# The centrifugal and centripetal force influence on spatial competition of agricultural land in Bandung Metropolitan Region

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**Abstract**. Agricultural activity has suffered a massive land functional shift caused by market mechanism in Bandung metropolitan region (BMR). We argue that the existence of agricultural land in urban spatial structure is the result of interaction between centrifugal and centripetal force on spatial competition. This research aims to explore how several recognized centrifugal and centripetal force influence to the existence of agricultural land in BMR land development. The analysis using multivariate regression indicates that there exists spatial competition between population density and degree of urbanization with agricultural land areas. Its extended spatial regression model suggested that neighboring situation plays an important role to preserve agricultural land areas existences in BMR. Meanwhile, the influence of distance between the location of the city center and employment opportunities is found to be insignificant in the spatial competition. It is opposed to the theory of von Thünen and monocentric model in general. One of the possible explanation of such condition is that the assumption of centrality does not met. In addition, the agricultural land density decay in the southern parts of the area was related to its geographical conditions as protected areas or unfavorable for farming activity. It is suggested that BMR was in the early phase of polycentric development. Hence, better policies that lead redirected development to the southern part of the region is needed as well as population control and regulation of land use.

## 1. Introduction

Indonesia has experienced rapid economic growth by transforming its national development policy to modern industry. One of the major agglomeration of industrial activity, especially in the textile industry is located in Bandung Metropolitan Region (BMR) [1]. BMR initially consists of two areas: the city of Bandung as core and its surrounded periphery region. It is administratively divided into three regencies and a city, and became the third largest metropolitan region in Indonesia.

Its recent urban development contributes to spatial mismatch of population growth trend and employment growth trends, namely disagreement between the population and employment center locations [2]. To cope with these problems the government has adopted a policy of counter magnet development, aimed at decentralizing the urban economic activities from Bandung City to its surrounding small towns, particularly Soreang, Majalaya, Banjaran, Padalarang and Ujung Berung. However, urban economics decentralizing policy does not work effectively, so that the Bandung city, the core of BMR, has grown faster than the small towns surround [1]. This implies that Bandung city

still played a strong role as the center of gravity, whereas their surrounded areas in east and southeastern part of the city have become uncontrolled urban sprawl [3].

Urban land use has become one of the main issues in Indonesia's urban land development. Recent urban development was followed by land use changes in the urban area and conversion of prime agricultural land to residential as well as other urban function in the peripheries [4]. The problems faced by BMR which has suffered massive land functional shift of agricultural activity. Having 340,000 hectares of area and 8.25 million of population, BMR facing serious threat to its agricultural land existence. The data from agricultural census showed that the number of agricultural activities in the region during the decade of 2003-2013 decreased by 22.75 percent, with about 84 percent of whom are smallholders. The conversion has not only taken place in the prime agricultural land of the urban fringe, but has also occurred on land designated as conservation areas, such as Northern Bandung [5]. This result not only could endanger food security, but also have detrimental impacts on the environment.

The integration of urban agriculture into urban economic system and urban ecosystems compete in acquiring land with other urban functions, affected by planning and urban policy [6]. In such case, we argue that the existence of agricultural land in urban spatial structure is the result of interaction between centrifugal and centripetal force on spatial competition. Therefore, the protection of agricultural land is a challenge for spatial planning in the urban area that requires special handling strategy. The policy making needs an accurate information on the extent of linkage characteristic of the spatial structure of urban land use against the competition. Nevertheless, research on spatial competition that is done in this area still has not received much attention. This research aims to derive several centrifugal and centripetal forces which believed to play important role in the spatial competition of BMR. Furthermore, we examine how each factor could explain the existence of agricultural land areas.

Although such literature came from a distinct model of urban structure, but the study of the morphology of the whole area of study has not yet provided so far. Assuming the city of Bandung as center gravity for surround areas [1] [3], we choose monocentric urban models as analysis base of urban spatial structure. It has an eminence of simple assumptions to generate a model of the spatial structure of a city with remarkable predictive power [7].

This paper is organized into six parts. The first part discusses the urban land development and agricultural land issue in BMR. In the second part, we present a review to what extent the existence of agricultural land could be considered as the result of spatial competition. In third parts, we derived several centrifugal and centripetal forces which believed to explain the existence of agricultural land as a result of spatial competition from a literature review. The fourth parts explain the methodology used and the results of the analysis. The fifth parts present the discussion of the model. In the last part, conclusion and some appropriate policy recommendations were proposed for the direction of development, with regard to the sustainability of agricultural land areas.

## 2. Spatial Competition

Urban spatial structures are shaped by market forces interacting with regulations, primary infrastructure investments and taxes [8]. From the perspective of classical theory, the monopolistic power of a firm against another within an area is determined from its production and transportation cost [9]. While production costs tends to be fixed, firms minimizing its cost by simultaneously choosing the location which could reduce transportation expenses. Since land resource is immobile, while the market located within specific area, the whole economics stakeholder such as household, farm, and firm will always compete for the most strategic spatial environment [10], known as spatial competition. The price elasticity of demand for the agricultural commodity is of crucial importance in determining even the direction of change in rent and the areas in which firms of the industries locate. But there raise questions to the extent of which parcel of land is available or should be taken to gather a spatial equilibrium?. The answers depend on how the urban structure is shaped trough the land use change process. [11] consider that the urban-rural land conversion was a special case of the more general equilibrium location of firms in a von Thünen plain changes in the condition of demand and supply for the commodities they produce.

[12] argue that this theory is appropriate to explaining the loss of agricultural land to non-agricultural uses.

As a human process, land use change is affected by spatial interaction [13]. Gravity model as the most widely used types of spatial interaction model interrelates two basic elements which influencing land use change: scale (mass factors) and distance. The land use change in the urban area shows that it was a dynamic organism constantly in process of evolution, which involve both modification of long-established function and the addition of new functions. Among the forces that determine the urban function, form, and pattern, two groups stand prominently [14]. The first factor is made up centrifugal forces to migrate from the urban center towards, and the second is centripetal force which promotes agglomeration in the center. These two forces usually influence agglomeration trough migration activity. But in broader perspective, [15] argue that its concept is closer to socioeconomic interaction and relate to spatial infrastructure. Empirical result has shows the two forces relation with urban structure dynamics (see [16]–[19] for example). Since the influence of each of these factors would differ depends on the context of the location, therefore it was important to recognize the effect of the two forces on the shape of urban spatial structure.

## 3. The Driving Forces

The first agricultural location and land rent theories were introduced by Ricardo in 1820 and von Thünen in 1826. Since then, agricultural location theory has played an important role in the development of urban land use theory [13]. Thünen developed a model of agricultural land use and its association with land rent as well as production. It was explained that land use function basically will follow a rule that involves certain spatial configurations. In such case, [20] believe that the Thünen theory not only associated with traditional geography and location theory but also includes the basis of the new geography of economic theory. The theory was later reinterpreted by Alonso and generalized its central concept of big rent curves into an urban context known as monocentric urban model, a critical analysis tool of urban structure.

The monocentric urban model explains a unit of land function as a function of distance from the urban center. It was allocated to the entity which has the highest land bid rent. The land rent declined as the distance from the CBD getting farther. Thus, the morphological pattern of land use close to the central business district (CBD) will be occupied by the economic activity which has the ability of capital to pay the land rent. The location of CBD becomes an attraction for employment seekers. These consequences of worker migration to the urban areas. To reduce housing cost, workers would have to live at a distance around the CBD. As a result, the amount of settlement location decays further from the CBD. The boundary between the urban area and the agricultural periphery is the point at which urban bid rents no longer exceed the amount that farmers will pay for land. Population growth and an improved transportation network cause the urban area to expand at the expense of the agricultural hinterland. From that explanation, we could derive several factors which are considered to have a relationship or influence to the spatial competition of agricultural land in the urban area [21].

### *3.1. Distance from city center*

In monocentric urban models, centrality occurs when distance becoming the main factor in determining spatial structures. It was first considered by Thünen which assume that a plain area will consist a lot of cities within the same distance from each other. Thünen also investigating how the distance can influence the agricultural production and land lease pattern. However, Thünen did not explain how to determine the distance [20]. [16] argues that following the monocentric model, residents assumed to commuting to work towards the city center. Therefore, the distance of the CBD holds a very important role in deciding the location of settlements. The progress of the transport system and technology is an important factor that encourages people to live at a distance from the city center. Thus the function of population is determined jointly by the location of the work and other exogenous factors.

A different perspective of distance importance on land use change process is provided by spatial interaction theory which emphasizes on gravity model [13]. [19] argued that the distance between the

residence and the employment location with the market can describe a closeness. The distance function is to hold settlement and business activities agglomerate near to the CBD. But at some tolerable point, living at a distance from their workplace would decrease the profit of commuting. As a result, some workers could change their job location near their settlement, Considering their sub-center in a region of the city, the use of linear distance between the centroid can explain the spatial organization of the urban and the possible impact on the landscape structure on a regional scale [18]. [17] agreed with the idea that the distance is a representation of the location factor. In their analysis, the distance was compared to the cost of transport in order to measure the spatial relationship between cities. Thus the of spatial linkages within the monocentric urban model can affect land use patterns.

### *3.2. Population density*

According to Thünen theory, a city that is within the same distance should have the same size too. However, Thünen didn't explain how to specify the size of the city [20]. In this case the size of the city related to the population density [17]. Based on monocentric urban model, the location of economic activity does not follow a particular dimension. At equilibrium, the particular economic activity will be in the city center. Furthermore, taking into account spatial constraints represented by the cost of transport, the location of settlements can be determined. That is, where the population is an endogenous factor, while the central location of economic activity is an exogenous factor and the density of the population depends on the location of economic activity center.

In monocentric and relatively compact region, urban or peri-urban uses of land have a higher efficiency and lower per-capita consumption of agricultural land [22]. [18] found that an indicator of population density can describe urban expansion and population displacement. The increase in the urban population, originating from the migration process [19]. [16] argues that the measurement location of people and the location where the work is based on the density can be mistaken for causality is hard to describe in a spacious suburban area. But a dense region still considered to indicate a preference in the selection of the location of urbanization. High population density is seen to have negative effects through increased population pressures on scarce resources such as farmland [23]. In densely populated locations, agricultural land spatial competition will be intense. Agricultural land will be reduced productivity due to pollution while increasing production costs due to high rents. As a result, it will be unable to compete and forced to switch its function.

### *3.3. The level of urbanization*

The location of new urban development is guided by a preference over lower density areas, yet in proximity to current urban development [24]. Economic agglomeration generates new growth centers that require manpower. A shortage of available workforce will pull urbanization from rural areas. Monocentric urban model of standard assumption met if residents choose residence that can maximize the function of individual needs with consideration of limited income and location of work [16]. With increasing urbanization, the number of the population will be increased so the need for land becomes larger [12]. [17] argued that population growth is naturally represented by their use of land for housing. As population grows, urban areas in the most central municipalities experience the most significant urban sprawl and loss of farmland. Moreover, the remaining farmland is located in the same areas that already have converted the most. These areas also experience significant pressure for continued land take [25].

Changes in the natural and agricultural land that occurs as a result of urban expansion were influenced by existing forms of spatial organization [18]. The experience in Norway and various countries shows that the main purpose of converting farmland into built-up areas has a strong relation to existing urban settlement areas [25]. [16] argues that employment growth in the city edge will affect the displacement of households out into an area far from the city center. In addition, the consumption of land on monocentric models are more efficient than the polycentric. The issue of land use for urbanization location choice other than to rely on the availability of land will also depend largely on the form of spatial organization. In this case, the type of land available for residential development of the area comes

from agricultural land. It could have a diverse impact on agriculture, whether increase agricultural profitability trough increase in demand or decrease of labor wage for the landless household [23]. But the capacity of regions to accommodate urbanization will depend heavily on remaining agricultural land areas.

### *3.4. Employment opportunity*

Von Thünen theory has evolved no just only associated with agricultural issues, but also industrial agglomeration. According to [20] monocentric structure built by Thünen have in common with the core-periphery model which initiated by Krugman in its principle. However, the Theory of Thünen has broader applications that can be used to explain the principles of centripetal and centrifugal in an urban. That urbanization will happen to the location of industrial competitiveness [17]. Due to the growth of regional and industrial agglomeration requires the growth of urban population as a prerequisite that must be met. To that end, mechanical factors such as employment and accessibility should be available. Employment opportunities which offered by a growth pole would attract the influx of people and industry from other areas which led to the raising demand for land. When such case occurs [12] argue that employment opportunities also contribute to the conversion of agricultural land to nonagricultural use.

In the model of monocentric, employment is assumed only in the city center. In other words, the location of residence of residents affected by the location of the workplace. In the agricultural terms, this is confirmed by [19] which states that the existence of farmers was usually found close to its farm location and market. Many experts consider that the city center has lost its economic base so that the new city grew away from the old town center, which called edge cities. As recursive models that concluded that market activity is determined by the location of settlements, [16] found that the greater the distance from downtown edge Cities, then employment will follow the location of the population, creating urban sprawl. Thus, the effect of the existence of employment in the nonagricultural sector is the driving factor that led to diminishing agricultural land.

## 4. Data and methods

We have identified several factors representing centrifugal and centripetal force of urban evolution, which assumed to have influences to the existence of agricultural land in BMR. These factors include distance and population density [16]–[19], as well as the level of urbanization [16]–[18] and employment opportunities [16], [17], [19]. While distance and employment opportunities were assumed to have a centripetal effect, density and urbanization level is considered to have opposite impact. Due to the data limitation, our object of research is smaller compared to the area of BMR which described in [1], since we exclude the district located in Sumedang Regency.

We construct hypothesis that these four factors have a significant influence in affecting the agricultural land in the metropolitan area of Bandung (Table 1). Each data used here is considered to be a representation, or as an approach to its actual figure. The whole data collected from National Statistics Agency, but since the data on district level available on different census activity, the time span used in this research was also varied. For instance, we use migration data from 2010 population census, agricultural land area data from agriculture census 2013, and employment growth data from 2016 economic census, this could lead to serious bias. Another possible shortage about the data used in this research is the lack of employment information at the district level which could explain employment opportunity. Therefore, we use the growth in the number of non-agricultural firms or business as an approach for determining employment opportunity.

To assess a theoretical model of urban land changes, some research, such as [11] and [12] suggested a test using regression analysis. However, this method has some fundamental assumption that needs to be fulfilled such as the normal distribution of error, appropriated error structure of the variables, independence of variables, and model linearity. Any violation of this assumption would make the forecasts, confidence intervals, and scientific insights yielded by the model inefficient or seriously biased or misleading. A common issue that often occurs in the discussion about location behavior is

spatial dependency. [24] argue that spatial dependence is an important factor to take into account when analyzing land use choices and conversion. Therefore, our method would employ spatial auto regression which incorporates location factors as an extension of multivariate linear regression method. As its properties, we evaluate its spatial autocorrelation condition, both global and locally.

**Table 1.** The description of variable used in linear regression modeling.

| Variable Type | Variable Name | Brief description of data used | Notation |
|---|---|---|---|
| Dependent variable | Agricultural land area ratio | The percentage of agricultural land area compared to the entire land area (%) | Y |
| Independent variable | Distance | Straight centroid distance to the central business district of Bandung (Km) | $X_1$ |
| | Population Density | Number of inhabitants per $Km^2$ (person) | $X_2$ |
| | Urbanization | The percentage of in-migrate residents on years 2005-2010 against the total population in 2010 (%) | $X_3$ |
| | Employment opportunity | Growth in the number of non-agricultural firms/ businesses during the years 2006-2016 (%) | $X_4$ |

## 5. Result and Discussion

Bandung Metropolitan Region (BMR) initially consist of 80 districts, where the average area of each district is 40.95 km2. Each district has approximately 103.000 people of average population in 2015, so that the density per km2 is about 8,213 inhabitants. The highest density located in Bandung City as the core of BMR, which reached nearly twice of its average. The ratio of agricultural land in the core area is only 11.75 %, half of the average area of agricultural land in the overall BMR. The main agricultural location distributes clustered in the eastern and southern area of BMR core (Figure. 1). The darker color of the map indicates a higher proportion of agricultural land area ratio.

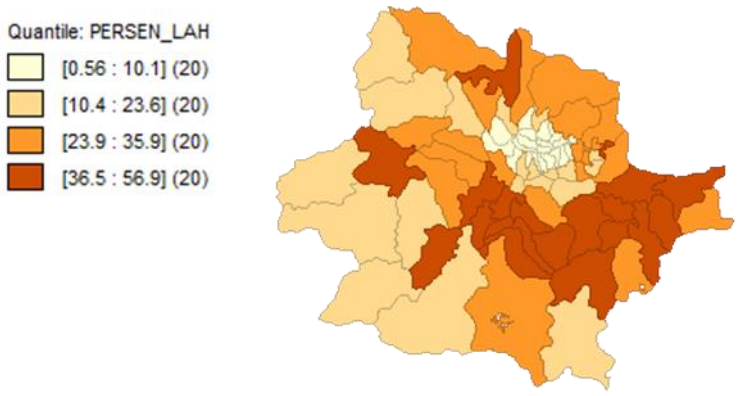


**Figure 1.** Spatial pattern of district's agricultural land area in BMR, 2013 (percent).

To examine the relationship between the influence of centrifugal and centripetal force to the existence of agricultural land, we made multivariate linear regression model from the data and checks its assumption first. Model (1) indicates strong linear relationship between the agricultural land area and the several centrifugal and centripetal forces, shown by a significant probability value of F statistics ($\alpha$ = 0,05). But a partial examination on each variables shows that only density and migration variables to have significant influence on the agricultural land area.

$$Y = 40,98 - 0,14X_1 - 0,001X_2 - 1,22X_3 + 0,052X_4 + \varepsilon \quad (1)$$

t-stat: 9,689* -0,697 -5,897* -3,637* 0,943
*) statistically significant at α = 0,05

The significance negative value confirms that both variables are a competitor for the existence of agricultural land areas. Population density is found to be less sensitive compared to urbanization. It took an increase of 1,000 people density per district to decrease of 1 % agricultural land area ratio ceteris paribus, compared to urbanization rate which only took 1 % of increase to have a 1,22 % of agricultural land area decrease. The whole assumptions are met, but the variation of the force which could explained is only 48,76 percent of adjusted $R^2$ value, which seems to be less favorable. This suggests that there might be other factors which could explain the variation of dependent variables.

**Table 2.** The linear regression's assumption test result.

| Indicators | Value |
|---|---|
| Multicoliearity Index | 7,367* |
| Jarque-Bera probability of normality of error | 0,498* |
| Breusch Pagan probability of heteroskedasticity | 0,146* |
| Koeneker Basset probability of heteroskedasticity | 0,120* |
| Moran's I | 0,004* |
| LM (Lag) | 0,001* |
| Robust LM (lag) | 0,004* |
| LM (error) | 0,020* |
| Robust LM (error) | 0,139 |

*) statistically significant at α = 0,05

With regard to the theory of Thünen and monocentric, the finding of distance and employment opportunities influence were contrary to the centrality assumption. One of the possible explanation of such condition is that the assumption of centrally located market or business district does not fulfilled. The agricultural land area density decay in the southern parts of the area affected by its non-plain topography as well as several areas has been protected or being unfavorable for farming and business activity. This support the argument of leap frog sprawl phenomenon of land development [26], which has divide market and employment concentration to several location within. Thus, both variables are excluded in the spatial auto regression model.

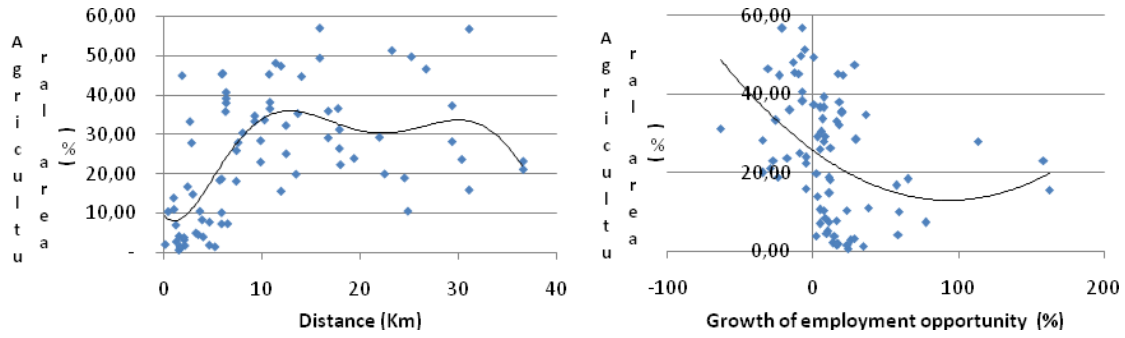


**Figure 2.** Plot of agricultural area compared to (a) distance to city core, and (b) growth of employment.

On assessing spatial autocorrelation, we use Queen contiguity to determine each district's neighborhood due to the nature of the border between districts. The analysis of spatial effect test shows that Moran's Index value is significant. This indicates that there are significant spatial variations, which could verify of visual interpretation of Figure 1. The Lagrange Multiplier (LM) for a lag effect and the

effect of error both showed a significant result. However, examination of Robust (LM) found that a lag effect has statistically significant while the error effect is not. It can be concluded that the spatial model used is the spatial lag as in equation (2).

$$Y = 0,372WY + 24,65 - 0,0007X_2 - 0,69X_3 + \varepsilon \quad (2)$$

t-stat: 3,846* 6,468* -4,443* -2,469*
*) statistically significant at α = 0,05

Model (2) has smaller value of AIC and SC so that it can provide better estimation results than the linear regression. The whole assumption regression has also been met so that the model fit for use. With concluded that the amount of agricultural land at a site in BMR could be determined by population density and degree of urbanization, as well as the amount of agricultural land areas in neighboring locations. Higher population density and urbanization would give negative impact to the existence of agricultural land area, while the presence of the area on neighboring district would make an opposite impact. Nevertheless, population density has less elasticity than the degree of urbanization and neighboring effect. This suggests that should be directed on better arrangement between the location for new settlements and existing agricultural land.

**Table 3.** The goodness of fit model comparison between linear and spatial regression.

| Indicators | Multivariate regression | Spatial regression |
|---|---|---|
| $R^2$ | 51,36 | 59,38 |
| AIC | 620,081 | 608,02 |
| Schwarz criterion | 631,992 | 617,548 |

The arrangement of development location should consider the existence of specific clusters in spatial arrangement. To evaluate local association of agricultural land area clusters, we use local indicators of spatial autocorrelation (LISA) and local G statistics [27], whereas the former is indicating a local cluster of similarity value, and the later shows local cluster of high or low value. The result shows that Bandung city as core area has the low dissimilarity and low value of agricultural land area clusters. High similarity clusters are found in the southeast and southwest area of the core, consist of 11 sub districts. Among those sub districts, there were 8 of them, whose exhibit clusters of high agricultural land area density. Such areas should be seen as a greenbelt, in which land use development caused by migration should be controlled.

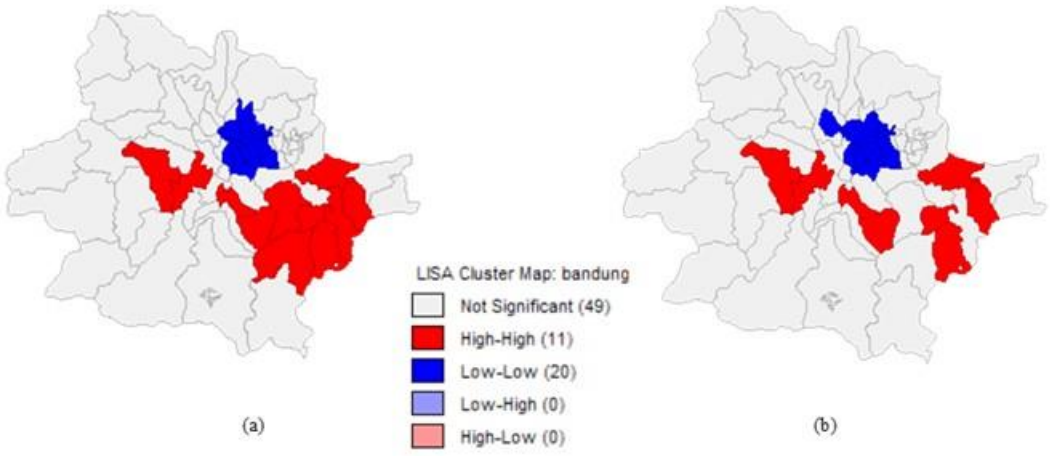


**Figure 3.** Clusters of significance agricultural land area measured by (a) LISA and (b) Local G Statistics

## 6. Conclusion

In urban areas, the existence of agricultural land is the result of spatial competition mainly driven by market mechanism between households, farms, and firms. BMR has suffered massive agricultural land use shift to non-agricultural function. In such case we argue that there were several centripetal and centrifugal force characteristics which has contributed to the spatial competition of agricultural land in BMR. The Characteristics assumed to affect the existence of agricultural land area in a location includes distance and population density, as well as the level of urbanization and employment opportunity. We use linear regression method with the addition of spatial effects to verify of how the whole and each factor influence to the area of agricultural land in the region. Assuming the city of Bandung as center gravity for surround areas, we choose monocentric urban models as analysis base.

The result indicates that spatial competition did occur between population density and degree of urbanization with the existence of agricultural land area in BMR showing by its negative relationships. On the opposite, the existence of agricultural land in neighboring locations has a positive influence to maintain its areas. It is implied that when an agricultural land area in a district is being extinct, their neighboring location will be affected too. The current condition shows that it was still exist some greenbelt areas of agricultural land in the southern parts of BMA core is under heavy pressure from a massive urbanization. Contrary to the argument of failing implementation of counter magnet policy, we believe that BMR has actually entering the early phase of polycentric development. However, it must be admitted that spatial mismatch could not be avoided due to the lack of infrastructure which connect between centers within the region. It was suggested a need for policy that lead to population control and provide regulation of land use within the radius of 5 to 15 km from the city center to maintain agricultural areas. The direction of development should deploy towards rural areas behind the agriculture land concentration, for example Ciwidey or Rongga sub districts. Through these policies is expected that the new growth center not only can reduce the socioeconomic impact, but can bring progress to the region bordering on the southwest. At the same time it needs the support of BMR infrastructure plan which mainly supported development in the south area of the metropolitan region. The planned infrastructures should be more compact due to the physical morphology of the Bandung basin area. The development in the north should be limited as well because there is a tendency to form population centers while there is a hill area [2].

However, this research still contains several drawbacks. Since we use discrete areal units for analysis, a certain modeling outcome can result from the underlying aggregation level and the configuration of zones. It means that the result is only a single manifestation of a range of possible results, the problems known as modifiable areal unit problem (MAUP) [28]. Yet, our model could only explain some variation of which agricultural land exists. We consider that there were still many possible factors which could help to explain the existence better. For the next research, it would be desirable to take road development impact on spatial competition of agricultural land into account. This suggestion came from two perspectives. First, the development of road infrastructure is more likely to be built at agricultural location, since its direct rejection of conversion would be minimum. Secondly, the increase of transportation accessibility and mobility due to the development in road project not only has caused raised wages both in agricultural and non-agricultural employment, but also the decline of agricultural employment working time [29]. This would also have an impact to the decrease in farming activity.

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