



CHARACTERISTICS OF GEOGRAPHICAL LOCATION AS A BASIS FOR PLANNING SETTLEMENT AND OPEN SPACE IN INUNDATED AREA OF BENGAWAN SOLO RIVER DOWNSTREAM, LAMONGAN, INDONESIA

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Abstract

The presence of a floodplain is a risk to the survival of the inhabitants in an area due to the possibility of settlement being submerged by flood due to river overflow. The situation can lead to some social impacts on settlement structuring and management. Therefore, this research aimed to determine the minimum criteria required for a housing development area with a focus on land suitability, space configuration, utilities, and open space. Geographical location was identified using Rupa Bumi Indonesia (RBI) map, but the profile consisting of slope, inundation height and duration, land use, and space configuration was determined through space syntax. The results showed the basic pattern of settlement in the form of the physical and non-physical orientation of the area. The spatial configuration of residential areas had the highest space integration value of 0.84, and the lowest was 0.26, while the highest level of space depth was 28. Geographical characteristics were used as the basis for further development of settlement layout with due consideration for the land use and open space concepts.

Keywords: Geographic profile, Configuration, Settlement, Open space

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INTRODUCTION

Floodplain is a potential threat to the downstream of Bengawan Solo River Basin in Lamongan, East Java, Indonesia, due to the possibility of inundation flood influenced by the physical characteristics of the river area, the location shown in Figure 1. According to *Rencana Tata Ruang Wilayah 2012-2031 (RTRW)* of Lamongan Regency, the area has a relatively flat slope, which is in the form of an alluvial plain, floodplain, and riverbank. The land around the basin is used for agriculture, and the work behavior of the community forms the pattern. Meanwhile, floodplain landform shows the potential for flooding by rain and river overflows. For example, the rain patterns in the upstream river for the 1990- 2016 period caused high water discharge in the downstream area (Auliyani, Nining W, 2020), leading to the possibility of inundation at any time. The trend led to the designation of the land around the Bengawan River downstream for agriculture with full, partial, and no irrigation (Prabowo, 1978 in Bulletin of Indonesian Economic Studies, 2006).



Figure 1: Research location
Source: Google Earth Satellite (2024), RTRW (2012)

The same trend was observed in the previous research conducted in Bangladesh, which divided the agricultural land use in the downstream with similar landforms into two, including the main inland used for different crops and the tidal for conditional planting (Seijger, 2019). Moreover, the increase in water discharge downstream has caused some changes in land use patterns from the original forest to the domination of agricultural activities and settlement (Fidiyawati, 2020). It was observed that the settlement located in the Bengawan Solo River downstream was based on the water orientation, with houses constructed partially or completely on stilts in the water area using building materials easily obtainable in the environment (Mulyati, 2016).

The trend observed showed that the growth of settlement patterns in the downstream area was related to the natural, environmental, and social factors. For example, the environmental aspect was in the form of agricultural practices dominated by the cultivation of rice and field crops to provide economic opportunities for the community to survive. This further influenced the social aspect, which was associated with the ability to live in groups and form a unique settlement pattern. The variations in the factors observed in each area can lead to the development of unique settlement pattern designs compared to the others.

LITERATURE REVIEW

Geographical Location

The development of residential areas to ensure long-term sustainability is based on the characteristics of geographical location (Veni, 2016). For example, the development of settlement in a particular landform considered to be vulnerable to disaster requires focusing on mitigation practices (Yenen & Hamamcioğlu, 2017). Those on the floodplain are required to adapt and develop modern settlements based on the area morphology (Zhu et al., 2019). The conversion of green land into residential areas can also influence flood risks based on the characteristics formed (Schober, 2020). Therefore, some of the criteria required to be assessed in the floodplain are land slope, inundation depth, length of inundation time, and land use (Sabaruddin, 2013).

The review of previous literature shows a research gap related to the development of physical settlement on inundated landforms. Therefore, the focus of this research is expected to be on sustainability after land use through the physical adaptation and orientation pattern of settlement to consider disaster risk as well as physical and non-physical accessibility. This is necessary because development is related to some criteria such as natural protection, landscape function, environmental ecosystems, connectivity, and integration. The natural protection aspect focuses on food production as well as the maintenance of soil quality, energy cycles, and natural resources. Moreover, quality of life elements includes mitigation of environmental risks such as floods, landslides, drought, and climate change. The physical components to be considered in building settlement and open space are land slope, as well as inundation duration and height.

Settlement Pattern

The dynamics of settlement located in the floodplain are expected to adapt to the prevailing disasters (Seher, 2016). Moreover, the settlements in inundated areas are influenced by the elevation and different cultures (Koteski, 2019), leading to the development of different regional landscapes and lifestyles based on geographical location as a form of survival (Ferdous, 2018). The concept of ideal

physical resilience is also recommended and facilitated in residential areas (McClymont et al., 2019). Infrastructures are also required to be improved to protect the social and cultural conditions in the environment, in addition to the construction of settlements on river bodies and embankments (Michiani, Junichiro Asano, 2019). Settlement patterns were initiated as a method to survive, and the process could be achieved in inundated areas through the consideration of the natural resources, energy sources, and response to disaster vulnerability. It is important to state that the pattern often found in peripheral areas is the linear rural settlement (Dorrel & Joseph P. 2020).

The research area selected is productive agriculturally and has economic value for the community. Meanwhile, previous research showed that the identification of economic value in any settlement led to the development and the need for the maintenance of the available resources, in this case, agricultural land. The existence of different social strata in the community located in an inundated area has led to several results. It was observed that the income of the community increased during stable inundation conditions when there was no flood overflow and river erosion (Ferdous et al. 2019). The developmental pattern of settlement in downstream areas always tends towards agricultural activities (Arifin, Fajri Rahman, 2020). The understanding of the resilience system related to settlement with participatory, socioecological, and sociopolitical conditions can lead to policy collaboration (Williams et al., 2019). The trend in the downstream river area has led to the formulation of policies related to inundation land use management (Restemeyer et al., 2019). It was reported that the development of settlements around rivers influenced the productivity of agricultural land (Yadav & G.S. Chauhan, 2020). However, the social conditions observed in the research area were not influenced by certain strata because the majority of people were farmers. The similarity of social status led to a settlement pattern capable of physically accommodating the needs of settlers, including security, comfort, and support for professions. The research gap identified is that there is no generally accepted, definite policy related to physical settlement patterns, with those conducted observed to be limited to macro spatial zoning without any detailed regulations on settlement patterns specific to regional resilience and local policies.

Configuration

Configuration is a key generator in spatial analysis to understand the morphology and structure of an area. The movement in the spatial configuration is influenced by the grid, which is the basic element related to spatial pattern analysis (Hillier, 1984). It is also important to state that the configuration focuses on the relationship between all the spaces (Peponis, Zimring, and Choi, 1990). Moreover, the measurement process focuses on determining the integration and

depth, as well as the description of how a space is related to the others in a system. The depth is considered when the access to a space requires passing through several others, and the opposite is known as shallowness, which is the existence of a direct relationship between the spaces. The concept is also explained as the sequence of spaces that start from a certain point to another with a higher value. Furthermore, space configuration is related to the cultural typology associated with the space formed (Ayyıldız, S., Durak, Ş., 2023). It is achieved through the interaction between user behavior and the system applied (Karimi, 2023), including the relationship between regional spaces (Putra & Prabani Setio Hastorahmanto, 2023).

The research gap in the context of space configuration is related to the current development of settlement patterns, mostly due to some adaptation factors influencing the provision of open space and orientation of residential areas. Observation from the Bengawan Solo River downstream shows that settlement is oriented towards ensuring community survival. This is identified from the efforts made in maintaining green land for agriculture and introducing supervision factors by setting the orientation of settlement towards agricultural land and ensuring buildings are directed towards the main road. The spatial configuration in rural areas is in a regional pattern that is different from that in urban areas.

Open Space

The open space in urban and rural areas has different purposes and functions. This is observed from the fact that the open space in rural areas tends to grow naturally based on the community's behavior without any specific standard, but only through the contextual situation (Khan, 2019). The natural relationship between humans and the environment is contextually different, leading to the formation of three open spaces with a focus on production, protection from natural disasters, and health (Ramayana, 2017). Moreover, the open space in rural areas is mostly public due to the existence of landscape elements such as water, trees, and rich sunlight (Xu & Liyuan Huang, 2022). It is mostly unplanned and develops through a natural process to become functional for the users (Ischak et al., 2023). The research location has agriculturally productive open space in the form of fields as well as roads developed through the paths walked by the people to reach their respective homes. The trend shows that agricultural land is an open space often used by the community to ensure interaction.

RESEARCH METHODOLOGY

Mapping analysis was adopted in this research using map-based data related to Sekaran Village, Lamongan Regency, East Java, Indonesia. The satellite imagery was derived from the *Rupa Bumi Indonesia* (RBI) Map provided by the *Badan Informasi & Geospasial* (BIG) in 2024.

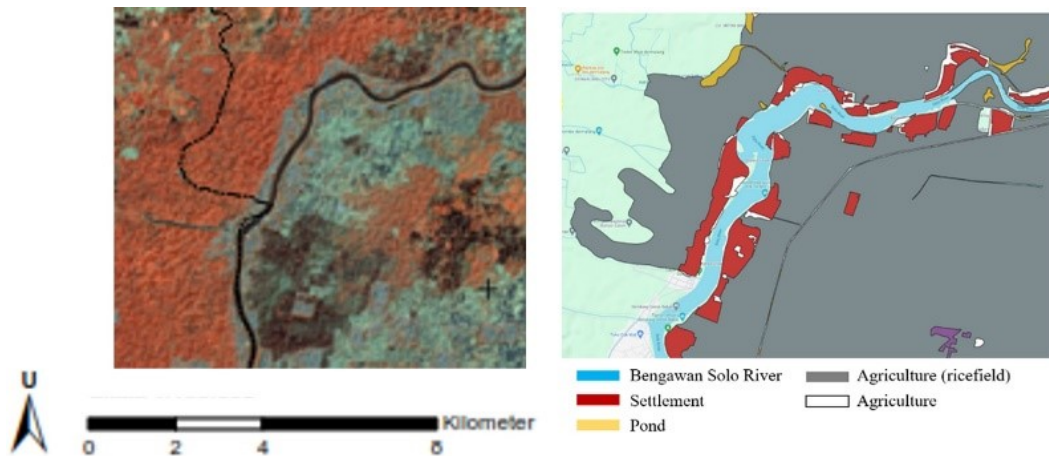


Figure 2: Land cover
Source: Rupa Bumi Indonesia (2024)

The map image in Figure 2 shows the area and also provides information on the land and water cover, as well as the slope classification.

Geographical characteristics were analyzed based on the environmental conditions of residential areas in the Bengawan Solo River downstream, specifically Sekaran Village, Lamongan Regency. The focus was on the determination of the vulnerability to inundation flood. This was achieved through the classification of land slope, depth, and period of flood inundation in Table 1, land use in Table 2, and space configuration in Table 3.

Table 1: Geographical profile classification

No	Classification	interval	Inundation depth (cm)	Inundation period (Hr)
1	Not Harmful	0 – 3 %	0 – 10	0 – 48,4
2	A little dangerous	3.1 % – 8 %	11 - 30	48,5 – 96,8
3	Quite dangerous	8.1 % - 15 %	31 - 50	96,9 – 145,6
4	Dangerous	15,1 % - 30 %	51 - 70	145,7 – 194
5	Very dangerous	> 30 %	> 70	> 194

Source: Sabaruddin (2013)

Table 2: Land use

No	Land Use
1	Agriculture
2	Fishery
3	Mining
4	Industry
5	Settlement

Source: Sabaruddin (2013)

Table 3: Configuration variables

No	Variables	Indicator
1	Configuration	Axial map
		Integration
		Depth
2	Settlement	Physical orientation
		Nonphysical orientation
		Pattern

Source: Hillier (1984) and Analysis result

The configuration was analyzed by focusing on settlement patterns with criteria such as the relationship between road spaces. This was achieved using the newest Depthmap-X 0.50 tool developed by Turner to analyze social movement through axis, visual, and isovist lines (Turner, 2004). The integration and depth values showing the level of space between road and settlement are presented in Table 3. Moreover, the model applied to analyze urban typology was the space syntax method, which focused on the integration and depth of space as well as the relationship between influential elements. The type of open space in the neighborhood was assessed through the solid-void method. This is based on the criterion that the solid is the area covered by buildings, while the void includes the gaps between buildings, roads, and open space (Trancik, 1986).

The results of mapping and space configuration analyses were used to determine settlement typology with a focus on the patterns, orientation, types of open space, and tendencies toward regional space. These were based on geographical characteristics formed in the Bengawan Solo River downstream.

ANALYSIS AND DISCUSSION

The analysis results of geographical characteristics showed that the research area had a land slope of 0-2%, classified as a low category. The land use pattern was observed to be mainly for the productive cultivation of rice and corn. Moreover, the analysis of flood vulnerability showed that the inundation depth was 30 cm, and the longest duration was 72 hours. This led to the application of different housing models such as ground floor elevation, stage, and floating.

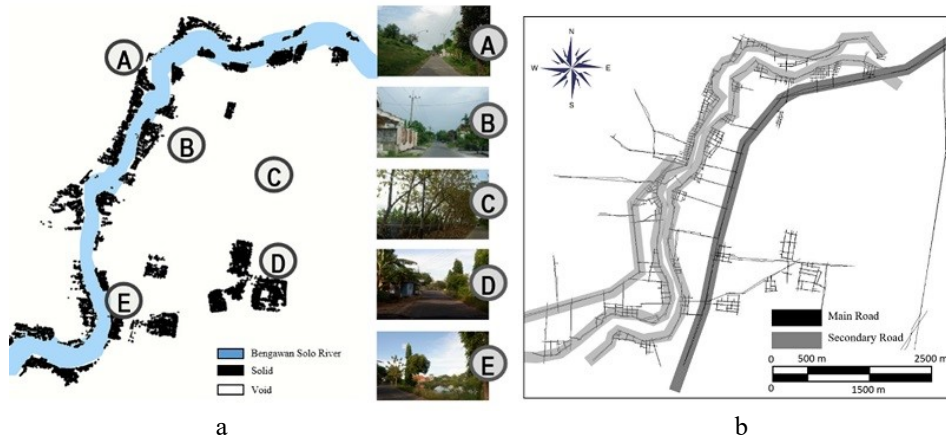


Figure 3: settlement area and street corridor

The urban character was the main road corridor, which functioned as the access to the land, as presented in Figure 3. Meanwhile, the secondary road corridors were concentrated along the river area for settlement. It was also observed that there was an elongated pattern following the river flow, as shown in Figure 3a, with a cluster representing each residential group, and the commercial area was found in the space around the river. The result also showed that the width of the main road was 7 meters while the neighborhood road had 3 meters, as shown in Figure 3b. Settlement was observed to have access to the riverbank, which was designated as the development zone.

The axial result in Figure 4 shows that the red aspect of the space corridor has the highest integration value of 0.85, while the blue has the lowest, 0.26. This showed that the space corridor was the most dominant by serving as the endpoint as well as the connection between the surrounding road spaces, leading to the main road. It was further observed that the R^2 value of the zone was 0.035, classified as weak.

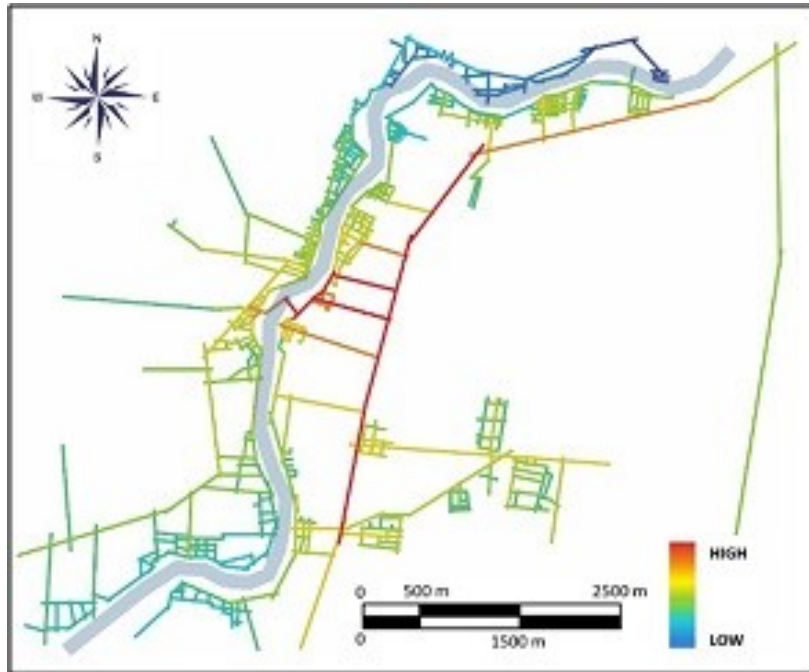


Figure 4: Axial Map Analysis

The analysis of the integration and connectivity showed that residential areas are accessible through a hierarchy of roads tiered towards the main road. The result also showed that the further distance of the connecting road space to the main road corridor was 28. Moreover, land use was dominated by agriculture, leading to the prioritization of access to agricultural land and residential areas, as well as the tendency of the community to gather and orient on the riverbank. Table 4 shows that the effect of connectivity on spatial integration was + 0.532079. This means that a lack of connectivity between areas can reduce spatial integration.

Table 4: Configuration result

ATTRIBUTES	High	Low
Nilai <i>Integration</i> (HH)	0.26	0.84
Nilai <i>Connectivity</i>	1	29
Nilai <i>Step depth</i>	0	28
Nilai R^2 (Regresi)	0.0352644	
Nilai $Y = X$	$Y = 0.00776491 x + 0.532079$	

Source: Analysis result (2024)

The spatial configuration showed that the settlement was oriented towards the riverbank area to meet the basic needs of life and utilize natural resources. The river was observed to be the main natural resource considered important for survival, and the adaptation of settlement was the major element of regional resilience, in addition to the mitigation of disasters. This was identified from geographical characteristics such as inundation flood vulnerability, land slope, and dominance of agricultural land that led to the settlement pattern of the research area as described in Figure 5.



Figure 5: Settlement Orientation

Based on Figure 5a, the road corridor is a physical factor influencing settlement patterns. This was because the physical orientation and direction of buildings were based on the flow of the road corridor that functioned as the main circulation access and link between the settlement and outside areas. The trend shows that the performance of a settlement can be determined through the existence of the road corridor. Meanwhile, Figure 5b shows the non-physical residential areas, and buildings are observed to be oriented towards agricultural areas. The intention is to ensure the control and security of the surrounding agricultural land. The non-physical orientation is important because the majority of people are farmers cultivating the surrounding land.

Open Space

Figure 6 shows that there are two different types of open space in the research area, including the road and productive green spaces. The road is the main open space often used for both ordinary social interaction and special community activities such as traditional ceremonies. Meanwhile, productive green space is

in the form of agricultural land, normally used for social interaction during the process of farming.



Figure 6: Open space existing

The setting of open space

The river boundary line around the research area is presented in Figure 7. Riverbank is observed to be utilized for different activities such as agriculture and fisheries.



Figure 7: settlement area and riverbank area

Source: Result Analysis, Processed from Google Earth (2024)

The trend shows that open space was zoned to ensure proximity to the people and accommodation of different activities. This was observed from the placement of residential areas in riparian spaces, agricultural settlements designated through orange color, as well as riverbank and agriculture presented in blue and red, respectively, in Figure 7. Moreover, open space, including gardens and support facilities for agriculture, serves as the transition between the settlement and the agriculture-river border in Figure 8.



Figure 8: Urban setting, riverbank, settlement, and farming

Open space is arranged to provide a transition that combines the urban park for residents, a waterfront area, and a plantation arrangement. Meanwhile, the agricultural area is equipped with supporting buildings that function as fields, greenhouses, and a mini traditional market.

CONCLUSION

In conclusion, this research aimed to understand the adaptation of settlement through the utilization of available resources for survival. The geographical profile of the research area showed a low slope and potential for inundation flood, thereby providing the community with the local knowledge to turn the disasters into natural resources through agriculture, fisheries, and trade. This shows that downstream river areas with floodplain landforms have high economic value for people capable of managing the condition. Therefore, there is a need for accurate spatial management for regional resilience. Some of the inundation flood management identified in residential areas was the elevation of the ground floor of buildings, stilt structures, and floating house models. The geographical settlement adaptation has led to the continuous development of the area to have a regional center with a space configuration consisting of roads, buildings, and land use.

Settlement pattern analysis showed physical and non-physical orientation to ensure the relationship between humans and space reflected the characteristics of rural areas. The physical aspect was observed oriented towards the direction of the road space, while the non-physical aspect is related to agricultural land. Moreover, social relations and interactions were conducted in an open space.

Naturally, without any special design, such as the road and productive green spaces. The spatial configuration was observed to influence the thematic open space used in transiting between waterfront, residential, and agricultural areas. Therefore, open space was identified to provide an additional function in addition to the utilization for agricultural purposes.

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