the overlay, overlapping, and stacking which is shown in Figure 1.

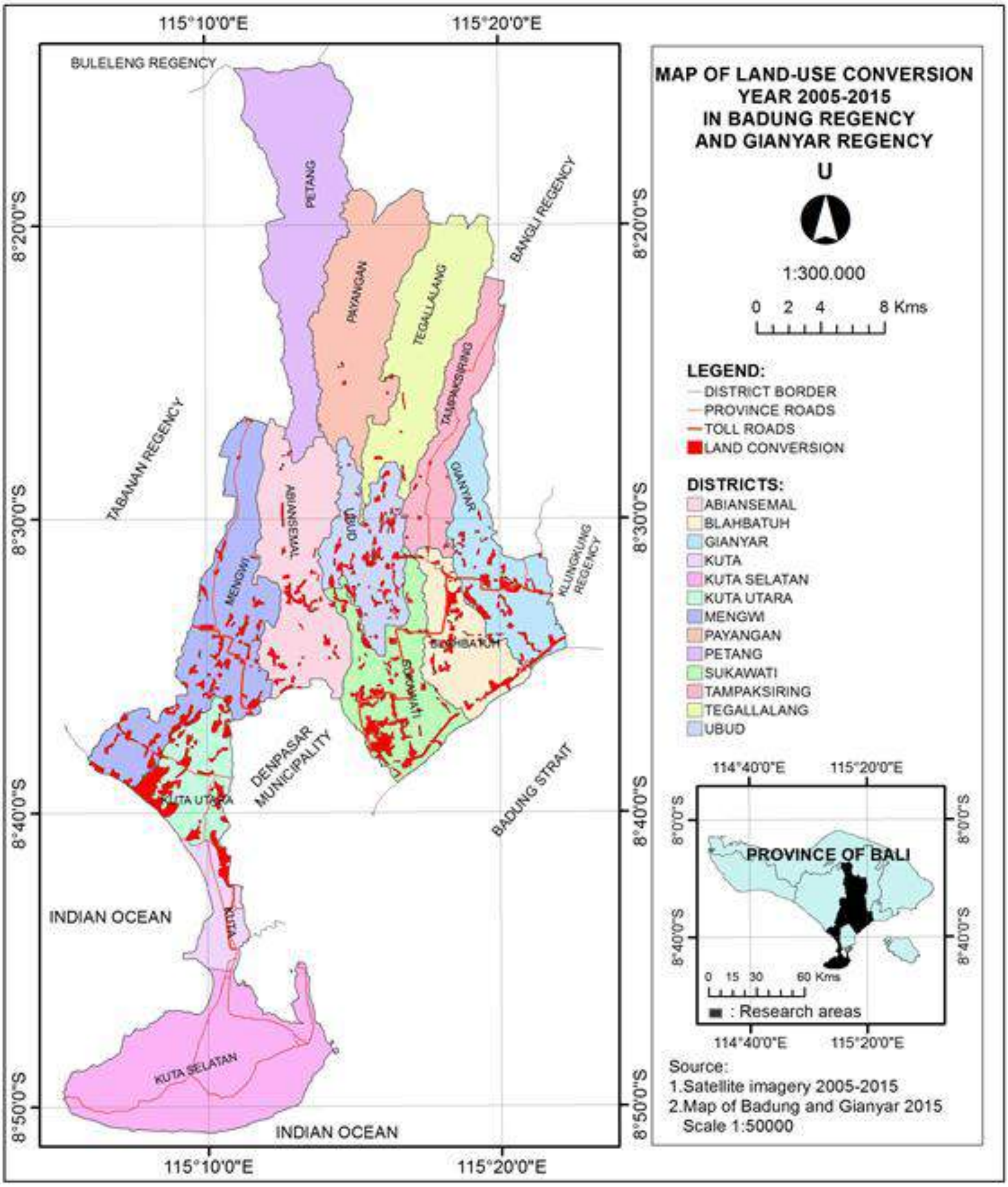

Figure 1. Map of land-use conversion in 2005-2015 in Badung dan Gianyar

The researchwas conducted in the administrative area of Ngawi. It lies geographically at 7° 14' 01"- 7° 37' 06" South Latitude, 111° 03'24"- 111° 42' 00" East Longitude. The land-use conversion from 2005 to 2015 is shown by black color, whereas the characteristic of the research area is presented in Table 3.

Table 3. Characteristic of research area in Badung Regency and Gianyar Regency

No.	Kabupaten	Kecamatan		Konversi		Kepadatan Penduduk (Jiwa/ha)	Kesejahteraan Masyarakat (%)	Produktivitas tanah (Ton/ha)
		Nama	Luas (ha)	(ha/ th)	(%)			
1	Badung	Abiansemal	6901	45.86	0.66	13.06	20	6
2	Gianyar	Blahbatuh	3970	57.27	1.44	17.19	28.2	6.2
3	Gianyar	Gianyar	5059	62.60	1.24	16	23	5.9
4	Badung	Kuta Utara	3386	171.48	5.06	34.29	28.65	6.3
5	Badung	Mengwi	8200	166.57	2.03	20	28.25	6.2
6	Gianyar	Payangan	7588	3.12	0.04	5.53	4.6	6
7	Badung	Petang	1150	2.67	0.23	8	15	6.2
8	Gianyar	Sukawati	5502	74.83	1.36	18	28.1	5.9
9	Gianyar	Tampaksiring	4263	9.28	0.22	8	16	6.3
10	Gianyar	Tegallalang	6180	7.75	0.13	7.35	10	6.2
11	Gianyar	Ubud	4238	36.07	0.85	16.82	21	6.5

Source : Central Bureau of Statistics of Badung and Gianyar

Administratively, the government of Badung Regency and Gianyar Regency consists of 11 districts (Figure 1 and Table 3). The widest administrative is Payangan (7588 ha), while the narrowest is Petang (1150 ha) as can be seen in Table 1. Kuta Utara experienced the most land-use conversion (5.06 %); whereas Payangan was the least (0.04 %). Moreover, the agricultural land area width was 50,476 ha, whereas the average conversion rate per year was 57.95 ha/yr (0.98 %). The average population growth rate per year was 3.25 %, and the average rice production was 6276.75 kg/ha (Central Bureau of Statistics of Ngawi, 2015, Table 3, and Figure 1).

Results of stacking-overlapping map of land-use in 2005 and 2015 were in the form of agricultural land-use conversion in every district in Ngawi. Results of delineation and digitalization of Landsat satellite imagery is tangible as the map. This map can describe the condition of the area (location) research on land-use conversion. The result of calculation from the relationship between X and Y (correlation coefficient) with SPSS is summarized in Table 4.

Table 4. Results of calculations of each dependent variable to the independent variables

Variabel	t	Sig T
1	2	3
Population density (X_1)	9.554	.0000
Comunity walfare (X_2)	-2.373	.0494
Land productuvity (X_3)	-.523	6173

Source: Data processing with SPSS 16 for Windows

Based on Table 4 it can be concluded that the independent variable (X_1 and X_2) affects the dependent variable (Y). The larger value of T (column 2) leads to the greaterthe effect of land-use conversion. The direction of relations between the two variables is determined by observing the marks/grades (+) and (-). In this study, the value is (+) means that the dense population in a region; the more land-use conversion from agricultural to the non-agricultural area.

Food security (rice production) is one of the objectives to meet the food demands locally and nationally. Regarding food production through improved food security, it can be pursued by the improvement of rice production which is mainly produced from agricultural land (paddy). One food security strategy that should be considered is public policy in the form of diversification, and the direction of development by the potential of the area (Benu et al. 2013).

Conversion of agricultural land to non-agricultural land could hamper the agricultural production and detrimental to food security. The rate of conversion of agricultural land to non-agricultural land in Bangladesh based on field surveys covering 24 villages of the six divisions of the country per year was 0.56%, and among them was affected by population growth (Quasem 2011). Meanwhile, the land-use conversion in Ngawiwas smaller at 0.024%. It is becauseBadung Regency and Gianyar Regency has a low population growth rate at 3.25 % (Table 1), while the average population growth rate in Indonesia until 2012 was 1.25% per year (Ramdani 2015).

As a result of the rate of population growth and the increased consumption of rice, the demand for rice will be continuously increased. In compensating theexpansion of these needs, rice production both locally and nationally should be increased adequately. Therefore, the land became one of the natural resources that always been a subject of debate regarding its practical use (Bardhan 2010). Several factors which determine the conversion of agricultural land is the number of inhabitants and the location of farmland, which can cause a decrease in the availability of food, especially rice because the land is needed to meet the consumption of rice as a staple food (Harini et al. 2012).

Based on the data in Table 1, the land requirement in 2015 was the number of population in 2015 divided by the needs of rice using the formula (2) with a population of 845500 population/capita and average productivity of land per year 6276,75 kg/ha, rice production per year formula (3). Hence, the need for land as a result of the population is as follows.

Land requirement= formula (2) / formula (3)

= (845500 jiwax139,15 kg/jiwa/th)/((6276,76x2)kg/ha/th x2x 61,6%)

= 15214.276 ha:

Equation of land-use conversion rate as function (x) as the formula (4) is:

Equation of land-use conversion rate as function (x) as the formula (4) is:

x=0=> f(x1)= f(0)= aebo

23217,87=a

$x=12{,}3989 \Rightarrow f(12{,}3989)=23217{,}87eb^{12{,}3989}$

$15214{,}28=23217{,}87eb^{12{,}3989}$

$b=-0{,}033667$

$f(x1) = 23217{,}87\ e^{-0{,}033667x}$ ....(6)

Equations of land-use conversion rate as function (x) as formula (5) is:

Equations of land-use conversion rate as function (x) as formula (5) is:

$x=0 \Rightarrow f(x2) = f(0)= aeb0$

$15214{,}28=a$

$x=1064{,}76 \Rightarrow f(1064{,}76)=15214{,}28eb^{1064{,}76}$

$23217{,}87=15214{,}28eb^{1064{,}76}$

$b=0{,}000397$

$f(x2) =15214{,}28\ e^{0{,}0003972x}$ ....(7)

From two equations (6) and (7) there will be a crossover point (x; y), and the point of intersection is a limit of food security in the area. To get the intersection of two equations we used Matlab R2010a software.

Equation 1 .... $f(x) = 23217{,}87\ e^{-0{,}033667x}$

Equation 2............$f(x) = 15214{,}28\ e^{0{,}0003972x}$

The intersections of the line (x; y) are (2027; 15289,41). The relationship between the width of the area and time to food security limit is shown in Figure 2.

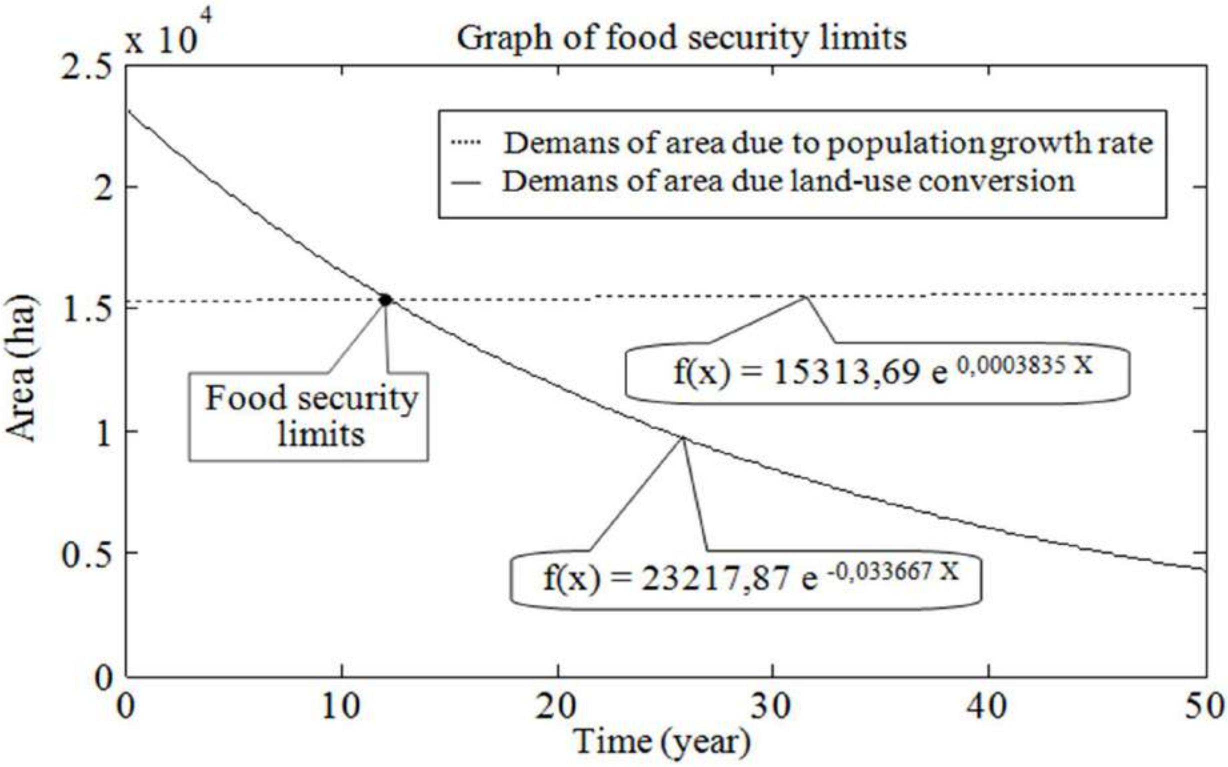

Figure 2. Graph of food security limits prediction in Badung Regency and Gianyar Regency

Cutting point coordinates (x; y) in Figure 2 is a "food security limit" is the meeting point between equation 1 and equation 2, means that in an area of 15289.41 ha and 2027 years to come to the area can only meet the need for food for its population. In other words, it cannot hold the export and import activity.

Based on the equation f(x) = 23217,87 $^{e\ -0,033667x}$ (land demands as a result of theland-use conversion rate) and f(x) = 15214,28 e ^{0,0003972x} (land demands due to increased population growth rate), it can be said that the process of land-use conversion and population growth are mutually reinforcing processes (occurring reciprocal relationships are mutually reinforcing). Therefore, as to achieve food security limit as shown in Figure 2, it requires a faster time, compared to only one single process.

This research shows that independent variables of population density (X1) and community welfare (X2) influence the dependent variable (Y), whereas, independent variable of land productivity (X3) does not. So, only those two independent variables influencing test of regression coefficient (partial test) on dependent variable are used as agriculture land consolidation data in the research area. Table 5.7 shows the data of land consolidation in the research area, and the score value of agricultural land consolidation of each independent variable is shown in Table 5.

Table 5. Characteristics of Research Area

No.	Sub Districts	Population Density		Community Welfare		Total of Score	Land Consolidation
		(caput/ha)	Score	(%)	Score		
1	Abiansemal	13.06	9	20	5	14	Agriculture
2	Blahbatuh	17.19	5	28.2	1	6	Urban
3	Gianyar	16	5	23	1	6	Urban
4	Kuta Utara	34.29	1	28.65	1	2	Urban
5	Mengwi	20	5	28.25	1	6	Urban
6	Payangan	5.53	9	4.6	9	18	Agriculture
7	Petang	8	9	15	5	14	Agriculture
8	Sukawati	18	5	28.1	9	14	Agriculture
9	Tampaksiring	8	9	16	5	14	Agriculture
10	Tegallalang	7.35	9	10	9	18	Agriculture
11	Ubud	16.82	5	21	1	6	Urban

Agriculture land consolidation as sustainable sawahs (rice field) which is hoped as rice warehouse in the research area is in sub districts of Abiansemal, Payangan, Petang, Sukowati, Tampaksiring, and Tegallalang. In the meanwhile, urban land consolidation as the area which is permitted for development is sub districts of Blahbatuh, Gianyar, Kuta Utara, and Mengwi. There is no buffer zone available in the research area.

This research can be applied as agricultural land consolidation for food security in other areas. To get more view, figure 3 shows about agricultural land consolidation.

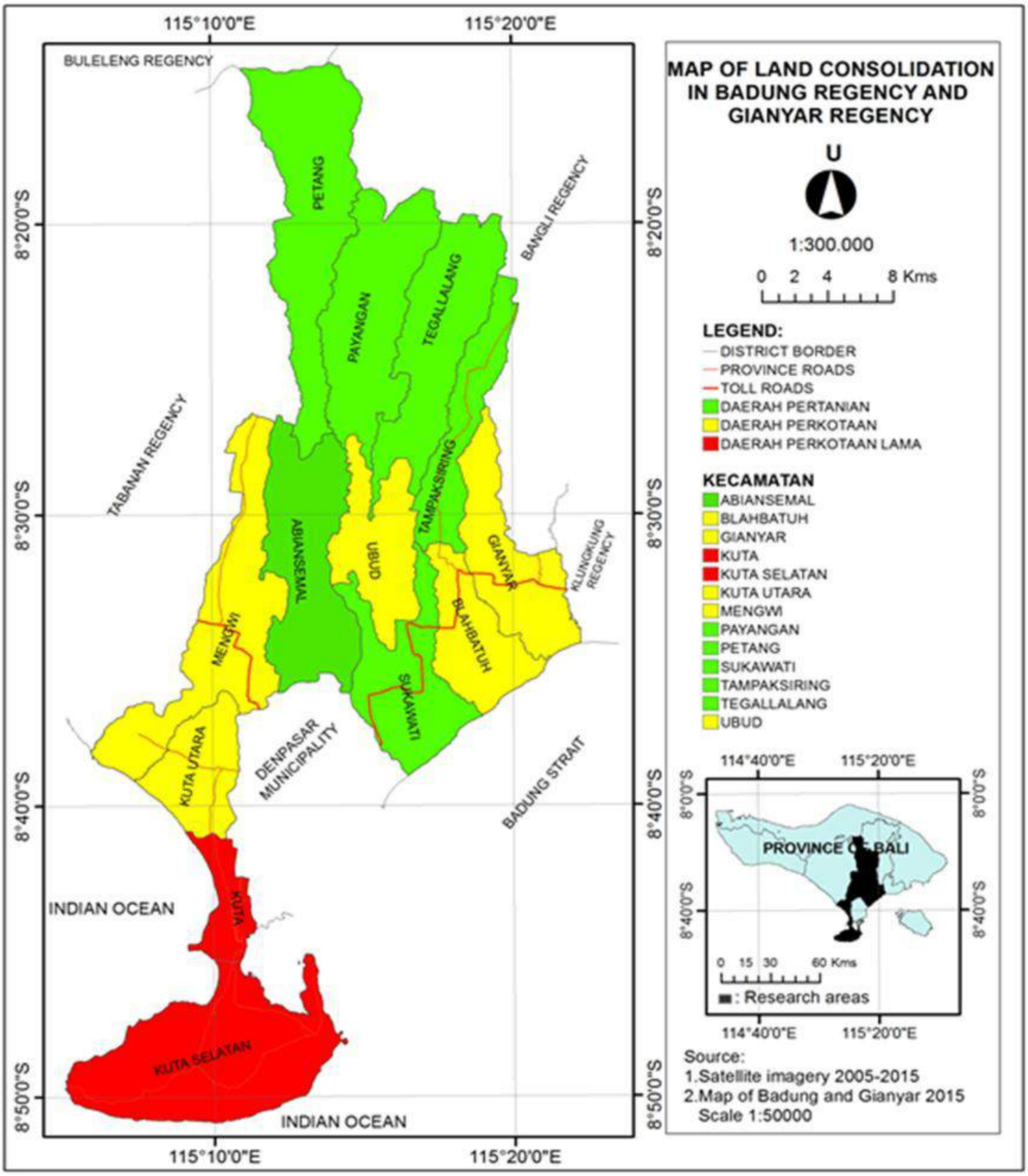

Figure 3. Map of land consolidation in Badung Regency and Gianyar Rigency

4. Conclusion

Convertion of agriculture to non-agriculture land use in the regency of Badung and Gianyar is influenced by population density. Whereas, food security limit in those two regencies will take place in 12.41 coming years, about year 2029, with agriculture land (sawahs) left will be only 15,289.41 ha.

Agriculture land consolidation takes place in the sub-districts of Abiansemal, Payangan, Petang, Sukowati, Tampaksiring, and Tegallalang. In the meanwhile, urban land consolidation is in the sub-districts of Blahbatuh, Gianyar, Kuta Utara, and Mengwi. This research can be used as agriculture land consolidation modeling for food security in other areas.

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