Analysis of open spaces in flood-prone areas in small-medium cities: a Case study of Palangkaraya City

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Abstract. City open space is an open space within a city, commonly used for parks, green spaces, and other open areas. The landscape of the city's open space can range from playing fields to highly maintained environments to relatively natural landscapes. In Palangkaraya city, there are many vacant open spaces located in flood-prone areas near a river stream. It has a significant function for the city environment, however, most of them are occupied illegally for settlements. Palangkaraya city is a small-medium city located in Central Kalimantan Province, Indonesia. The city is surrounded by forest 285,349.28 hectares while the size of the city itself is 168,000 hectares with a population of 376,647 people. According to Burgess, a small-medium city is a city with a population of more than 100,000 people but a little bit less than the minimum number of the population categorized as a medium city which is 500,000 people. The use of the vacant open spaces in flood-prone areas in such a small-medium city like Palangkaraya city is mainly for environmental function. This research will measure scientifically the use of the vacant open spaces in flood-prone areas for environmental function, hence city policy on the development of city open spaces can be formulated to increase benefits from the existence of city open spaces within a small-medium city.

1. Introduction

1.1. An overview of vacant open spaces in floodprone areas
The growth of vacant open spaces within city spaces in many growing cities in developing countries is very rapid. In Indonesia, many of the open spaces are illegally occupied. People squatting illegally on land to which they have no right according to law. Vacant open spaces mostly situated on marginal lands, such as floodplains, along riverbanks, the slopes of hills, or even along railways. Living places are definitely hazardous. Threats of some potential hazards to the settlements will put the settlers into risks that at the end should be paid economically. A hazard consists, simply a threat to humans or what they value, and can result in damage or loss.

The underlying reasons why vacant open spaces still exist in urban spaces are poverty, population growth, urbanization, and land scarcity within city areas. Rapid industrialization and urbanization have brought an increase in the number of people living in urban areas. Some of them can afford houses informal markets but many of them who are low-income groups cannot. As long as land and housing price goes up, exceeding the limit of low-income groups’ ability in housing purchasing, then the low-income groups are seeking for cheap lands even for free. They start occupying vacant lands within urban areas which some of the lands like floodplain area actually are prohibited to be dwelled due to the laws such as Spatial Planning Law number 26/1992, Environment Management Law number...
Living in those kinds of vacant open spaces that potentially threaten by some possible hazards is not so easy. They live in a state of uncertainty as they have no tenure over the land that they occupied illegally. The settlers are continuously threatened by unpredictable disasters. Both external and internal hazards affect their livelihoods. They are frequently ill as a result of the poor quality of their environment and exposure to disease. They are unable to overcome their problems, as they are low-income groups. They are in a state of persistent poverty and frustration. Disasters may cause death and loss, while poor housing and sanitation also threaten their health. As noted by the World Health Organization (WHO), in the developing world 21% of children die as a result of diarrhea, acute respiratory infection, malaria, measles, and prenatal conditions. Most of them live in such an unhealthy environment like generally found in many vacant open spaces. Density in informal settlements is high. Households are divided and sub-divided to accommodate families and friends that have also moved to the urban areas, or migrated because of conflicts in their previous settlements. High density means that disease is easily spread; therefore, the effects of the diseases on illegal settlers are great.

The risk of living in vacant open spaces on such floodplain areas nearby the river stream can be divided into internal and external risks depending on a kind of hazard. Internal risks are associated with a lack of development, lack of financial accessibility, environmental deterioration. While external risks have a source outside the settlements such as flood and fire.

Settlers, who live in vacant open spaces, take benefit both from the proximity of their houses to CBD where they work in since they can save time and cost of transportation and utility maximization since the settlements are relatively close to urban infrastructure and facilities.

Living with taking such kinds of risks on one side while getting some benefits of dwelling in those areas on the other side, where it might prevent the settlers to remain living in such kind of settlements, is an interesting issue for discussion.

1.2. History of vacant open spaces s in Central Kalimantan Province, Indonesia

In 1957, the new city of Palangkaraya was formally established by the first president of Indonesia, Ir. Soekarno, aimed as a capital for the new province, Central Kalimantan. The City of Palangkaraya was developed from one small village which was called Pahandut Village. In the very beginning, all of the houses in the village were located on the riverbank of Kahayan, simply because, in the past, where roads were not exist yet and the river is a natural resource to provide water and fish, people use the river for transportation way and their resources. So, by constructing houses on the riverbank, they ease their own way to get close with the river, the source of life. All of the floodplain areas near the Kahayan river have been occupied a long time before Palangka Raya’s establishment. It was reported that a couple of temporary houses have dwelled in Mentawai, Flamboyan, and Danau Seha long time before 1957.

![Figure 1](image.png)

**Figure 1.** (A) Flamboyan Area in 1957, (B) Flamboyan Area in 1960.  
*Source: Palangkaraya Municipality, 1998*
Figure 2. (A) Flamboyan area in 2018, (B) Mendawai area in 2018, (C) Danau Seha 2018

Source: Google Earth, 2018

2. Study area

The area of study in this research is located in Palangkaraya Municipality in three different locations of vacant open spaces in floodplain areas.

Figure 3. Area of study
3. The model

3.1. Factor of illegality
We assume that expected utility in place of reception will be a pull factor that might affect household heads to take resettlement options. If expected utility in place of reception higher than expected utility in place of origin then resettlement option might be taken by household heads. This hypothesis has been tested by research [1] in Srilanka. The result shows that expected utility is seemingly more considered by households who took resettlement decisions. Following Grote.et.al achievement, we propose that expected utility in place of origin can be influenced by the illegality factor. If the land status is not clear let say illegal which means without land title due to a law break, then expected utility must be reduced because utility suppliers will have a constraint for maximizing. Hence, we introduce the factor of illegality ($\alpha$) that significantly will reduce expected utility in place of origin ($v_{in}$).

$$\alpha > 0$$

3.2. Resettlement decision
Following [2] and fact-finding in research [1] in Srilanka, that a household head decides to displace if the expected utility of staying in the place of origin is lower than the expected utility from displacement. As expressed:

$$EU_{id} > EU_{in}$$ \hspace{1cm} (1)

where:

$U_{ij}$ is the indirect utility function of the household $i$ at the place $j$

$j = d$ denotes the place of reception and $j = n$ denotes the place of origin

$E$ is the expectation operator

We consider illegality is a factor that influences expected utility in place of origin. We write a factor of illegality $\alpha$. Then expected utility in place of origin should be written as :

$$EU_{in} = v_{in} - \alpha_n$$ \hspace{1cm} (2)

where

$EU_{in}$ is the expected utility in place of origin

$v_{in}$ is observable utility in place of origin

$\alpha_n$ is illegality factor in place of origin $\alpha > 0$

We can rewrite the expected utility in place of reception as :

$$EU_{id} = v_{id} + \varepsilon_{id}$$ \hspace{1cm} (3)

where :

$v_{id}$ is the observable utility

$\varepsilon_{id}$ is a random term with a mean of zero

The random term includes all unknown or not quantifiable variables.

We rewrite equation (1) as follows:
\begin{align*}
v_{id} + \varepsilon_{id} & > v_{in} - \alpha_n \tag{4}
\end{align*}

Thus, the formal statement of the equilibrium condition of this model is as follows:

- Let \( v_{id} \) be the expected utility in the place of reception.
- Let \( \varepsilon_{id} \) be a random term of all unknown or not quantifiable variables with a mean of zero
- Let \( v_{in} \) be the expected utility in the place of origin
- Let \( \alpha_n \) be the factor of illegality in the place of origin

At equilibrium, we write as following

\begin{align*}
v_{id} &= v_{in} - \alpha_n - \varepsilon_{id} \tag{5}
\end{align*}

We assume that there are no significant differences in expected utilities between the place of origin and place of reception. Hence if expected utilities in place of the reception are predicted remain the same as expected utilities in place of origin:

\begin{align*}
v_{id} &= v_{in}
\end{align*}

Then we expect settlers will decide to take resettlement because expected utilities in place of origin will be deteriorated by illegality. The equilibrium will be change as following:

\begin{align*}
v_{id} &> v_{in} - \alpha_n - \varepsilon_{id} \tag{6}
\end{align*}

Conversely, resettlement decision will not occur if

\begin{align*}
v_{id} &< v_{in} - \alpha_n - \varepsilon_{id} \tag{7}
\end{align*}

The observable utility of staying at the place of origin or moving to the place of reception depends on a variety of factors. Firstly, the perception of safety level both at origin and reception. Secondly, the income and the standard of living in both origin and reception affect the level of utility. Thirdly, resettlement and information costs depending on access to transport and information are important for the estimation of the cost and benefit of resettling. And finally, the resettlement propensity might be affected by socio-demographic characteristics of the household as these determine the household's preference structure.

Thus, we write the observable utility as follows:

\begin{align*}
v_{ij} &= f(S_{ij}, Y_{ij}, C_{ij}, Z_{ij}) \tag{8}
\end{align*}

where:

- \( S_{ij} \) is a perception of safety for the household at the place
- \( Y_{ij} \) is income and standard of living for the household at the place
- \( C_{ij} \) is resettling and information costs
- \( Z_{ij} \) is household characteristics which influence preferences

3.3. Flood risk assessment

By living so close to the river stream, the dwellers risk getting jeopardized by the annual flood from the run-off water of the river. In order to know to what extent, the annual flood is risking the settlements, the measure of flood risk namely Flood Risk Index (FR1c) on the basis of pressure and release model (PAR model) will be introduced [3,4]. The basic equation is expressed as follows:

\begin{align*}
R &= H \times V \tag{9}
\end{align*}

where:

- \( R \) is a risk
- \( H \) is a hazard
- \( V \) is a vulnerability
In this case, a Flood Risk Index has been calculated by multiplying vulnerability and hazard index. The average depth of inundation has been assigned as the hazard index. And for calculating the vulnerability index, the percentage area covered with houses has been considered. Hence the following steps are:

1. The whole study areas are divided into 200 m x 200 m grid. The total number of blocks is 94.
2. Calculating the average of inundation depth in each block is based on inundation data in the three settlement from 1997-2007
3. For each block, an integer value ranging from 0-5 has been assigned as a hazard index according to inundation depth shown in table 1.

| Inundation depth (Km²) | % with respect to the inundated area | % with respect to the whole area |
|------------------------|------------------------------------|----------------------------------|
| 4 m or higher          | -                                  | -                                |
| 3 m – 4 m              | 0.8                                | 21%                              | 14%                             |
| 2 m – 3 m              | 1                                  | 27%                              | 17%                             |
| 1 m – 2 m              | 0.6                                | 16%                              | 10%                             |
| Less than 1 m          | 1.36                               | 36%                              | 23%                             |
| TOTAL                  | 3.75                               | 100%                             | 64%                             |

Table 2. Hazard Index

| Inundation Depth | Hazard Index |
|------------------|--------------|
| No Inundation    | 0            |
| Less than 1 m    | 1            |
| 1 m – 2 m        | 2            |
| 2 m – 3 m        | 3            |
| 3 m – 4 m        | 4            |
| 4m or higher     | 5            |

For vulnerability index, a value ranging from 0-10 has been set per each block. Weight factor 10 for the area covered by houses and for 0 for unused land. Equation 2 has been used for calculating the vulnerable index.

\[ VI = \frac{(10 \times A) + (0.\text{NU})}{At} \]  

(10)

where:
A = Area covered by houses per block
NU = Non used land
At = Total Area of each block

Then

\[ FRI_c = HI \times VI \]  

(11)

where
FRI_c = Flood Risk Index (ranging from 0 to 50)
HI = Hazard Index (ranging from 0 to 5)
VI = Vulnerability Index (ranging from 0 to 10)
Table 3. Area classification according to the flood risk index

| Flood Risk Index ($FRI_c$) | Level of Risk |
|---------------------------|---------------|
| 1-5                      | Low-Risk Area |
| 5-10                     | Medium-Risk Area |
| More than 10             | High-Risk Area |

We calculated the vulnerability index and hazard index in the 94 grids using water inundation data of flood events from 1997-2007, data of houses in terms of size and amount in each grid, in order to define $FRI_c$ in each grid. We use color to differ $FRI_c$ in each grid on a scaled aerial photo as following in figure 4.

![Flood risk map](image)

Figure 4. Flood risk map

4. Conclusion
Vacant open spaces in the flood-prone areas which were occupied illegally by settlements are affected by flood at a high risk that can possibly damage their assets. It became hazardous areas at a certain level. Thus as a result utility level which is determined by the perception of safety will decrease to a certain level. Expected utilities in place of origin are deteriorated by the illegality factor of the settlements. Some observable utilities in public facilities such as electricity, clean water provision, waste disposal, telephone, and pathway have become worse with less attention of local government and providers in redevelopment. It indicated that expected utilities in the place of origin will constantly become worse and the exposure to flood hazards will become large. This deterioration in the place of origin will be a push factor and at the same time a pull factor of the place of reception that affects resettlement decision. In addition, the perception of illegality in the settlers who live in those vacant open spaces in flood-prone areas significantly affected the decision on whether to stay or to
displace. Settlers who perceive clearly the illegality tend to displace to the place of reception. Hence it proved our main hypothesis that if expected utilities in place of origin are deteriorated due to illegality factor and larger exposure to flood hazard, then expected utilities in place of reception will be a pull factor for settlers to take resettlement option.

References
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