Livable floodplain settlement, force adaptation, or landform adaptation? (Case in Bengawan Solo river downstream)

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Abstract. The growth of settlements in the floodplain area downstream of Bengawan Solo has caused by conversion from agricultural to residential areas so that the growth of the settlements in this area have a high vulnerability to river floods. Mapping of Landsat results was carried out in residential areas affected by river floods and compiled with settlement tracing maps. Overlay results are analyzed by referring to the concept of building distance, building boundaries with rivers, building boundaries with roads. The results obtained are the pattern of adaptation of the settlements to the area that is the place of inundation, the tendency of adaptation based on function orientation, and physical orientation of the settlement pattern of floodplain downstream of the Bengawan Solo river.

1. Introduction
Reduced forest area and increased residential areas downstream of the Bengawan Solo river, making it vulnerable to flooding during the rainy. Floodplain land use affects future development [1]. Different models of flood characteristics affect the adaptation model and the losses incurred [2]. Understanding of territorial problems due to land use and activities of residents other than agriculture, because there are still tertiary activities in society [3].

The unsuitable adaptation of settlements that is causing disasters will also ecological damage caused by adaptation, making ecological rehabilitation on a spatial scale that requires a paradigm shift in human behavior including settlement adaptation [4]. There is only one factor that influences the evolution of settlements, the distance between settlements and human activities [5]. Sustainability is defined as meeting needs without compromising the capabilities of future generations [6]. The four aspects of the concept of sustainability and balance are, environmental, social, economic, and cultural [7]. So that transportation and infrastructure become dominant in the use of residential land [8]. Sustainability in the local context is knowledge, participatory in finding a balance between shelter, the environment, and saving budgets [9]. The land selection process is one of the ideal steps to develop a sustainable and suitable settlement according to the landscape context in an area.

Safety adaptations for development include Watergate and river protection wall construction [10]. Physical characteristics of settlements are based on spatial structure and facilities according to occupant behavior [11]. The impact on settlements and agriculture by the climate in inundated areas is seen from
sedimentation and geochemical [12]. Adaptation of infrastructure and drainage facilities for urban areas in inundation and flood areas, using a simulation approach and flood prediction [13]. Guidelines for developing coastal settlements by taking into account the characteristics of coastal geosystems that are safe from disaster vulnerability [14]. Settlement changes depend on population growth and then affect land use, the conversion of agricultural land to residential [15]. This research is to look at the pattern of settlement adaptation in the downstream area of the Bengawan Solo river, by estimating the physical orientation of the settlement and the monitoring function of the surrounding.

1.1. Floodplain landforms
Flood plains are the main landform of river deposition [16]. Floodplain is an alluvial landform adjacent to a channel, bounded and separated by a channel, formed from sedimentary material transported by river flows. Besides, inundation also reflects a series of landforms with various types of environmental energy from high to lowest [17].

Figure 1a shows the various types of floodplain areas, natural form with the inundation land type, man-made inundation land type, and inundation land type without embankment, according to the Water Resources Management Regulation [18,19]. Floodplain which is a plain area located around a river embankment, the floodplain is a water catchment area.

The formation of a floodplain consists of six major processes that form it [17], are:
- Starting from the point as a point of area increment
- Developed into additional land around the riverbank area
- Developed by appearing a channel or channel on the land
- Develops with an increasing slope around the riverbank
- There was the addition of another new development point
- A new channel or channel appears from the existing one

1.2. Settlement adaptation
Figure 1b describes the type of settlement adaptation from the perspective of economic capacity, divided into two types, natural and engineered, the tendency for community settlements with middle and lower economies to follow a natural pattern, moving away from the maximum overflow area from river overflows, while people with an economic capacity above it tend to engineer the existing landscape by making artificial embankments to secure settlements [19].

Land use for settlements complies with the regulations on river boundaries as in the illustration in Figure 1 (b), it is explained that the ideal adaptation for building structures around the river is an adaptation being developed are stilt houses [20], where the stilt structure is in the body area, water, as well as the ground floor conditions of the building, are not affected by the tidal phenomenon. However, in the context of the floodplain which has wet and dry characteristics, this kind of settlement model is not efficient. The concept of a house on stilts in a puddle of land has an effect in the form of the
emergence of negative space under the building if the land conditions are dry, and the stilted building will be effective if the flooded have a certain height volume.

Figure 2 (a) Is the position of residential before calculating flood overflow in settlements, Figure 2 (b) is a form of adaptation to settlements by increasing the height of the residential by considering the maximum discharge from flood [21].

2. Methods
This study is to see the settlement adaptation patterns that grow in the downstream area of the Bengawan Solo river, by estimating the physical orientation of the settlement and the monitoring function of the surrounding, the method using a graphic morphological analysis based on map imagery. The analysis approach is based on abiotic, biotic, and culture components. The research data that will be used is the location map data that has been selected based on the results of satellite images which include topographic maps, land cover maps, and settlement growth maps.

Landsat imagery is a remote sensing technology developed by NASA [22]. By adjusting the spectral channels, and by determining appropriate digital processing and analysis techniques and methods, Landsat image data can be used for land use mapping, land cover, and environmental monitoring [23]. Figure 2 below is an interpretation of Landsat images with a dark color indicator, this is the inundation land cover, the location marked as the research location, administratively located in Trucuk sub-district, Bojonegoro Regency.

2.1. Abiotic
The first step is to analyze the abiotic components of the study area using Landsat 8 imagery, this map to identify historical flood periods, identify land cover, and land topography. The period time of this mapping is 2010 to 2019. The result is a geophysical landform in the study area, results of the biotic analysis were followed by an inventory and analysis of the biotic components in the research area. The biotic components analyzed were settlement and land-use change for the period 2010 to 2019. In this stage are the biographical profiles of settlement areas. This bio geophysical profile is an identification of changes between land use and the landscape in the study area, at this stage, it is advocated with an analysis of the adaptation of settlement areas. The next stage is the analysis of the cultural component in the research area as a local intelligence to adapt in settlements by the surrounding population to the threat of flood inundation that occurs in the research area.

Overall the analysis in stage 1 and stage 2 is to look at land and settlement morphology from 2010 to 2019. Stage 3 is a combination of morphological analysis between land and settlement. In this combination, the settlement adaptation form to the inundated landscape will be determined. In this case, force adaptation in the form of settlement pattern by providing artificial embankments without taking into account the maximum river overflow and inundation, it is to form adapting if the settlement takes into account the river overflow and maximum inundation [19]. The solid void analysis is used as the last step to determine the adaptation patterns of settlements in the research area.
3. Results and discussion

Figure 4 shows the results of the Landsat in the research area and tracing of settlement patterns from 2010 to 2015. In this figure, it can be seen that the majority of land use in the research area is land with vegetation cover and some settlements. Adaptation to settlement patterns in this area tends to follow river flow, which has not fully considered landforms. The mapping results, some settlement groups tend to be very close to the riverbank, while in other parts of the study area, settlements have considered river boundaries. The settlement growth in 2015 did not change too much.

![Figure 3. Land-use 2010 – 2015 [24].](image)

![Figure 4. Natural embankment.](image)

Settlement growth occurs at several points in the research location, as in Figure 4 that settlement growth tends to remain in the river banks. In addition to the growth of settlements, in the 2019 image, there has been a change in river flow patterns. This change in the pattern of the river is the construction of a dam, resulting in infrastructure growth in the area. The image has shown the old flow pattern has a land cover in the form of vegetation, which indicates agricultural land.

The settlement adaptation in the study area in Figure 4 shows that the adaptation is in an inundated area that has a natural embankment so that one of the settlement groups has a long distance from the riverbank but is in an inundated land basin. The tendency for people to stay near rivers is a way of life for the community to be close to work locations. The majority of people living in the inundated area are farmers, they use land far from the riverbank as agricultural land. The growth of residential areas affects building density, in Figure 5 (a) it can be seen that the density of buildings forms linear zoning of settlements following the river flow pattern and linearly following the main road so that the concentration of settlement orientation leads to the main transportation and rivers.
Land utilization farther from the riverbank tends to be used as agricultural surrounded by residential areas as shown in Figure 5 (a) so that this agricultural area forms an inner court area that is covered by settlement boundaries. In Figure 5 (b) it can be seen that the results of the settlement pattern on the inundation area around the downstream of the Bengawan Solo river, at point A is the type of settlement located on the riverbank, settlement adaptation uses stage structural engineering, point B is the residential area on the river embankment with settlement adaptation distance from the river, settlement adaptation by elevating the ground floor of the building to the land surface, point C is agricultural land that is cultivated by the local community.

The local genius of the community regarding the context of inundated land is known by utilizing in the middle of land as agricultural, with the land-use model as described in the solid void map in Figure 6. Based on the results of the solid void analysis which looks at the form of built-in land cover and open space, it is found that the settlement pattern is physically a settlement that forms a linear pattern to the river, but in spatial function, the settlement has an outward orientation pattern towards the river as an anticipatory form, while the inward orientation functions as a supervisory and monitoring function.

Another local genius is using building floor elevation to a simple technical adaptation strategy implemented by the local community. The concept of raising the ground floor of the building is to fill and pavement as the main material. The application of the building height still has not considered the maximum discharge height of the overflow factor, it can be seen that the variation in the height of the ground floor of the building is different in each house. The concept of raising the ground floor of the building is also applied in technical infrastructure areas. Access roads that are inside the research area are also elevated from the land surface. The main infrastructure enhancement includes the road network and regional drainage. The material used in the research area is a massive paving material that can absorb some of the standing water. This material was chosen by the surroundings because of the ease of availability and distribution of raw materials.
4. Conclusion
The settlements in the research area have adapted by considering the overflow river flooding in terms of the overflow range and discharge height of the overflow, some have adapted but are still not optimal. Adaptation of settlement patterns to follow river patterns by giving river boundaries, building models adapt the building by raising the ground floor of the building against the ground, but not entirely by considering the highest discharge from river overflow. Some of the other settlement patterns are located on the riverbank, the residential building model adapts to the stilted building that is above the ground. Settlement patterns have physical and functional patterns. The physical pattern serves as an anticipatory orientation to the threat of disaster, the function pattern is an orientation for agricultural supervision and monitoring as a community livelihood.

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