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**Conference Paper**

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54th Congress of the European Regional Science Association: "Regional development & globalisation: Best practices", 26-29 August 2014, St. Petersburg, Russia

**Provided in Cooperation with:**

European Regional Science Association (ERSA)

*Suggested Citation:* Miyata, Yuzuru; Shibusawa, Hiroyuki; Permana, Indrawan (2014) : Economic Analysis of Illegal Settlements in Flood Prone Areas in Palangkaraya City in Indonesia: A General Equilibrium Approach, 54th Congress of the European Regional Science Association: "Regional development & globalisation: Best practices", 26-29 August 2014, St. Petersburg, Russia, European Regional Science Association (ERSA), Louvain-la-Neuve

This Version is available at:

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# Economic Analysis of Illegal Settlements in Flood Prone Areas in Palangkaraya City in Indonesia - A General Equilibrium Modeling Approach -

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## Abstract

Since initially stemming from von Thünen's work (1826), bid-rent approach has been rigorously applied to analyze land use configuration. Alonso (1964), Muth (1969), Beckman (1973), Solow (1973), and Fujita (1989) are among the scientists who greatly contributed to forward von Thünen's theory into complexities in urban context. Particularly Fujita (1989) has showed solution of a utility optimizing problem to define the bid-rent function which gives the maximum ability of households to pay land under a fixed utility and at distance from the Central Business District (CBD). The bid rent concept provides richer analysis of the locational choice of households in the city.

Our study considered a small-medium city of a developing country located in tropics where a massive deforestation and river flood significantly jeopardize some areas in the city. It is Palangkaraya city in Central Kalimantan province, Indonesia. There are two types of land classified in the city. One is called normal land where the river flood is not able to inundate while another one is namely flood prone areas. The flood prone areas are occupied by settlements which are mostly illegal. Here illegal settlement refers to those kinds of settlements which were built on parcels with no legal clearance on land ownership including those which were constructed without building permission (Kapoor & Blanc, 2008).

This paper aims to analyze configuration of residential land use pattern in Palangkaraya city, Indonesia applying bid-rent approach which incorporated the expected flood damage rate (EFDR) on household assets. The EFDR is employed to predict the damage by the river flood since flood occurrences are stochastic and such appropriate data on flood occurrences is not available. Previously, Permana and Miyata (2009) showed a partial equilibrium urban economics model, introducing the EFDR. However, we realize that the partial equilibrium model, however, slightly lack of reality since income is assumed to be exogenously given. We develop a general equilibrium model taking into account firms in the Central Business District (CBD), and by incorporating the expected damage rate on household's asset, the new bid rent function and bid max lot size function are obtained. Applying the general equilibrium modeling approach, one can derive the conclusion that the bid rents by low income households get higher than those by high income households in flood prone areas. This is the contrary conclusion being highlighted as compared with that in the traditional urban economics.

JEL Classification: R14, O18, D50

Keywords: *Bid-Rent Approach, General Equilibrium Model, Flood prone Areas, Palangkaraya City, Indonesia*

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## 1. Introduction

Misuse of vulnerable land such as flood prone areas for illegal settlements within city areas is being a common phenomenon mainly in developing countries around the world. For instance, in many towns and cities in Indonesia, along with, the growth of slums within its urban areas in the last three decades, occupations of the flood prone areas by illegal settlements significantly increased. In the last decade, about 29,116.14 hectares of slum areas within Indonesian's cities have been considered as illegal as it inappropriately occupied designated areas (UN Habitat, 2004 and NUSSP, 2007).

Term of illegal settlement refers to a settlement in which housing units have been constructed outside the framework of formal law, including housing units built on land for which the property rights are not clear and built without a building permit. As a kind of slum, illegal settlements are considered as an urban problem. Its existence reflects the failure of local government and national government as well to provide affordable housing provisions for the poor. It is also depicting such indecisive implementation of laws which mainly influenced by political interest and money-oriented interest. Therefore, it is no wonder that in some cases, slum organizers maintain a close connection with some official authorities who guarantee tolerances for the illegal occupation.

Palangkaraya city in Central Kalimantan province, like many other growing cities in Indonesia is facing rapid urbanization. Along with the large increment of its population that exceed limit of developable land availability, then under-developed parcels of land in flood prone areas alongside river bank in urban areas are often occupied for residential use mainly by low income groups. The urbanization contributed urban problems to Palangkaraya city such as the appearance of irregularity in its land use pattern. As the city is urbanized, land and housing become scarce by degrees and become unaffordable particularly for low income groups, therefore some flood prone areas, a kind of wetland near a river stream, at last was misused by the low income group constructing formation of illegal settlements. Without equipped by adequate urban infrastructures and facilities, health problems and environmental problems then easily come into being in the settlements leading to deteriorations.

The theory of land use has been articulated for both agricultural and urban setting. In agricultural context, the work of von Thünen (1826) can be considered as the first effort to explain agricultural land use by employing bid rent approach. And later on by Alonso (1964), it was extended into urban context. This approach has the same essence with indirect utility function approach which has been introduced into urban land use model by Solow (1973). Furthermore Fujita (1989) introduced the concept of bid rent that mimics a von Thünen's model. He showed that by employing the bid rent function approach, urban economics models can be developed more rigorously than previous models, thus providing deep explanations about land use in urban setting.

This study basically follows Fujita's approach (1989). But differently from Fujita who yet considered heterogeneity of land quality, the study considered two types of lands in the city, one is normal land another one is flood prone areas, reflecting more a real conditions of particular cities which located on such river basins. This article aimed at introducing a general equilibrium model considering division of land quality in a city area henceforth theorizing the occupation of flood prone area for illegal settlement.

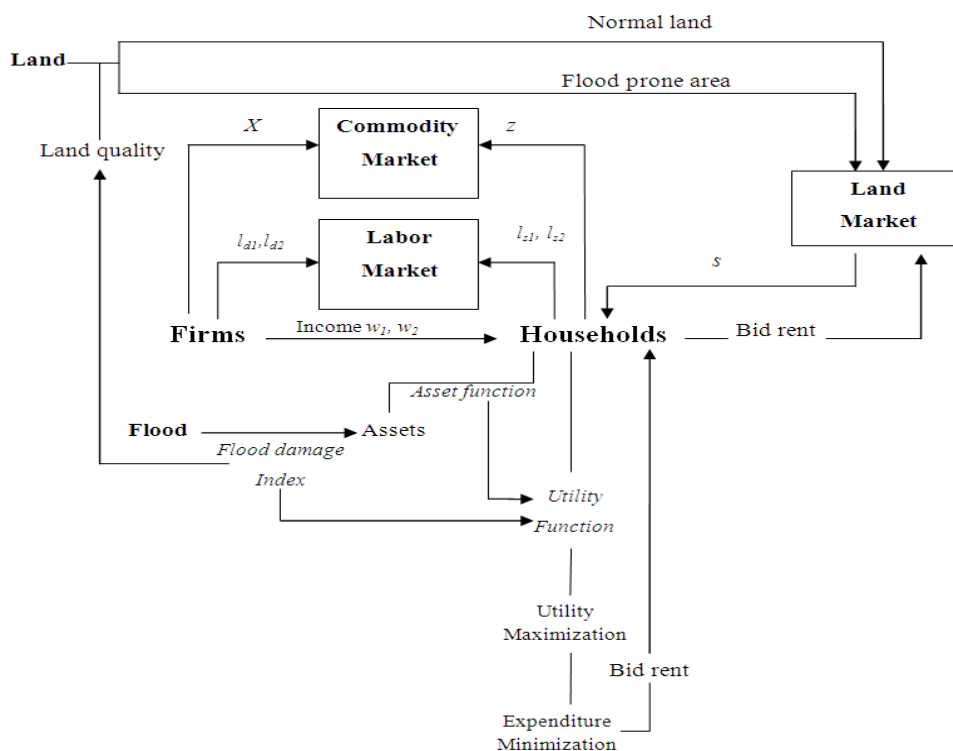
## 2. The Model Development

The general equilibrium model is constructed following the standard urban economics using the bid rent function approach as rigorously extended by Fujita (1989). However, our model can be distinguished from the Fujita's model and other urban economics model in the following manners;

- (1) Our model takes into account land quality in a city area namely normal land and flood prone area. The normal land has no flood risk while the flood prone area faces stochastically flood occurrences. Such this assumption is not discussed yet in the Fujita's model.
- (2) The expected flood damage on household's asset is introduced in our model for estimation of damages caused by stochastic flood events. Moreover, asset of households is by definition introduced here as an increasing function of income. Hence, the expected flood damage and asset function which is defined as an increasing function of income will measure land quality which must be considered in utility maximization problem, yielding different types of bid rent function and bid max lot size function.

The model under the study is based on the following assumptions:

- (1) The study area is assumed to be a monocentric city. All firms are located in the Central Business District (CBD) and are assumed to be homogenous producing single type of commodities.
- (2) There are two types of households in the city. They are high income households and low income households. The households consume goods and land. The commodity is assumed to be the numeraire.
- (3) The city is closed for the high income group but open for the low income group. Thus the number of high income households is fixed while that of low income households is internally determined depending upon the supreme utility level.
- (4) There are two types of land in the city. The normal land is assumed to have no flood risk, while the flood prone area is facing the flood risk with occurrence probability. In addition, location and size of the flood prone areas in the city are fixed.

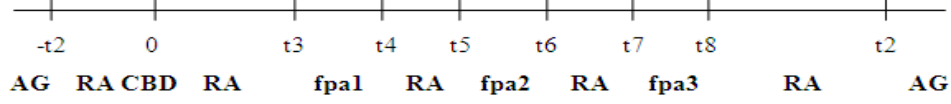


**Figure 1. Structure of the Model**

Figure 1 shows structure of the model. There are three markets and two economic agents in the city. Firms produce goods and supply it to commodity market. Households supply labors to labor market. In labor market, wage of both type households is determined. And by maximizing its ability to pay land, each household determines its residential choice. Moreover, the existence of stochastic floods figured such land quality as well as put potential damage risks to household's assets, assuming the utility function is discounted in the flood prone area.

## 2.1 Linear Shape of the City

The city has a linear shape figuring one dimension side of the city hence reducing complexity. There is a city centre where all firms are located. Left side of the city is figured by normal land and while right side is varied by normal land and flood prone areas. There is agricultural land located just outside of the city area. Hence, the linear shape of the city is graphically presented as follows:



**Figure 2. Linear Shape of the City**

where

CBD : Central Business District

fpa : flood prone area

RA : residential area

AG : agriculture land

-t2 and t2: city boundaries

## 2.2 Firms

All of firms are assumed to be located in the CBD. Each firm produces single type of commodities. Agglomeration economy is necessary to be taken into account. As observed in many cities, strong agglomeration economy works in CBD. Thus many firms want to concentrate in CBD.  $N^\theta$  is introduced to represent the agglomeration economy assuming it is a function the number of high income households. Then the production function of firms may be written as follows:

$$X = N_1^\theta \left\{ \zeta^{\frac{1}{\sigma}} ld_1^{\frac{\sigma-1}{\sigma}} + (1 - \zeta)^{\frac{1}{\sigma}} ld_2^{\frac{\sigma-1}{\sigma}} \right\}^{\frac{\sigma}{\sigma-1}} \quad 0 < \sigma < 1 \quad (1)$$

where

$X$ : output of a firm

$N_j$ : number of high income households

$ld_j$ : demand for skilled labor

$ld_2$ : demand for unskilled labor

$\zeta$ : share parameter

$\sigma$ : elasticity parameter

$\theta$ : elasticity parameter

Each firm is a price taker for commodities and production factors. Due to the linear homogeneity of degree one in each firm's technology, the equilibrium profit in each firm becomes zero. To obtain the conditional demand for labors in a firm, we consider the cost function.

$$\min C = w_1 ld_1 + w_2 ld_2 \quad (2)$$

subject to

$$X = f(ld_1, ld_2) \quad (3)$$

Then the conditional demands for labors in each type of households are obtained as follows

$$ld_1 = \frac{\zeta X}{w_1^\sigma N_1^\theta (\zeta w_1^{1-\sigma} + (1 - \zeta) w_2^{1-\sigma})^{\frac{\sigma}{\sigma-1}}} \quad (4)$$

$$ld_2 = \frac{(1 - \zeta) X}{w_2^\sigma N_1^\theta (\zeta w_1^{1-\sigma} + (1 - \zeta) w_2^{1-\sigma})^{\frac{\sigma}{\sigma-1}}} \quad (5)$$

Both types of the households supply inelastically labors  $ld_1$ ,  $ld_2$  to the representative firm, obtaining income  $w_1$ ,  $w_2$ . Here the representative high-skilled labor of the high-income group earn relatively higher wage rate than that the representative low-skilled labors of the low-income group. Then the inequality is written as follows:

$$w_1 > w_2 \quad (6)$$

### 2.3 Households

As the city area is facing frequent flood occurrences, we consider flood damage to asset of each type of the households. The amount and value of the assets may depend on income. The asset possibly has value twofold or more from income depending on the kind of the assets. Therefore the asset function can be considered as an increasing function of income. We define asset function as follows:

$$A_i(\mathbf{t}) \equiv (w_i)^\gamma \quad (\gamma > 1) \quad (7)$$

where:

$w_i$  : household's income

$\gamma$  : elasticity parameter

Since floods occur stochastically, hence to avoid such possible bias instead of using past-recorded flood occurrences as a data source, we estimate flood damage on household's asset using index which express damage rate by stochastic flood occurrences. Then the expected flood damage rate on household's asset is introduced as follows:

$$c(\mathbf{t}) \equiv \int_0^\infty P(Q(\mathbf{t}))c(Q(\mathbf{t}))dQ(\mathbf{t}) \quad (8)$$

where

$c(\mathbf{t})$  : the expected damage rate on household asset at location  $\mathbf{t}$

$P(Q(\mathbf{t}))$  : probability density function of flood volume  $Q(\mathbf{t})$

$c(Q(\mathbf{t}))$  : damage rate on household asset when the flood volume is  $Q(\mathbf{t})$

We incorporate asset function and the expected damage rate on household assets into the utility functions in the two types of the households. It is assumed that each household would feel unsecured if it lives in a flood prone area because of its expectation on frequent floods. So the utility function is assumed to be discounted in a flood prone area therefore the expected flood damage is not included in budget constraint. Then, the household utility function at location  $\mathbf{t}$  is assumed to be expressed as follows:

$$u_i(z_i(\mathbf{t}), s_{Hi}(\mathbf{t})) \equiv \frac{z_i(\mathbf{t})^{\alpha_i} s_{Hi}(\mathbf{t})^{\beta_i}}{1 + c(\mathbf{t})A_i(\mathbf{t})} \quad (9)$$

$(\alpha_i + \beta_i = 1)$  for

$\mathbf{t} \notin [t_3, t_4] \cup [t_5, t_6] \cup [t_7, t_8]$  and  $\mathbf{t} \in [t_3, t_4] \cup [t_5, t_6] \cup [t_7, t_8]$

where

$i = 1$  for a high income household and  $i = 2$  for a low income household  $u_i(z_i(\mathbf{x}), s_{Hi}(\mathbf{x}))$  : household utility function at location  $\mathbf{t}$

$z_i(\mathbf{t})$  : household consumption at location  $\mathbf{t}$

$s_{Hi}(\mathbf{t})$  : household's land at location  $\mathbf{t}$

$c(\mathbf{t})$  : damage rate by flood  $c(\mathbf{t}) = 0$  on the normal land and  $0 < c(\mathbf{t}) < 1$  in the flood prone area

$\alpha_i$  and  $\beta_i$  : elasticity parameters in the utility function

$A_i(\mathbf{t})$  : household asset at location  $\mathbf{t}$

Both types of the households endows available working time  $l_{s1}, l_{s2}$  to the firms obtaining income of  $w_1, w_2$ . In household locational equilibrium, the household utility level takes the same value,  $u_i^*$  being irrespective of household residential place. Therefore the household bid rent function is specified as follows:

$$r_{Hi}(\mathbf{t}) = \max \frac{w_i - z_i(\mathbf{t}) - kt}{s_{Hi}(\mathbf{t})} \quad (10)$$

subject to

$$u_i(\mathbf{t}) = u_i^* \quad (11)$$

where

$r_{Hi}(\mathbf{t})$  : household's bid rent at location  $\mathbf{t}$

$i = 1$  for a high income household and  $i = 2$  for a low income household

$w_i$  : household income of each type of household

$s_{Hi}(\mathbf{t})$  : household's land at location  $\mathbf{t}$

$u_i^*$  : household's utility level

$k$  : cost of transportation

$t$  : distance from the CBD

To solve the maximization problem (10) and (11), we consider the following expenditure function.

$$E_i(\mathbf{t}) = \min_{z_i, s_{Hi}} z_i(\mathbf{t}) + r_{Hi}(\mathbf{t})s_{Hi}(\mathbf{t}) \quad (12)$$

subject to

$$u_i^* = \frac{z_i^{\alpha_i}(\mathbf{t})s_{Hi}^{\beta_i}(\mathbf{t})}{1 + c(\mathbf{t})(w_i)^\gamma} \quad (13)$$

Then the compensated demand function for consumption and land are obtained as follows:

$$z_i(\mathbf{t}) = (1 + c(\mathbf{t})w_i^\gamma) \left( \frac{\alpha_i}{\beta_i} \right)^{\beta_i} r_{Hi}^{\beta_i}(\mathbf{t})u_i^* \quad (14)$$

$$s_{Hi}(\mathbf{t}) = (1 + c(\mathbf{t})w_i^\gamma) \left( \frac{\beta_i}{\alpha_i} \right)^{\alpha_i} \left( \frac{1}{r_{Hi}(\mathbf{t})} \right)^{\alpha_i} u_i^* \quad (15)$$

Therefore the expenditure function is solved as follows:

$$E_i(\mathbf{t}) = (1 + c(\mathbf{t})w_i^\gamma) \left( \frac{\alpha_i}{\beta_i} \right)^{\beta_i} r_{Hi}^{\beta_i}(\mathbf{t})u_i^* + r_{Hi}(\mathbf{t}) (1 + c(\mathbf{t})w_i^\gamma) \left( \frac{\beta_i}{\alpha_i} \right)^{\alpha_i} \left( \frac{1}{r_{Hi}(\mathbf{t})} \right)^{\alpha_i} u_i^* \quad (16)$$

This expenditure function must be equal to the household income at location  $\mathbf{t}$ , yielding the household bid rent function.

$$r_{Hi}(\mathbf{t}) = \beta_i \alpha_i^{\frac{\alpha_i}{\beta_i}} \left[ \frac{w_i - kt}{[1 + c(\mathbf{t})w_i^\gamma]u_i^*} \right]^{\frac{1}{\beta_i}} \quad (17)$$

Substitute equation (17) into equations (14) and (15), then we obtain the demand for goods and the bid max lot size which are as follows:

$$z_i(\mathbf{t}) = \alpha_i (w_i - kt) \quad (18)$$

$$s_{Hi}(\mathbf{t}) = \left[ \frac{1}{\alpha_i (w_i - kt)} \right]^{\frac{\alpha_i}{\beta_i}} [1 + c(\mathbf{t})w_i^\gamma]^{\frac{1}{\beta_i}} u_i^* \frac{1}{\beta_i} \quad (19)$$

As income of the high-income household is relatively higher than income of the low-income household, as shown in inequality (6), the model suggests that in the normal land where no flood risk the high income household can offer a higher bid rent than that by the low income household under appropriate elasticity parameters, hence as a result the normal land would be resided by high income households. While conversely, in the flood prone areas,

the bid rent by the high income household gets lower than that by the low income household, hence as a result the flood prone areas are occupied by low income households.

## 2.4 City Boundary

The city boundary is determined by the intersection between the slope of the bid rent by the high income household and the constant line of agricultural land rent. This is expressed by equation (20) implying the fringe areas are populated by high income households.

$$r_{H1}(-t_2) = rA \quad (20)$$

Thus the following equation is obtained as follows:

$$\beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} \left[ \frac{w_1 - kt}{[1 + c(\mathbf{t})w_1^\gamma] u_1^*} \right]^{\frac{1}{\beta_1}} = rA \quad (21)$$

Solving  $t$  in equation (21), we determine the city boundaries in the left and right hand sides in the city as follows:

$$-t_2 = \frac{1}{k} \left\{ w_1 - \left( \frac{rA}{\beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}}} \right)^{\beta_1} \right\} [1 + c(\mathbf{t})w_1^\gamma] u_1^* \quad (22)$$

$$t_2 = \frac{1}{k} \left\{ w_1 - \left( \frac{rA}{\beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}}} \right)^{\beta_1} \right\} [1 + c(\mathbf{t})w_1^\gamma] u_1^* \quad (23)$$

## 2.5 The Number of Population

The number of population in the normal land is determined as follows:

$$N_1 = \int_{-t_2}^0 \frac{1}{s_{H1}} dt + \int_0^{t_3} \frac{1}{s_{H1}} dt + \int_{t_4}^{t_5} \frac{1}{s_{H1}} dt + \int_{t_6}^{t_7} \frac{1}{s_{H1}} dt + \int_{t_8}^{t_2} \frac{1}{s_{H1}} dt \quad (24)$$

Each term in equation (24) is calculated as follows:

$$\begin{aligned} \int_{-t_2}^0 \frac{dt}{s_{H1}} &= \int_0^{t_2} \frac{dt}{s_{H1}} = \int_0^{t_2} (\alpha_1(w_1 - kt))^{\frac{\alpha_1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} u_1^{*-\frac{1}{\beta_1}} dt \\ &= \frac{1}{k} \beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} w_1^{\frac{1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} u_1^{*-\frac{1}{\beta_1}} - \frac{rA}{k} \end{aligned} \quad (25)$$

$$\begin{aligned} \int_0^{t_3} \frac{dt}{s_{H1}} &= \int_0^{t_3} (\alpha_1(w_1 - kt))^{\frac{\alpha_1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} u_1^{*-\frac{1}{\beta_1}} dt \\ &= \frac{1}{k} \beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} w_1^{\frac{1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} u_1^{*-\frac{1}{\beta_1}} - \frac{1}{k} \beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} (w_1 - kt_3)^{\frac{1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} u_1^{*-\frac{1}{\beta_1}} \end{aligned} \quad (26)$$

$$\begin{aligned} \int_{t_4}^{t_5} \frac{dt}{s_{H1}} &= \int_{t_4}^{t_5} (\alpha_1(w_1 - kt))^{\frac{\alpha_1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} u_1^{*-\frac{1}{\beta_1}} dt \\ &= \frac{1}{k} \beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} (w_1 - kt_4)^{\frac{1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} u_1^{*-\frac{1}{\beta_1}} - \frac{1}{k} \beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} (w_1 - kt_5)^{\frac{1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} u_1^{*-\frac{1}{\beta_1}} \end{aligned} \quad (27)$$

$$\int_{t_6}^{t_7} \frac{dt}{s_{H1}} = \int_{t_6}^{t_7} (\alpha_1(w_1 - kt))^{\frac{\alpha_1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} u_1^{*-\frac{1}{\beta_1}} dt$$



$$= \frac{1}{k} \beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} (w_1 - kt_6)^{\frac{1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} u_1^{*-\frac{1}{\beta_1}} - \frac{1}{k} \beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} (w_1 - kt_7)^{\frac{1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} u_1^{*-\frac{1}{\beta_1}} \quad (28)$$

$$\int_{t_8}^{t_2} \frac{dt}{s_{H1}} = \int_{t_8}^{t_2} (\alpha_1 (w_1 - kt))^{\frac{\alpha_1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} u_1^{*-\frac{1}{\beta_1}} dt$$

$$= \frac{1}{k} \beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} (w_1 - kt_8)^{\frac{1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} u_1^{*-\frac{1}{\beta_1}} - \frac{rA}{k} \quad (29)$$

Substituting equations (25), (26), (27), (28) and (29) into equations (24), the number of high income households in the city is obtained as follows:

$$N_1 = \frac{2}{k} \beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} w_1^{\frac{1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} u_1^{*-\frac{1}{\beta_1}} - \frac{1}{k} \beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} (w_1 - kt_3)^{\frac{1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} u_1^{*-\frac{1}{\beta_1}}$$

$$+ \frac{1}{k} \beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} (w_1 - kt_4)^{\frac{1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} u_1^{*-\frac{1}{\beta_1}} - \frac{1}{k} \beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} (w_1 - kt_5)^{\frac{1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} u_1^{*-\frac{1}{\beta_1}}$$

$$+ \frac{1}{k} \beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} (w_1 - kt_6)^{\frac{1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} u_1^{*-\frac{1}{\beta_1}} - \frac{1}{k} \beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} (w_1 - kt_7)^{\frac{1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} u_1^{*-\frac{1}{\beta_1}}$$

$$+ \frac{1}{k} \beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} (w_1 - kt_8)^{\frac{1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} u_1^{*-\frac{1}{\beta_1}} - \frac{2rA}{k} \quad (30)$$

The equilibrium utility level in a high income household is calculated as follows:

$$u_1^* = \left\{ \frac{2}{k} \beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} w_1^{\frac{1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} - \frac{1}{k} \beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} (w_1 - kt_3)^{\frac{1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} \right.$$

$$+ \frac{1}{k} \beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} (w_1 - kt_4)^{\frac{1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} - \frac{1}{k} \beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} (w_1 - kt_5)^{\frac{1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}}$$

$$+ \frac{1}{k} \beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} (w_1 - kt_6)^{\frac{1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} - \frac{1}{k} \beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} (w_1 - kt_7)^{\frac{1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}}$$

$$\left. + \frac{1}{k} \alpha_1^{\frac{\alpha_1}{\beta_1}} \beta_1 (y_1 - kt_8)^{\frac{1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} \right\}^{\beta_1} \left( N_1 + \frac{2rA}{k} \right)^{-\beta_1} \quad (31)$$

The number of the population in the flood prone areas is determined as follows:

$$N_2 = \int_{t_3}^{t_4} \frac{dt}{s_{H2}} + \int_{t_5}^{t_6} \frac{dt}{s_{H2}} + \int_{t_7}^{t_8} \frac{dt}{s_{H2}} \quad (32)$$

where  $N_2$ : Number of low income households

Each term in equation (32) is calculated as follows:

$$\int_{t_3}^{t_4} \frac{dt}{s_{H2}} = \int_{t_3}^{t_4} (\alpha_2 (w_2 - kt))^{\frac{\alpha_2}{\beta_2}} [1 + cw_2^\gamma]^{\frac{1}{\beta_2}} u_2^{*-\frac{1}{\beta_2}} dt$$

$$= \frac{1}{k} \beta_2 \alpha_2^{\frac{\alpha_2}{\beta_2}} (w_2 - kt_3)^{\frac{1}{\beta_2}} [1 + cw_2^\gamma]^{\frac{1}{\beta_2}} u_2^{*-\frac{1}{\beta_2}} - \frac{1}{k} \beta_2 \alpha_2^{\frac{\alpha_2}{\beta_2}} (w_2 - kt_4)^{\frac{1}{\beta_2}} [1 + cw_2^\gamma]^{\frac{1}{\beta_2}} u_2^{*-\frac{1}{\beta_2}} \quad (33)$$

$$\int_{t_5}^{t_6} \frac{dt}{s_{H2}} = \int_{t_5}^{t_6} (\alpha_2 (w_2 - kt))^{\frac{\alpha_2}{\beta_2}} [1 + cw_2^\gamma]^{\frac{1}{\beta_2}} u_2^{*-\frac{1}{\beta_2}} dt$$

$$= \frac{1}{k} \beta_2 \alpha_2^{\frac{\alpha_2}{\beta_2}} (w_2 - kt_5)^{\frac{1}{\beta_2}} [1 + cw_2^\gamma]^{-\frac{1}{\beta_2}} u_2^{*-\frac{1}{\beta_2}} - \frac{1}{k} \beta_2 \alpha_2^{\frac{\alpha_2}{\beta_2}} (w_2 - kt_6)^{\frac{1}{\beta_2}} [1 + cw_2^\gamma]^{-\frac{1}{\beta_2}} u_2^{*-\frac{1}{\beta_2}} \quad (34)$$

$$\int_{t_7}^{t_8} \frac{dt}{s_{H2}} = \int_{t_7}^{t_8} (\alpha_2(w_2 - kt))^{\frac{\alpha_2}{\beta_2}} [1 + cw_2^\gamma]^{-\frac{1}{\beta_2}} u_2^{*-\frac{1}{\beta_2}} dt$$

$$= \frac{1}{k} \beta_2 \alpha_2^{\frac{\alpha_2}{\beta_2}} (w_2 - kt_7)^{\frac{1}{\beta_2}} [1 + cw_2^\gamma]^{-\frac{1}{\beta_2}} u_2^{*-\frac{1}{\beta_2}} - \frac{1}{k} \beta_2 \alpha_2^{\frac{\alpha_2}{\beta_2}} (w_2 - kt_8)^{\frac{1}{\beta_2}} [1 + cw_2^\gamma]^{-\frac{1}{\beta_2}} u_2^{*-\frac{1}{\beta_2}} \quad (35)$$

Substituting equations (33), (34) and (35) into equation (32), the number of low income households in the flood prone areas is calculated as follows:

$$N_2 = \frac{1}{k} \beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} (w_1 - kt_3)^{\frac{1}{\beta_1}} [1 + cw_1^\gamma]^{-\frac{1}{\beta_1}} u_1^{*-\frac{1}{\beta_1}} - \frac{1}{k} \beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} (w_1 - kt_4)^{\frac{1}{\beta_1}} [1 + cw_1^\gamma]^{-\frac{1}{\beta_1}} u_1^{*-\frac{1}{\beta_1}}$$

$$+ \frac{1}{k} \beta_2 \alpha_2^{\frac{\alpha_2}{\beta_2}} (w_2 - kt_5)^{\frac{1}{\beta_2}} [1 + cw_2^\gamma]^{-\frac{1}{\beta_2}} u_2^{*-\frac{1}{\beta_2}} - \frac{1}{k} \beta_2 \alpha_2^{\frac{\alpha_2}{\beta_2}} (w_2 - kt_6)^{\frac{1}{\beta_2}} [1 + cw_2^\gamma]^{-\frac{1}{\beta_2}} u_2^{*-\frac{1}{\beta_2}}$$

$$+ \frac{1}{k} \beta_2 \alpha_2^{\frac{\alpha_2}{\beta_2}} (w_2 - kt_7)^{\frac{1}{\beta_2}} [1 + cw_2^\gamma]^{-\frac{1}{\beta_2}} u_2^{*-\frac{1}{\beta_2}} - \frac{1}{k} \beta_2 \alpha_2^{\frac{\alpha_2}{\beta_2}} (w_2 - kt_8)^{\frac{1}{\beta_2}} [1 + cw_2^\gamma]^{-\frac{1}{\beta_2}} u_2^{*-\frac{1}{\beta_2}} \quad (36)$$

## 2.6 Market Equilibrium Conditions

There are three markets in this model namely commodity market, labor market, and land market. Then the equilibrium condition for the three markets respectively are described as equation (37) to (62)

### 2.6.1 Commodity markets

Total output by the firms which is equal to total consumption by the households is determined as follows:

$$X = \int_{-t_2}^0 \frac{z_1}{s_{H1}} dt + \int_0^{t_3} \frac{z_1}{s_{H1}} dt + \int_{t_4}^{t_5} \frac{z_1}{s_{H1}} dt + \int_t^{t_7} \frac{z_1}{s_{H1}} dt + \int_{t_8}^{t_2} \frac{z_1}{s_{H1}} dt + \int_{t_3}^{t_4} \frac{z_2}{s_{H2}} dt + \int_{t_5}^{t_6} \frac{z_2}{s_{H2}} dt + \int_{t_7}^{t_8} \frac{z_2}{s_{H2}} dt$$

$$+ \int_{-t_2}^0 \frac{kt}{s_{H1}} dt + \int_0^{t_3} \frac{kt}{s_{H1}} dt + \int_{t_4}^{t_5} \frac{kt}{s_{H1}} dt + \int_t^{t_7} \frac{kt}{s_{H1}} dt + \int_{t_8}^{t_2} \frac{kt}{s_{H1}} dt + \int_{t_3}^{t_4} \frac{kt}{s_{H2}} dt + \int_{t_5}^{t_6} \frac{kt}{s_{H2}} dt + \int_{t_7}^{t_8} \frac{kt}{s_{H2}} dt$$

$$+ \int_{-t_2}^0 \frac{r_{H1}}{s_{H1}} dt + \int_0^{t_3} \frac{r_{H1}}{s_{H1}} dt + \int_{t_4}^{t_5} \frac{r_{H1}}{s_{H1}} dt + \int_{t_6}^{t_7} \frac{r_{H1}}{s_{H1}} dt + \int_{t_8}^{t_2} \frac{r_{H1}}{s_{H1}} dt + \int_{t_3}^{t_4} \frac{r_{H2}}{s_{H2}} dt + \int_{t_5}^{t_6} \frac{r_{H2}}{s_{H2}} dt + \int_{t_7}^{t_8} \frac{r_{H2}}{s_{H2}} dt \quad (37)$$

Each term in equation (37) is calculated as follows:

$$\int_{-t_2}^0 \frac{z_1}{s_{H1}} dt = \int_0^{t_2} \frac{z_1}{s_{H1}} dt = \int_0^{t_2} \alpha_1 (w_1 - kt) (\alpha_1 (w_1 - kt))^{\frac{\alpha_1}{\beta_1}} [1 + cw_1^\gamma]^{-\frac{1}{\beta_1}} u_1^{*-\frac{1}{\beta_1}} dt \quad (38)$$

$$= -\frac{\beta_1 \alpha_1^{\frac{1}{\beta_1}}}{k(2\beta_1 + \alpha_1)} \left( \frac{rA}{\beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}}} \right)^{2\beta_1 + \alpha_1} \left[ [1 + c(t)w_1^\gamma] u_1^* + \frac{1}{k(2\beta_1 + \alpha_1)} \alpha_1^{\frac{1}{\beta_1}} \beta_1 w_1^{\frac{2\beta_1 + \alpha_1}{\beta_1}} [1 + c(t)w_1^\gamma]^{-\frac{1}{\beta_1}} u_1^{*-\frac{1}{\beta_1}} \right] \quad (39)$$

$$\int_0^{t_3} \frac{z_1}{s_{H1}} dt = -\frac{\beta_1}{\alpha_1 k(2\beta_1 + \alpha_1)} (\alpha_1 (w_1 - kt_3))^{\frac{2\beta_1 + \alpha_1}{\beta_1}} [1 + cw_1^\gamma]^{-\frac{1}{\beta_1}} u_1^{*-\frac{1}{\beta_1}} + \frac{\beta_1}{k(2\beta_1 + \alpha_1)} \alpha_1^{\frac{1}{\beta_1}} w_1^{\frac{2\beta_1 + \alpha_1}{\beta_1}} [1 + cw_1^\gamma]^{-\frac{1}{\beta_1}} u_1^{*-\frac{1}{\beta_1}} \quad (40)$$

$$\int_{t_4}^{t_5} \frac{z_1}{s_{H1}} dt = -\frac{\beta_1}{\alpha_1 k(2\beta_1 + \alpha_1)} (\alpha_1 (w_1 - kt_5))^{\frac{2\beta_1 + \alpha_1}{\beta_1}} [1 + cw_1^\gamma]^{-\frac{1}{\beta_1}} u_1^{*-\frac{1}{\beta_1}} + \frac{\beta_1}{\alpha_1 k(2\beta_1 + \alpha_1)} (\alpha_1 (w_1 - kt_4))^{\frac{2\beta_1 + \alpha_1}{\beta_1}} [1 + cw_1^\gamma]^{-\frac{1}{\beta_1}} u_1^{*-\frac{1}{\beta_1}} \quad (41)$$

$$\int_{t_6}^{t_7} \frac{z_1}{s_{H1}} dt = -\frac{\beta_1}{\alpha_1 k(2\beta_1 + \alpha_1)} (\alpha_1 (w_1 - kt_7))^{\frac{2\beta_1 + \alpha_1}{\beta_1}} [1 + cw_1^\gamma]^{-\frac{1}{\beta_1}} u_1^{*-\frac{1}{\beta_1}} + \frac{\beta_1}{\alpha_1 k(2\beta_1 + \alpha_1)} (\alpha_1 (w_1 - kt_6))^{\frac{2\beta_1 + \alpha_1}{\beta_1}} [1 + cw_1^\gamma]^{-\frac{1}{\beta_1}} u_1^{*-\frac{1}{\beta_1}} \quad (42)$$





$$\begin{aligned}
& -\beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} (w_1 - kt_5)^{\frac{1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} u_1^{*\frac{1}{\beta_1}} + \beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} (w_1 - kt_6)^{\frac{1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} u_1^{*\frac{1}{\beta_1}} \\
& -\beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} (w_1 - kt_7)^{\frac{1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} u_1^{*\frac{1}{\beta_1}} + \beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} (w_1 - kt_8)^{\frac{1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} u_1^{*\frac{1}{\beta_1}} - \frac{rA}{k} \\
& + \beta_2 \alpha_2^{\frac{\alpha_2}{\beta_2}} (w_2 - kt_3)^{\frac{1}{\beta_2}} [1 + cw_2^\gamma]^{\frac{1}{\beta_2}} u_2^{*\frac{1}{\beta_2}} - \beta_2 \alpha_2^{\frac{\alpha_2}{\beta_2}} (w_2 - kt_4)^{\frac{1}{\beta_2}} [1 + cw_2^\gamma]^{\frac{1}{\beta_2}} u_2^{*\frac{1}{\beta_2}} \\
& + \beta_2 \alpha_2^{\frac{\alpha_2}{\beta_2}} (w_2 - kt_5)^{\frac{1}{\beta_2}} [1 + cw_2^\gamma]^{\frac{1}{\beta_2}} u_2^{*\frac{1}{\beta_2}} - \beta_2 \alpha_2^{\frac{\alpha_2}{\beta_2}} (w_2 - kt_6)^{\frac{1}{\beta_2}} [1 + cw_2^\gamma]^{\frac{1}{\beta_2}} u_2^{*\frac{1}{\beta_2}} \\
& + \beta_2 \alpha_2^{\frac{\alpha_2}{\beta_2}} (w_2 - kt_7)^{\frac{1}{\beta_2}} [1 + cw_2^\gamma]^{\frac{1}{\beta_2}} u_2^{*\frac{1}{\beta_2}} - \beta_2 \alpha_2^{\frac{\alpha_2}{\beta_2}} (w_2 - kt_8)^{\frac{1}{\beta_2}} [1 + cw_2^\gamma]^{\frac{1}{\beta_2}} u_2^{*\frac{1}{\beta_2}} \\
& - \frac{\beta_1}{k(2\beta_1 + \alpha_1)} \beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} \left( \frac{rA}{\beta_1 \alpha_1^{\beta_1}} \right)^{2\beta_1 + \alpha_1} [1 + cw_1^\gamma] u_1^* + \frac{\beta_1}{k(2\beta_1 + \alpha_1)} \beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} w_1^{\frac{2\beta_1 + \alpha_1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} u_1^{*\frac{1}{\beta_1}} \\
& - \frac{\beta_1}{k(2\beta_1 + \alpha_1)} \beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} (w_1 - kt_3)^{\frac{2\beta_1 + \alpha_1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} u_1^{*\frac{1}{\beta_1}} + \frac{\beta_1}{k(2\beta_1 + \alpha_1)} \beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} w_1^{\frac{2\beta_1 + \alpha_1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} u_1^{*\frac{1}{\beta_1}} \\
& - \frac{\beta_1}{k(2\beta_1 + \alpha_1)} \beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} (w_1 - kt_5)^{\frac{2\beta_1 + \alpha_1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} u_1^{*\frac{1}{\beta_1}} + \frac{\beta_1}{k(2\beta_1 + \alpha_1)} \beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} (w_1 - kt_4)^{\frac{2\beta_1 + \alpha_1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} u_1^{*\frac{1}{\beta_1}} \\
& - \frac{\beta_1}{k(2\beta_1 + \alpha_1)} \beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} (w_1 - kt_7)^{\frac{2\beta_1 + \alpha_1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} u_1^{*\frac{1}{\beta_1}} + \frac{\beta_1}{k(2\beta_1 + \alpha_1)} \beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} (w_1 - kt_6)^{\frac{2\beta_1 + \alpha_1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} u_1^{*\frac{1}{\beta_1}} \\
& - \frac{\beta_1}{k(2\beta_1 + \alpha_1)} \beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} \left( \frac{rA}{\beta_1 \alpha_1^{\beta_1}} \right)^{2\beta_1 + \alpha_1} [1 + cw_1^\gamma] u_1^* + \frac{\beta_1}{k(2\beta_1 + \alpha_1)} \beta_1 \alpha_1^{\frac{\alpha_1}{\beta_1}} (w_1 - kt_8)^{\frac{2\beta_1 + \alpha_1}{\beta_1}} [1 + cw_1^\gamma]^{\frac{1}{\beta_1}} u_1^{*\frac{1}{\beta_1}} \\
& - \frac{\beta_2}{k(2\beta_2 + \alpha_2)} \beta_2 \alpha_2^{\frac{\alpha_2}{\beta_2}} (w_2 - kt_4)^{\frac{2\beta_2 + \alpha_2}{\beta_2}} [1 + cw_2^\gamma]^{\frac{1}{\beta_2}} u_2^{*\frac{1}{\beta_2}} + \frac{\beta_2}{k(2\beta_2 + \alpha_2)} \beta_2 \alpha_2^{\frac{\alpha_2}{\beta_2}} (w_2 - kt_3)^{\frac{2\beta_2 + \alpha_2}{\beta_2}} [1 + cw_2^\gamma]^{\frac{1}{\beta_2}} u_2^{*\frac{1}{\beta_2}} \\
& - \frac{\beta_2}{k(2\beta_2 + \alpha_2)} \beta_2 \alpha_2^{\frac{\alpha_2}{\beta_2}} (w_2 - kt_6)^{\frac{2\beta_2 + \alpha_2}{\beta_2}} [1 + cw_2^\gamma]^{\frac{1}{\beta_2}} u_2^{*\frac{1}{\beta_2}} + \frac{\beta_2}{k(2\beta_2 + \alpha_2)} \beta_2 \alpha_2^{\frac{\alpha_2}{\beta_2}} (w_2 - kt_5)^{\frac{2\beta_2 + \alpha_2}{\beta_2}} [1 + cw_2^\gamma]^{\frac{1}{\beta_2}} u_2^{*\frac{1}{\beta_2}} \\
& - \frac{\beta_2}{k(2\beta_2 + \alpha_2)} \beta_2 \alpha_2^{\frac{\alpha_2}{\beta_2}} (w_2 - kt_8)^{\frac{2\beta_2 + \alpha_2}{\beta_2}} [1 + cw_2^\gamma]^{\frac{1}{\beta_2}} u_2^{*\frac{1}{\beta_2}} + \frac{\beta_2}{k(2\beta_2 + \alpha_2)} \beta_2 \alpha_2^{\frac{\alpha_2}{\beta_2}} (w_2 - kt_7)^{\frac{2\beta_2 + \alpha_2}{\beta_2}} [1 + cw_2^\gamma]^{\frac{1}{\beta_2}} u_2^{*\frac{1}{\beta_2}} \quad (63)
\end{aligned}$$

## 2.6.2 Labor market

Labor supply of each type of households equals to number of each type of households. Then equilibrium condition in the labor market is reached when labor supply from each type of households equals to labor demand. Then the equalities are written as follows:

$$ls_1 = ld_1 = N_1 \quad (64)$$

$$ls_2 = ld_2 = N_2 \quad (65)$$

## 2.6.3 Land market

Denoting the agriculture land, which is an exogenous variable, by the  $rA$ , the market rent function over the city in equilibrium,  $r(\mathbf{t})$ , is denoted as follows:

$$r(\mathbf{t}) \equiv \max\{r_{H1}(\mathbf{t}), r_{H2}(\mathbf{t}), rA\} \quad (\text{on the normal land}) \quad (66)$$

$$r(\mathbf{t}) \equiv \max\{r_{H1}(\mathbf{t}), r_{H2}(\mathbf{t})\} \quad (\text{in the flood prone area}) \quad (67)$$

Furthermore, due to periodical floods, the flood prone area cannot be used for agriculture. The flood prone area is assumed to be located within the residential area. Hence when we assume that city centre where business area

located is a point, and the residential area is located surrounding the city centre, the land equilibrium condition are expressed as follows:

$$r(t) = r_{H1}(t) \geq r_{H2}(t) \quad (68)$$

for  $t \in$  residential area on the normal land

$$r(t) = r_{H2}(t) \geq r_{H1}(t) \quad (69)$$

for  $t \in$  the flood prone area

$$r(t) = r_{H1}(t) = rA \quad (70)$$

for  $t \in$  city boundary

### 3. Numerical Simulations

The following section 3 presents numerical simulations using statistical data and field survey data of Palangkaraya city. However, the available data might be less consistent due to poor data management. Therefore, some difficult estimations were merely approached through approximations.

#### 3.1 Estimating Parameters

Parameter  $\alpha$  in utility function of both households is calculated as follows:

$$\alpha_1 = \frac{px_1}{w_1} \quad \text{and} \quad \alpha_2 = \frac{px_2}{w_2}$$

where

$\alpha_1, \alpha_2$ : elasticity parameter

$p$ : price of consumption goods

$x_1, x_2$ : consumption goods by high income households and low income household

$w_1, w_2$ : wage of high income households and low income households

and since

$$\alpha + \beta = 1$$

then parameter  $\beta$  can be easily determined. Furthermore, parameter  $\gamma$  in asset function is a bit difficult to be estimated, due to lack of appropriate statistical data provided by the local government. However, by using field survey data, parameter  $\gamma$  for both types of the households can be roughly estimated using equation as follows:

$$\ln A_1 = \gamma_1 + \ln w_1$$

$$\gamma_1 = \ln A_1 - \ln w_1$$

and

$$\ln A_2 = \gamma_2 + \ln w_2$$

$$\gamma_2 = \ln A_2 - \ln w_2$$

The following are parameter  $\alpha$ ,  $\beta$ , and  $\gamma$ , as presented in Table 1.

**Table 1. Elasticity Parameters in the Utility Function**

	Elasticity Parameters		
	$\alpha$	$\beta$	$\gamma$
<b>High Income Household</b>	<b>0.62</b>	<b>0.38</b>	<b>1.49</b>
<b>Low Income Household</b>	<b>0.73</b>	<b>0.27</b>	<b>1.13</b>

Other parameters such as  $\theta$ ,  $\sigma$ ,  $\zeta$  are very difficult to be estimated due to lack of data. However, by employing a calibration technique and conducting a sensitivity analysis many times, those parameters can be roughly approached as presented in Table 2.

**Table 2. Elasticity Parameters in the Production Function**

Elasticity Parameters		
$\theta$	$\sigma$	$\zeta$
<b>1.5</b>	<b>0.1</b>	<b>0.3</b>

### 3.1 Result Analysis

Results of the numerical simulation are summarized as follows:

#### 3.1.1 The Bid Rent

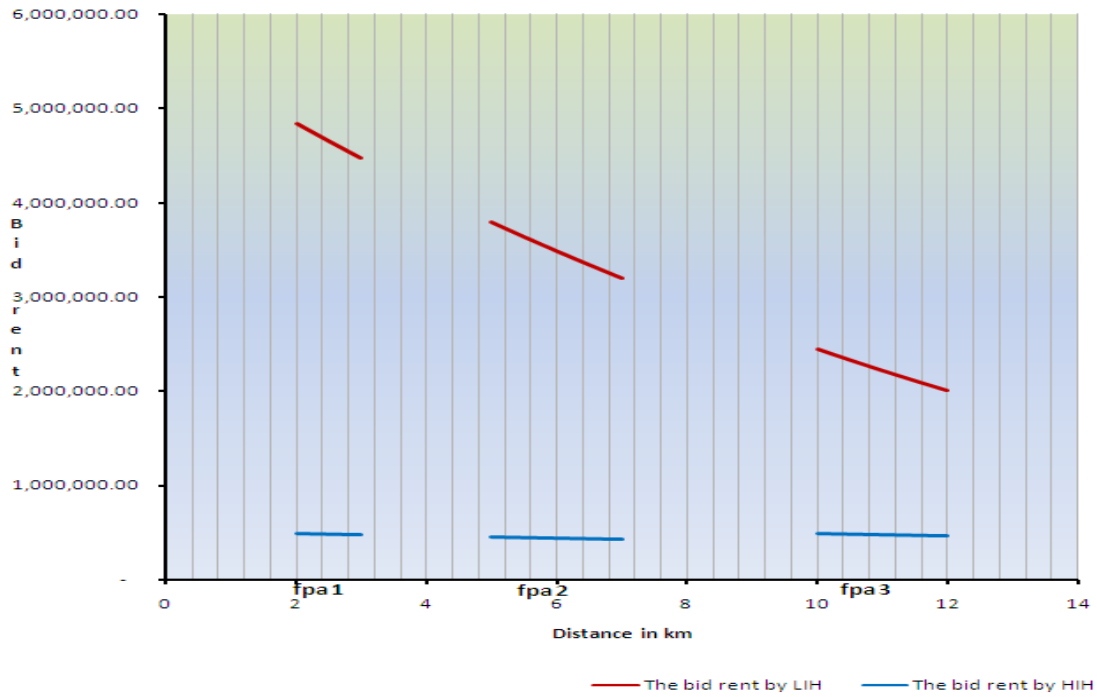
Numerical simulation results taking necessary data of Palangkaraya city in Figure 3 showed that in flood prone areas, the bid rent by representative high income household gets lower than by representative low income households suggesting that the representative low income household would reside flood prone areas. This result can be highlighted as a new finding thus appropriately providing a systematic explanation regarding the existence of the illegal settlements in the flood prone areas.

Implication of the model is that in the flood prone areas where the expected damage rate on household's asset takes value  $0 < c < 1$ , the high income household would face a great loss on their assets, hence while enjoying a fixed utility level, their ability to pay land rent extremely gets down even lower than that the bid rent by the low income households. Therefore, as a result the flood prone areas are resided by the low income household. Summarizing this interpretation, we obtain *Proposition 1*.

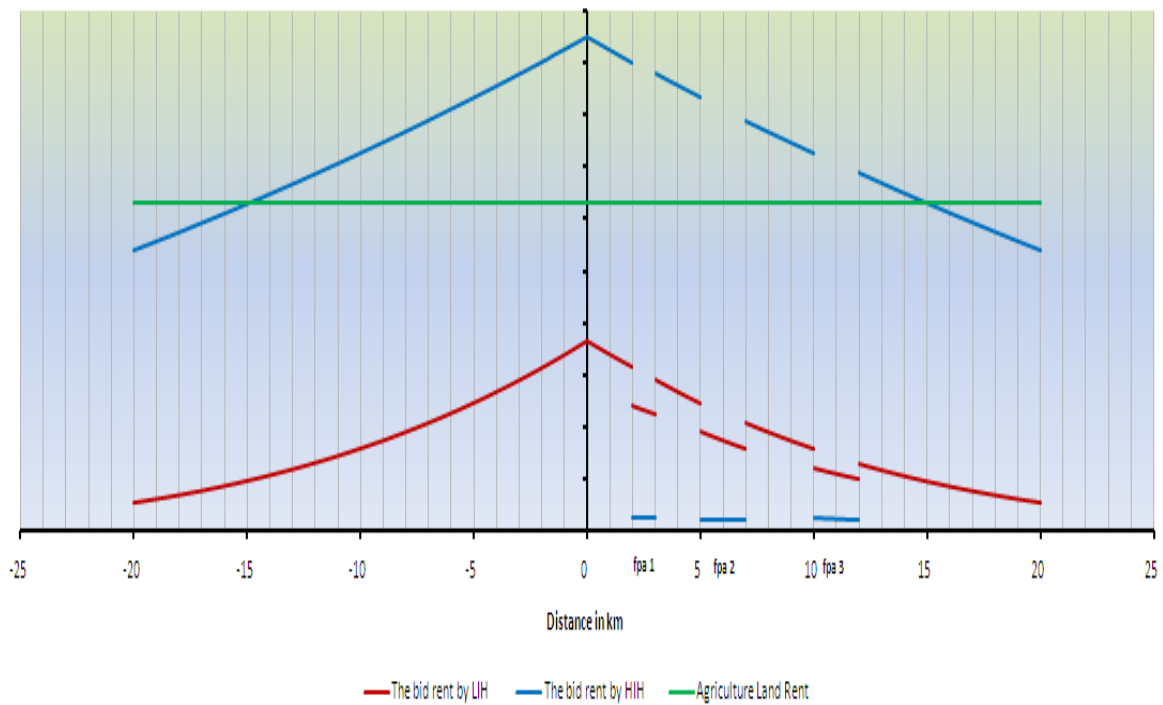
#### *Proposition 1.*

In flood prone areas where the expected damage rate on household's asset takes value  $0 < c < 1$ , bid rent by the representative high income households under appropriate utility level gets lower than that by low income households.

Furthermore, by applying the bid rent approach to the left side and right side of the city, a theoretical residential land use pattern in the city was depicted showing that the high income households populated the normal land while the low income households mushroomed the tiny flood prone areas as can be seen in Figure 4.



**Figure 3. Bid Rent Curve of Representative Households in the Flood Prone Areas**



**Figure 4. Bid Rent Curve of Representative Households in the City**

Next implication of the model is that since  $w_1 > w_2$ , and in the normal land where there is no flood occurrences, the expected damage rate on household's assets must take value  $c=0$ , then the bid rent by the



representative high income households get higher than that by the representative low income households hence the normal land is used by the high income households.

Conversely in the flood prone areas where flood occurrences frequently taking place, the bid rent by the representative low income households under an appropriate utility level gets higher than that by the representative high income households leaving the flood prone areas is used by the low income households. Summarizing this interpretation, we obtain *Proposition 2*.

**Proposition 2.**

In a city area where flood prone areas exist, high income households locate in normal land while low income households populate flood prone areas depicting a residential land use pattern.

**3.1.2 The Bid Max Lot Size**

Bid max lot size determines optimal lot size afforded by the representative households. The model implies that the optimal lot size is obtained when the bid rent given by budget line just in tangent with household`s utility at fixed level. In the flood prone areas, as wage of the representative high income household higher than that wage of the representative low income household, hence the optimal lot size of the high income household is larger than that of the low income household.

Figure 4 showed that the representative low income households afforded smaller lot size as compared with the high income households in the flood prone areas. Furthermore, the optimal lot size in flood prone areas is compared with optimal lot size in normal land, the result is that the optimal lot size in the flood prone areas is smaller than that in the normal land. Summarizing this interpretation, we obtained *Proposition 3*.

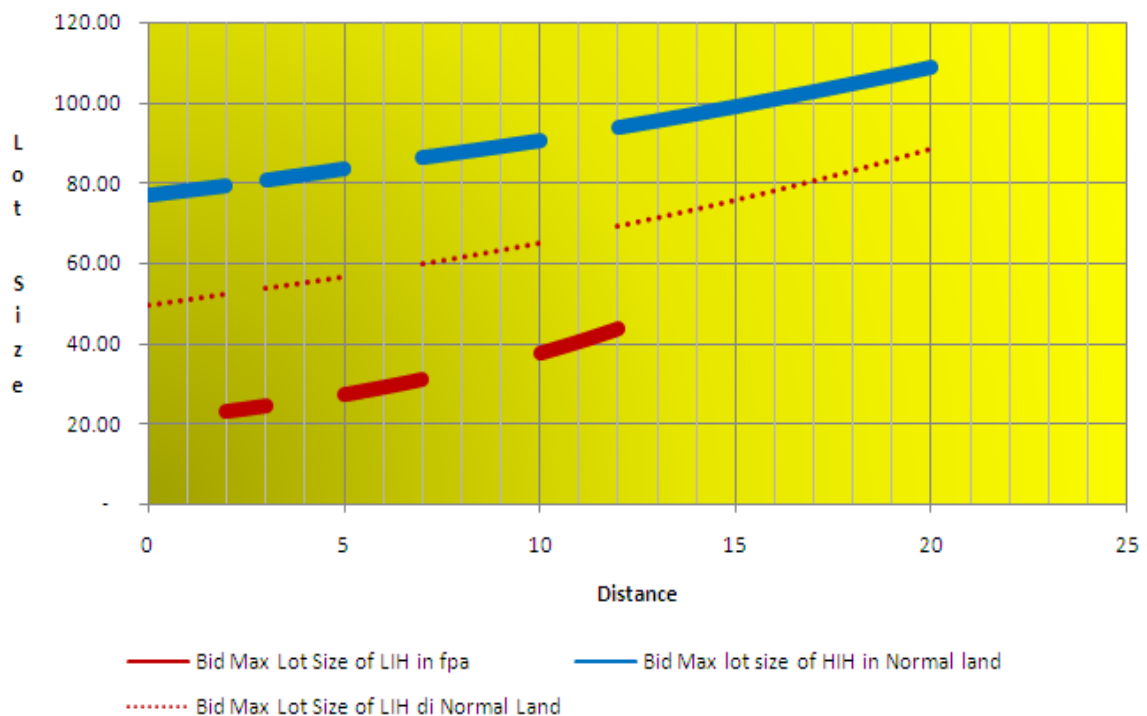
**Proposition 3.**

Optimal lot size in flood prone areas is smaller than that in normal land.

However, as bid rent by the low income households prevailed in the flood prone areas, hence the optimal lot size in the flood prone area is represented by the optimal lot size of the low income household. Summarizing this interpretation, we obtained *Proposition 4*.

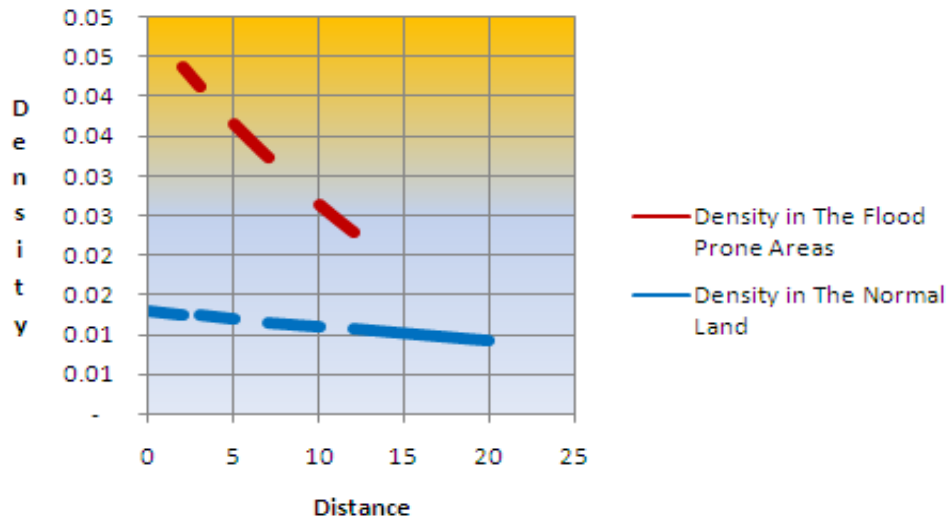
**Proposition 4.**

As bid rent by low income households prevails in flood prone areas, the optimal lot size in flood prone areas is represented by the optimal lot size of low income households.



**Figure 5. Bid Max Lot Size in the City**

In addition, as density is a reciprocal of the bid max lot size, Figure 4-5 showed that densities in the fixed flood prone areas are the highest as compared with other densities in the normal land. This conclusion is quite natural however it reflects high density in most occupied flood prone areas as observed in many urban areas. Summarizing this interpretation, we obtained *Proposition 5*.



**Figure 6. Density in the City**

***Proposition 5.***

Density in flood prone areas is higher than that in normal land implying that flood prone area is more populous than that normal land.

**3.1.3 Policy Simulations**

In the previous simulation, it is showed that change in utility level also positively alters the bid max lot size. In this case, the utility level must be a supreme utility level outside of the city, in the surrounding rural areas otherwise the increase of utility level must shift household’s budget line. So the supreme utility development policy implements supreme utility development projects at surrounding rural areas policy is expected to reduce densities in the flood prone areas. This chapter evaluates four cases for the three flood prone areas.

Base Case: no supreme utility development policy intervention, business as usual case

Case 1: Introduction of the supreme utility development policy. The policy is implemented through utility development projects in the surrounding rural areas. Effectiveness level of the policy is 50%, and it could, by assumption, increases a half or 50% of the previous utility level in the surrounding rural areas, which is equal to utility level in the flood prone areas.

Case 2: The supreme utility development policy takes an effectiveness level at 75%. It could, by assumption, increases the utility level in the surrounding rural areas by 75% of the previous utility level.

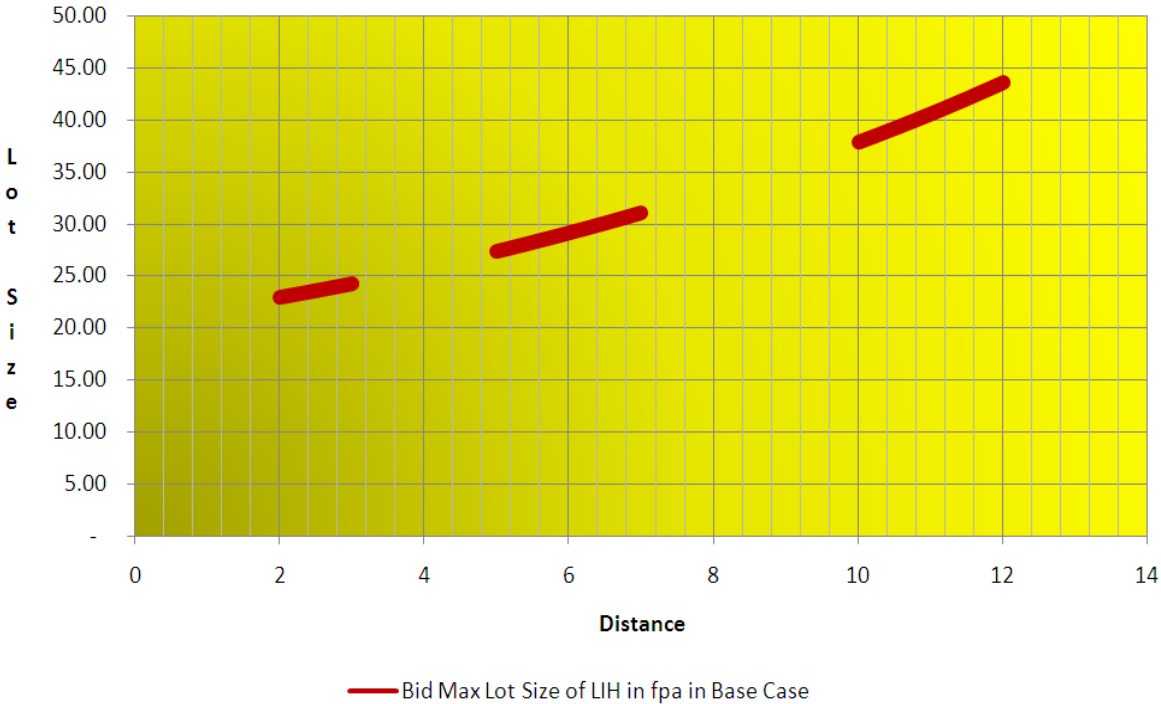
Case 3: The supreme utility development policy takes full effectiveness level at 100%. It could, by assumption, increases the utility level in the surrounding rural areas at doubling rate which is 100% from the previous utility level.

Moreover, the increase of the previous utility level (in the base case) to be 50%, 75%, and 100% reflects by assumption the effectiveness level of the supreme utility development policies. If the effectiveness level takes 50%, then utility level in the surrounding rural areas, by assumption, increases by 50%. If the effectiveness level is 75% then the utility level by assumption, also increases by 75%. And if the policy takes a full effectiveness level hence successfully doubling the previous utility level, then the utility level is assumed taking an increase by 100%. These assumptions intuitively can be justified as based on a common opinion that a successful and an effective

policy normally change a level of utility at full rate. In this case 100% increase of the level can be regarded as a full rate.

1) Base case

Let us first examine the three flood prone areas. As bid rent by low income households prevailed in the flood prone areas, therefore the optimal lot size in the flood prone areas is represented by lot size of low income households. Here, flood prone area 1 (fpa1) is Danau seha neighborhood located in range 2-3 km from the CBD , flood prone area 2 (fpa 2) is Flamboyan neighborhood located in range 5-7 km from the CBD, and flood prone area 3 (fpa 3) is Mendawai neighborhood located in range 10-12 km from the CBD. In addition, location and size of the flood prone areas are fixed. Then the optimal lot size in the three flood prone areas is shown in Figure 7.



**Figure 7. Lot Size in the Flood Prone Areas in Base Case**

As shown in Figure 7, the optimal lot size increase as distance gets farer. The smallest optimal lot size is located in fpa 1 with size 23.59 m<sup>2</sup> per household on average while the largest is located in fpa 3 with size 40.59 m<sup>2</sup> per household on average. By range 23.59 m<sup>2</sup> – 40.59 m<sup>2</sup> per household, the three flood prone areas are classified as slum areas where living conditions is deteriorating as minimum living space exist.

2) Case 1

Introduction of supreme utility development policy is aimed at reduction of density in the flood prone areas. The supreme utility development policy for instance such as national health insurance, basic national education support, etc must be implemented in surrounding rural areas and must be equal to the utility level in the flood prone areas. By applying equation 4-36, utility level in the surrounding rural areas can be estimated. Then next calculation procedure is that value of the utility level is changed to be bigger than that the previous one.

Case 1 is aimed at observing to what extent the optimum lot size can be achieved as change of utility level reach 50% of that previous level.

3) Case 2

The utility level in the surrounding rural areas increased 75% from the base value, as the supreme utility development induced 75% of the utility level from the base value.

4) Case 3

The utility level in the surrounding rural areas increased 100% from the base value, as the supreme utility development induced 100% of the utility level from the base value. Or we may say that in this case 3, the policy takes full effectiveness to increase the utility level in the surrounding rural areas at 100% from the base case.

Then results of case 1, case 2, and case 3 are compared with the base case. It is arrayed in Figure 8 and Figure 9.

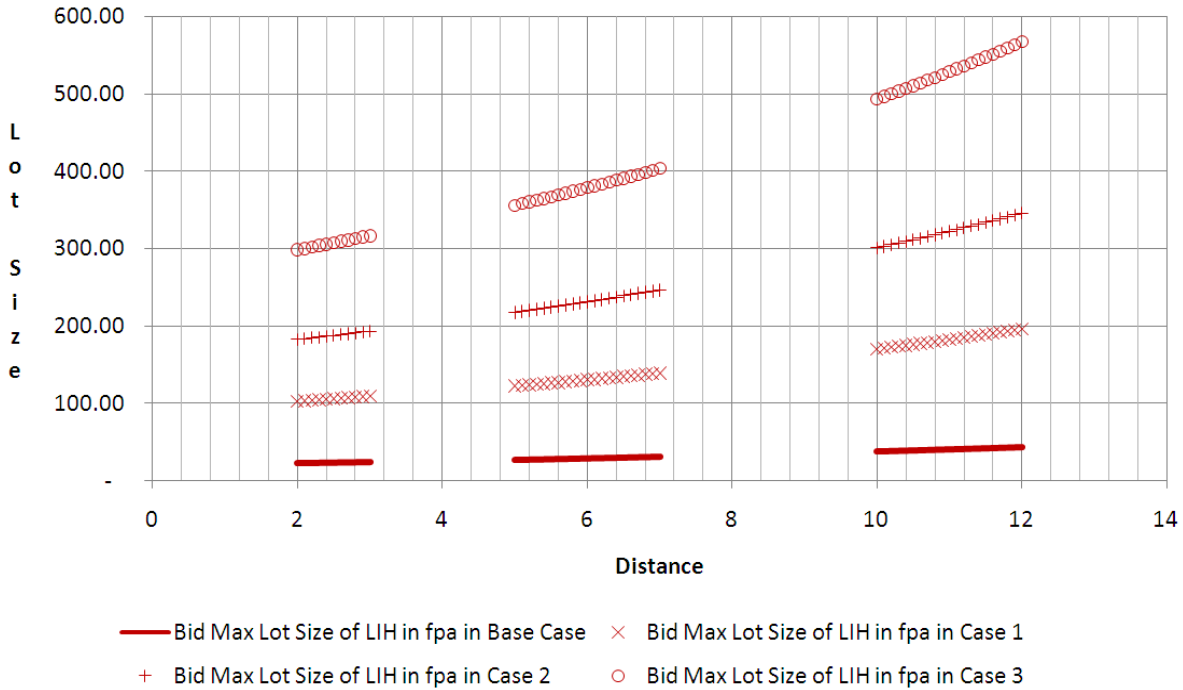


Figure 8. Change of Lot Size in the Flood Prone Areas

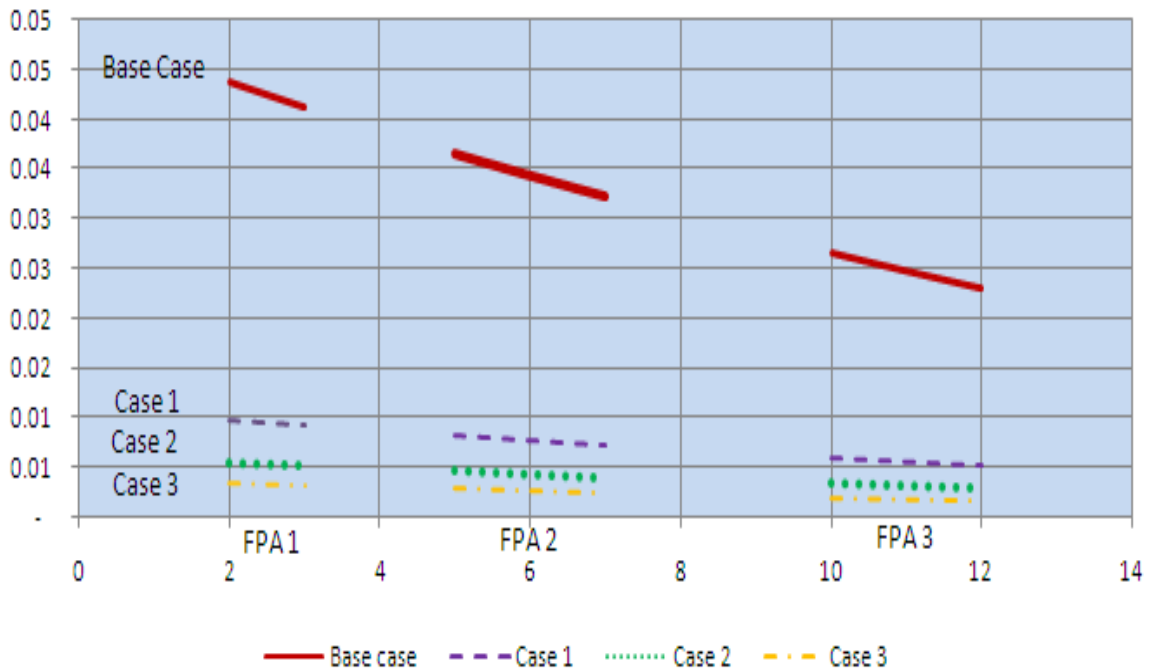


Figure 9. Change of Density in the Flood Prone Areas by Case 1, Case 2, and Case 3

Figure 8 showed that the optimal lot size in the flood prone areas increased by ratio 3.49, 6.95, and 12.03 as the previous utility level in the surrounding rural areas increased by 50%, 75%, and 100%. In addition, the smallest previous lot size is 23.59, by inducement of utility level increase 50%, 75%, and 100%, hence the optimal size became 105.91, 187.44, and 307.36 respectively.

Percentage change of density in the flood prone areas by case 1, case 2, and case 3 as compared with the base case is calculated and shown in Table 3.

**Table 3. Percentage Change of Density in the Flood Prone Areas by Case 1, Case 2, and Case 3 as Compared with the Base Case**

	<i>Percentage Change of Density in the Flood Prone Areas as compared with the base case</i>
<b>Case 1</b>	76%
<b>Case 2</b>	86%
<b>Case 3</b>	92%

Figure 9 showed that the density in the flood prone areas decreased by percentage change 76%, 86%, and 92%, as the previous utility increased by 50%, 75%, and 100%.

Table 3 showed that the 50% effect of the supreme utility development to the base case has significantly reduced the density in the flood prone area by percentage change 76% from the highest density which is 0.03, to become 0.009 on average.

Furthermore, slopes of density in the flood prone areas in case 1, case 2, and case 3 are compared as shown in Table 4.

**Table 4. Changing Rate of Densities in the Flood Prone Areas by Case 1, Case 2, and Case 3**

	<i>Changing Rate of Densities in the Flood Prone Areas by Case 1, Case 2, and Case 3</i>
<b>Case 1 (50%)</b>	0.0006
<b>Case 2 (75%)</b>	0.0003
<b>Case 3 (100%)</b>	0.000019

Such the comparison is simply aimed at investigating significances of the decrease of the density in the flood prone areas by the increases of the utility level in the surrounding rural areas. The simulation results showed that the slopes of density in case 1, case 2, and case 3 take value 0.0006, 0.0003, and 0.000019 respectively. Just comparing the results, one can conclude that slope of density in case 1 is steeper than that in case 2 and case 3. This conclusion indicates that 50% increase in the utility level by development of surrounding rural areas would reduce density in the flood prone areas at better changing rate than that by case 2 and case 3.

## 5. Concluding Remarks

This study has applied new urban economics approach in general equilibrium framework to analyze illegal settlements in flood prone areas. This attempt has presented a general equilibrium model which incorporated the expected flood damage rate on household's assets hence deriving another type of bid rent function and bid max lot size. The model is considerably more realistic than that the partial equilibrium model, since income now is being internalized rather than being merely given. The bid rent function take into account land quality indexed by the value of the expected damage rate on household's assets implying that in flood prone areas, a high income household definitely is facing huge damage on his assets (i.e durable goods and house) hence under fixed utility level, his bid for land rent is getting down even lower than a low income household. This should be highlighted significantly differing from the previous literature.

The numerical simulation based on Palangkaraya city's data showed that in the normal land, the bid rent by the representative high income households is higher than that by the low income household depicting such land use pattern in which high income household populated the normal land. Conversely, in flood prone areas, the bid rent by the representative low income households could get higher than that by the representative high income households; hence as a result the low income households overpopulated the flood prone areas. Arraying those results altogether, and then a land use pattern in the city was depicted. High income households resided the normal land and low income households occupied the flood prone areas.

Furthermore, the numerical simulation on the bid max lot size which determines the optimal lot size afforded by the representative households in the city showed that the bid max lot size in the flood prone areas is smaller than that in the normal land hence reciprocally pointing that the flood prone areas are denser than that the normal land. The numerical simulation also showed that in the flood prone areas, the optimal lot size of the representative high income household is larger than that the low income household, however as the bid rent of the low income households prevailed in the flood prone areas hence the optimal lot size in the flood prone areas is represented by the low income households.

A density in an area reflects number of population living in the fixed area. Therefore the density in the fixed flood prone areas, which is higher than that in the normal implied that the fixed flood prone areas are more populous than that the normal land.

Policy simulations showed that 50% increase of the utility level in the surrounding rural areas as effectiveness level of the supreme utility development policies by assumption take value 50% would significantly reduce density in the flood prone areas with changing rate 76%. The optimal lot size gets larger from 23.59, the previous one, to be 105.91. This concludes that the supreme utility development policy followed by implementation of utility development projects in the surrounding rural areas could deflate the occupied flood prone areas to be more open space thus preserving its ecological functions.

Furthermore, a comparison changing rate of the density in case 1, case 2 and case 3 showed that 50% increase of the effectiveness level of the supreme utility development policies would set a decline of density curve in the flood prone areas more persistent than that by 75% increase and 100% increase. The supreme utility development policies should be implemented in surrounding rural areas of the city. Those could be such as basic health insurance, basic education support, and social safety net for rural inhabitants.

## REFERENCES

- [1] Alonso, W.(1964). *Location and Land Use: Toward a General Theory of Land Rent*, Harvard Univ. Press.
- [2] Beckmann, M.(1973), "Equilibrium Models of Residential Land Use", *Regional and Urban Economics* 3:4, 361-368
- [3] Fujita, M.(1989). *Urban Economic Theories, Land use and City size*, Cambridge University Press, Canada.
- [4] Kapoor, M&Blanc D, (2008), "Measuring Risk on Investment in Informal (Illegal) Housing: Theory and Evidence from Pune, India," *Journal of Regional Science and Urban Economics* 38,311-329
- [5] Muth, R.F, *Cities and Housing*, University of Chicago Press, 1969
- [6] Soegijoko, et al. (2005), *Bunga Rampai Pembangunan Kota Indonesia Dalam Abad 21, Buku 1 Konsep dan Pendekatan Pembangunan Perkotaan di Indonesia*, URDI-YSS-Jakarta: Lembaga Penerbit Fakultas Ekonomi Universitas Indonesia, Indonesia.
- [7] Solow, R.M, (1973), "On Equilibrium Models of Urban Locations". In J.M Parkin ed., *Essays in Modern Economics*, pp 2-16. London: Longman
- [8] von Thünen, J.H, (1826), *Der Isolierte Staat in Beziehung auf Landwirtschaft und Nationaleconomie*, Hamburg.
- [9] Walker, R (2004), "Theorizing Land-Cover and Land-Use Change: The Case of Tropical Deforestation", *Journal of International Regional Science Review* 27,3; pp.247-270,