SPATIAL MODELING OF LAND USE CHANGES IN THE NORTH COASTAL CITY OF SURABAYA

By

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Abstract

The North Coast of Surabaya City has a dynamic development which is the result of the driving and inhibiting factors of the city's development. The driving factor that has a high significance for the development of the north coast of the city of Surabaya is the activity of Teluk Lamong Harbor, good accessibility to the city center. Based on this, this study aims to predict changes in land use in the North Coast of Surabaya City based on the perspective of a balance point formed from the driving factors (economic driving factors) and inhibiting factors (ecological factors).

The analytical method used is Markov-cellular automata is a type of artificial intelligence based on iteration calculations on raster data. The iteration is carried out on raster data on the probability of land use change which is formulated from the multi-factors driving land use change and inhibiting land use change. The number of pixels that became the reference in the iteration process was analyzed using Markov analysis. In formulating the probability map of land use change, logistic regression methods and artificial neural networks are used.

The research results are expected to be divided into four analysis outputs, the first point is the prediction of the distribution of tidal inundation in the next 20 years. The results of the analysis at this stage will be used in the analysis of the probability map of land use change as an inhibiting factor for land use change. The second point is to identify the factors that influence land use change. Factor identification was performed using v-cramer's analysis which was used as the basis for cluster and cellular automata analysis. The third point of this research is the output of cluster analysis based on the sub-region's response to the factors that influence the development of the city. The analysis was carried out on raster data using Raster Multidimentional Scaling analysis so as to be able to produce cluster analysis that was able to explain urban phenomena spatially. The fourth point in this study is to formulate a spatial model of land use change that is able to accommodate the response of spatial patterns to the balance point resulting from factors and trajectorically able to explain the pattern formed from each response change in the same area.

Keywords: Markov, Cellular Automata, Land Use Change, Land Use

1.1 Background

The North Coast of Surabaya City has a dynamic and heterogeneous regional development. This heterogeneity and dynamics is the implication of the different characteristics of urban sub-areas that are different both in terms of thematic development, urban functions and differences in the factors driving and inhibiting urban development. Some areas have indications of stagnation due to the influence of sea tides which result in a decrease in land value. For areas that have good adaptation to disaster factors, they have a faster and more massive development acceleration when compared to areas that do not have sufficient capacity to respond to tides.

The driving factors that have a high significance for the development of the north coast of Surabaya City are the activities of Teluk Lamong Harbor, good accessibility to the city center and differences in the hierarchy and function of the bordering area. Each urban characteristic and land use class type has a different response to these factors which are the result of the equilibrium point from the economic aspect which is the result of the driving factors and the ecological aspect as the limiting factor. Based on this, this study aims to predict changes in land use in the North Coast of Surabaya City based on the perspective of a balance point formed from the driving factors (economic driving factors) and inhibiting factors (ecological factors).

The results of the research are expected to formulate a spatial model of land use change that is able to accommodate the response of spatial patterns to the balance point resulting from factors and trajectorically able to explain the pattern formed from each response change in the same area. Based on this, this research will predict land use that accommodates the above factors in order to determine the size, spatial, temporal and visualization to formulate sustainable planning.

1.2 Research purposes

This study is intended to model the trend of land use development and predict the area and direction of development of the North Coast of Surabaya. The following are the objectives and research questions in this study.

1. Predicting the area of tidal inundation on the North Coast of Surabaya City in
2. Identify factors that influence land use change
3. Identify regional clusters based on the homogeneity of responses to factors that affect land change

1.3 Scope

The scope of the area in this study is the north coast of the city of Surabaya. Meanwhile, the scope of discussion in this study assumes that the conditions of land use change on the north coast of Surabaya City during the years 2002-2022 have a pattern or trend that can be reflected for the next 20 years. The analysis conducted in this study is limited as follows.

1. The modeling of tidal inundation in this study did not take into account the factors of land subsidence and shoreline changes. The factors used are DEM and the highest tides.
2. Land use modeling in this study does not accommodate the new land use class, which is not included in the projection base map, namely the existing land use map.
3. This study did not formulate land suitability in the formulation of the probability map of land use change. The map of the probability of land use change is generated from the pattern formed by the independent variable (land use class) and the independent variable (factors that affect changes in each land use class). This is done so that the prediction results truly reflect the adaptation of each land use to tidal inundation.

1.4 Research Contribution

In this study, the benefits of research are divided into two, namely theoretical benefits and practical benefits. The theoretical benefit of this study is the development of regional planning science. In this study, we will discuss methods for predicting the spatial development of urban areas, especially for areas that have developmental inhibiting factors in the form of tidal inundation. Thus, it can help researchers to understand the urban phenomena that occur on the north coast of Surabaya City more clearly. In addition, the expected benefit of this study is to provide important input to planners, government and society in predicting and making appropriate spatial policies.

1.5 Literature review

1.5.1 Impact of Tidal Inundation on Land Use

The trend of urban development on the island of Java forms a pattern of ribbon development, which is linear in the coastal areas, especially in the northern coastal areas of Java. This phenomenon has resulted in tidal inundation which is one of the disasters that has great potential to cause disruption to development activities and activities. According to Wuryanti (2002) the impact of tidal inundation is the inundation of land which increases coastal erosion and intrusion of seawater into the mainland, both of which have implications for the decline in clean water quality which results in health problems and a decrease in agricultural

productivity. According to Marfai et al. (2008), tidal inundation has an impact on people's daily activities such as domestic activities and other work. Public services that function to support domestic activities such as water supply and electricity cannot be used during high tides. The reason people don't work during high tides is that the trip is disrupted and there is no access to work and to take care of their families and household appliances. Based on the above, if it is correlated with the function of the coastal urban area which has regional functions as a port area, industry and warehousing, tourism, settlements. Tidal inundation is a very serious threat to the urban system, both from the internal and external aspects of the area. Tidal inundation as a negative externality from the environment has a significant impact on land value decline, areas that have a history of disasters tend to reduce land values that are low (Yunus, 2008). This decrease in land value has an impact on the lack of interest in land so that it has an impact on meeting land needs. The lack of interest in land that has a history of tidal inundation can result in changes in land use as an adaptation to land value decline.

1.5.2 Factors that cause tidal inundation

Tidal inundation can cause material losses and lead to a surge in personal or community needs. Many factors influence or cause an increase in tidal inundation in coastal areas. According to Marfai (2003) in general the cause of this increase is due to sea level rise, land cover changes, human population increases, and land subsidence. These three factors have a positive correlation with the increase in the incidence and area of tidal inundation in coastal areas. This was added by Hildaliyani (2009) who stated that the factors that influence the increase in the level of vulnerability to tidal inundation are changes in land cover from undeveloped land to built up land, changes in coastline, sea level rise. Based on this, if it is correlated with conditions on the coast of Surabaya City which has a phenomenon of a low rate of land subsidence, and a low rate of land cover change, this variable is not used as a variable in modeling tidal inundation. The variables used in this study as modeling variables for tidal inundation are sea level rise (HHWL) and DEM. If it is correlated with conditions on the coast of Surabaya City which has a low rate of subsidence and a low rate of land cover change, this variable is not used as a variable in modeling tidal inundation. The variables used in this study as modeling variables for tidal inundation are sea level rise (HHWL) and DEM. If it is correlated with conditions on the coast of Surabaya City which has a low rate of subsidence and a low rate of land cover change, this variable is not used as a variable in modeling tidal inundation. The variables used in this study as modeling variables for tidal inundation are sea level rise (HHWL) and DEM.

1.5.3 Land Use

According to Jensen (2000) land use is the designation and management activities in land management based on human interests such as settlements, offices, gardens, recreation areas and so on. Added by Arsyad (2010) land use is defined as any form of human intervention (interference) on land in order to meet the needs of life, both material and spiritual. Land use is a physical manifestation of objects that cover land and are related to human activities on a plot of land (Lillesand and Kiefer, 1987). Based on the above theory in this research, land use is the designation and management activities in land management in order to meet the needs of life, both material and spiritual.

1.5.4 Factors influencing land use change

Changes in land use can be influenced by two factors, the first is the factors that encourage physical, economic and social development of the region and the second is the factors that hinder the physical, economic, and social development of the region. The factors used in this study are distance from the CBD, distance from trade and service centers, distance from urban facilities, distance from industrial centers, level of accessibility to growth centers, distance from growth centers (trade and service centers) in areas bordering the research area. , slope, distance at the point where the road system meets, historical disaster. The following is the underlying theory related to this study:

No	City Development Theory	Substance	Factor
1	Growth Pole Theory	1. Urban development (land use) is influenced by growth centers in the form of the CBD. CBD as a growth center has a locational advantage effect for areas that have a high level of accessibility to CBD. 2. Urban development (land use) is influenced by growth centers both functionally (industry) and geographically (concentration of facilities). The growth center in the form of an industrial area significantly affects the development of the city. This is based on the fulfillment of the need for industrial activities in the form of industrial worker settlements so that the closer the area is to the industrial center, the higher the potential for the area to develop. If viewed from the service center, development will be more directed to areas that are included or reached on the scale of service facilities so that the closer to the center of the facility, the higher the potential for the area to develop. 3. City development (land use) is influenced by proximity to areas that have a function as a provider of goods and services (trade and service centers) 4. Urban development (land use) is influenced by the level of accessibility to the growth center area.	1. CBD Center 2. Trade and Service Center 3. Industrial Center 4. Centralization of facilities 5. Accessibility to growth centers
2	Urban Base Theory	1. Urban development (land use) is influenced by the provision of goods and services in the internal area of the city, also influenced by the provision of goods and services in areas directly adjacent to the city itself.	1. Growth Center (center of industry, trade and services) in the area bordering the research area
3	City morphology theory	1. Urban development (land use) is influenced by slope. Built-up areas in modern conditions tend to be built on flat slope conditions 2. Urban development (land use) is influenced by the road network and especially the circulation system – transportation routes and meeting points (nodal points). This meeting point or nodal has a tendency to be the peak of land value so that it has great potential in the development of built-up land 3. Urban development (land use) is influenced by historical disasters. Disaster history is an inhibiting factor for urban development. Areas that have a historical disaster have low land values so they are less attractive.	1. Slope 2. Roads and meeting points between road networks 3. Disaster History

Table 2.1Theory of Land Use Change

Based on the theory related to regional development, the factors used in this study are distance from the CBD, distance from trade and service centers, distance from urban facilities, distance from industrial centers, level of accessibility to growth centers, distance from growth centers (trade and service centers)) in the area bordering the research area, slope, distance to the meeting point of the road system, historical disaster.The following are previous studies that underlie this research:

No	Title	Writer	Source	Target	Variable	Method	Output
1	GIS Modeling in Coastal Flooding Analysis : A Case Study in the Yellow River Delta, China	Xiajun Yang	Department of Geography, University of Georgia	1. Knowing the new areas of flooding	-Land-wide use	DEM and Idrisi Analisa analysis	find out new areas of flooding caused by high tides
				2. Knowing the probability of a new flood area	-broad-probability		
				3. Knowing the new flood area with a risk level of 20%	-Land-wide use		
2	Simulation of Urban Land Development and Land Use Change Employing GIS with Cellular Automata	Tsai-chu Wu, bo-yi Hong	Dept. of land management and development , Chang Jung christina university, Taiwan	1. Knowing the variables that affect land change	-vacant use, residential use, commercial use, official land, school sites, parks, roads, gas stations and parking lots, sewage farm and substation, conserved land. land price, land price growth rates, the number of land ownership, population: Unit grid average population, the number of public facilities, distance to the nearest roads, floor area ratio.		Land Use Prediction in 2016
				2. know the probability of land development model		Model logistic regression	

No	Title	Writer	Source	Target	Variable	Method	Output
				3. Prediction of land use change 2007-2016		Cellular Automata Simulation	
3	Vulnerability assessment of combined impact of sea level rise and coastal flooding for china coastal region using remote sensing and GIS	Jie Yin, Shiyuan Xu, Jun Wang and friends	Department of Geography Shanghai Normal University	1. vulnerable land areas with high tides		DEM analysis	identification of coastal areas of China that are vulnerable to flooding caused by rising sea tides.
				2. rental land area with high tide flood	-high tide prediction sea-year-wide impact from flooding on land	DEM analysis	
				3. social and economic vulnerability			
				4. strategy and adaptation			
4.	Determination of land use effect on flood risk by using integration of GIS and remote sensing	irfan roots and friends	dept. of middle east geographu beyazit, istanbul, turket	1. Land use characteristics and hydrological risks	-Classification of land use -history of flood events	supervised classification using erdas 9.1	making flood modeling based on the frequency of repetitions per year 10, 50, and 100 years
				2. hydrological modeling and flood mapping	-river flow-river cross-sectional-land use	modeling flood repetition frequency	
				3. the creation of the flood model		Using HEC Georas modeling	
5	STUDY OF THE IMPACT OF LAND USE DYNAMICS ON EROSION AND HYDROLOGICAL CONDITIONS OF WANGGU WATERSHED	La Ode Alwi1, Naik Sinukaban2, Soleh Solahuddin 2, and Hidayat Pawitan2		1. The dynamics of land use in the Wanggu watershed	-classification of land use-year-area change	last year and most recent year area calculation	determine the influence of land use dynamics with erosion and hydrological conditions
				2. Impact of land use dynamics on erosion and hydrological conditions	-prediction of erosion-surface runoff-surface flow coefficient-river regime coefficient	comparison of land use dynamics in different years	
				3. evaluation of land use suitability	-land capability class-Land use-erosion-Etol	comparison of erosion value and Etol value for each land use class	
6	Simulation of Land Use Change using Genetic Algorithms Neurology Network Based Cellular Automata	Cao Min, Shi Xiao	Key Laboratory of Virtual Geographical Environment Ministry of Education,	Comparison of results from land use prediction using ANN-CA and GANN-CA	-model accuracy value		This study shows that the GANN-CA model has better simulation results with smaller neural

No	Title	Writer	Source	Target	Variable	Method	Output
			Nanjing Normal University				network errors and higher accuracy results.
7	Simulation of Precise Scale Land Use Change Based on the Markov-cellular Automata Model	Shuqing Wang, Xinqi Zheng, Lin Wang	School of Land Science and Technology China University of Geosciences	1. Land use change analysis 2001 and 2005	-Land use-area comparison	Cellular Automata-Markov	based on the results of the study show that it is possible to simulate future land use change using precise and high-resolution maps
				2. Land Use Prediction in 2012	-Land use-area comparison		
8	Research of Flood Risk Map Information Management System Based on ArcGIS	Hongliang Gou, Shuguang Liu, Guihui Zhong	Department of Hydraulic Engineering, Tongji University, China	create a flood risk map information management system	-map data-Social geography-Hydrological data-Engineering data-Rescue Materials	GIS Analysis	creation of a flood risk map information management system based on GIS
9	Global land-use and land-cover change : What we learned so far	HJ Geist and Ef Lambin		Knowing the influencing factors of land use change	-big economic changes-technological effects-social-political factors-changed policies		factors influencing land use change
10	modeling land use land cover changes using cellular automata in a geo-spatial environment	Anuj Kumar Singh	international institute for geo-information science and earth observation, Enschede, Netherlands	Identification of land use classification	-Land Use Class-Year	Cellular Automata Analysis	land use prediction
				Knowing the factors that affect land use	-rainfall-slope-slope-height-aspect-distance from roads-distance from city-distance from tourist center-distance from industry		
				Land use prediction			

Source: Literature Review, 2022

1.6 Research methodology

The research approach used is a rationalism approach, which is a method that believes that the source of truth comes from sensual empiricism, logical empiricism (thought, abstraction and simplification) and ethical empiricism (idealism and reality) (Djumaedi, 2002). The purpose of research with a rationalism approach is to build a theoretical conceptualization

related to multi-hazards and land use vulnerabilities that are realistic so that they are accessible to human reasoning. This type of research is descriptive research which aims to make a systematic, factual and accurate description of the facts and characteristics of certain research objects.

The analytical method used to predict land use change in the North Coast of Surabaya was carried out in four research targets. The first stage is the prediction stage for the distribution of tidal inundation in the next 20 years. Analysis related to the prediction of the distribution of tidal inundation using two data, namely HHWL and DEM. The results of the analysis at this stage will be used in the analysis of the probability map of land use change as an inhibiting factor for land use change.

The second stage is to identify factors that influence land use change. Factor identification was performed using v-cramer's analysis. This analysis is carried out on every land use change identified in the North Coast of Surabaya City for the period 2002 – 2022. In predicting land use change, in addition to analyzing the factors that influence land use change, an analysis related to the trend of land use changes is also needed.

The third stage of this research is to conduct a cluster analysis based on the sub-region's response to the factors that influence the development of the city. The analysis was carried out on raster data using Raster Multidimentional Scaling analysis so as to be able to produce cluster analysis that was able to explain urban phenomena spatially.

The fourth stage in this research is an analysis of the tendency of land use changes to determine the type of land use change that occurs and the direction of the land use change. Probability analysis of land use change is also carried out in this third stage. This analysis is useful for identifying areas that have the potential to experience land use change. Probability analysis of land use change is carried out on each type of land use change identified.

The results of the analysis of stages I, II, III and IV are used as the basis for the analysis of land use change. So it can be concluded that in the analysis of land use changes, three core data are needed, namely factors that affect land use changes, trends in land use changes and the probability of land use changes. Figure 1 presents an explanation of the analytical method and a description of the analysis used based on the research objectives.

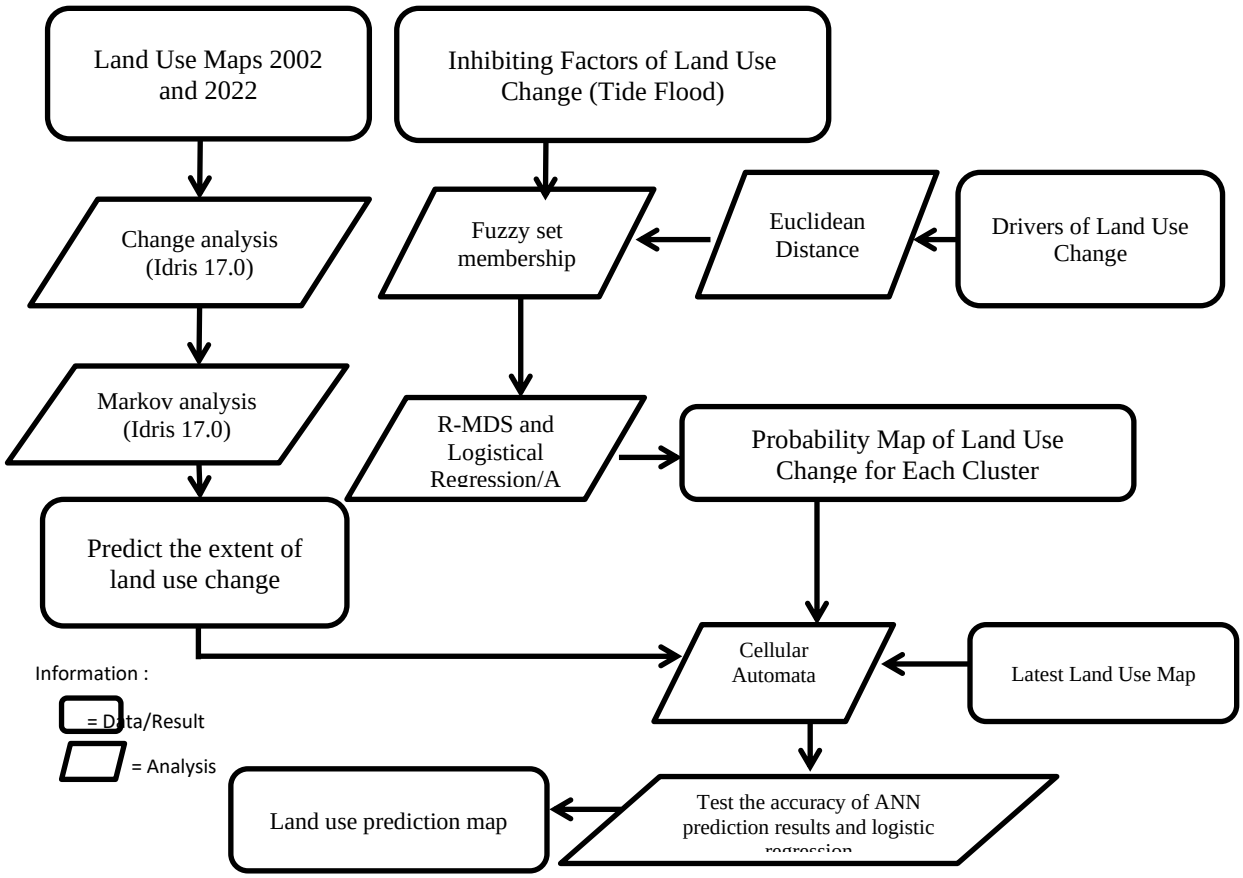

Figure 1. Flow of Research Methodology

1.7. Results and Discussion

1.7.1 Predicting the area of tidal inundation on the North Coast of Surabaya City

Prediction of the distribution of tidal inundation in the North Coast of the City of Surabaya adapted from the research of Pratomoatmojo (2012). The data used in this analysis are DEM and the highest tide (HHWL). The DEM used in this analysis is the DEM from spline interpolation.Spline interpolated DEM has the lowest RMSE value so it has the highest level of validity when compared to the kriging interpolation method.**Figure 2**presents a flow analysis of the distribution of tidal inundation in the North Coast of Surabaya City.

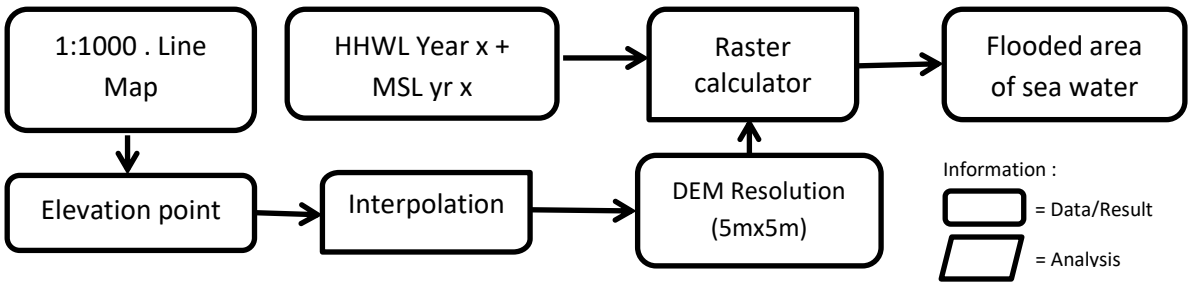

Figure 2. Inundation Potential Analysis Flow

In the raster calculator process, the equations used in the modeling to produce a tidal inundation area are as follows.

Inun2030=CON([DEM] <= HHWL), 1, 0).....(1)

The above equation is used to model inundated and unflooded areas. The flooded area is symbolized by 1 and the unflooded area is 0. The next analysis is to determine the maximum height using the following formula .

L_inun=[Inun] * HHWL.....(2)

This equation is a transition equation to formulate the depth and inundated area . The basic data in this study are DEM modeled results and HHWL.

Depth2030 = CON ((([L_inund]-[DEM_]) *[Inun])
0,0,Depth)…….... .(3)

1.7.2 Identifying factors that influence land use change in the North Coast of Surabaya City

The analysis to identify the factors that influence land use change in the North Coast of Surabaya City uses a quantitative factor analysis method using the v-cramer's value.V-cramers were used to measure the strength of the association between variables. In this study, the lower limit value used as a reference that the land use factor has a relationship or correlation with land use changes is 0.20. The factor having v-cramer's value 0.20 is used as a factor of land use change.

The identified factors are then used in the next stage, namely in the stages of logistic regression analysis and neural network analysis. Factor treatment in logistic regression analysis and artificial neural network analysis had significant differences, in logistic regression analysis

the second factor analysis was carried out after factor analysis using v-cramer's. Factor analysis performed in logistic regression analysis is the ROC value, pseudo R-square value and standard deviation. Meanwhile, in the analysis of artificial neural networks, the factors resulting from the v-cramer's analysis are directly used as factors that influence land use changes.

1.7.3 Identify regional clusters based on the homogeneity of responses to factors that affect land change

This sub-chapter discusses spatial analysis to perform cluster analysis where the analytical tool used is R-MDS or multidimensional scaling raster analysis which is more directed at uniform non-hierarchical clusters, the selection of non-hierarchical clusters as the basis for analysis is adjusted to the type and purpose of the analysis. where the type of data used does not represent strata and the purpose of the analysis is to find a homogeneous cluster of spatial data (raster) that is able to represent in detail the character of the area based on the inhibiting and driving factors of urban development.

1.7.4 Predicting the land use of the North Coast of Surabaya to accommodate tidal inundation

In this sub-chapter, we will discuss the prediction of land use on the North Coast of Surabaya City. This land use prediction analysis is divided into three stages, namely making a map of the probability of land use change, prediction of pixel changes from each land use class and prediction of land use change. The following is a scheme that presents the analysis stage in producing a predictive map of land use change

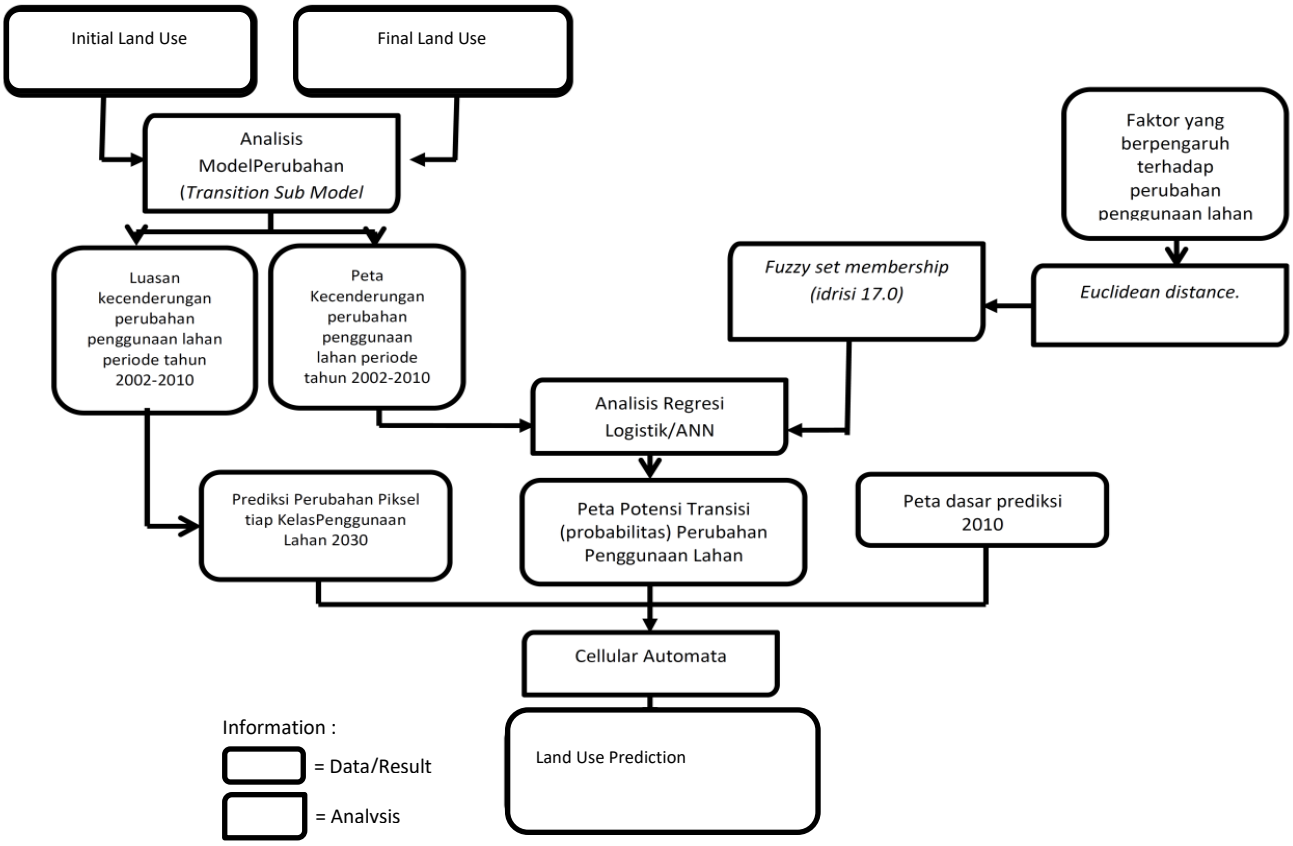

Figure 4. Prediction Flow of Land Use Change

In the stage of making the probability map of land use change, it is divided into four stages of analysis. The analyzes are Euclidean distance analysis, fuzzy set membership analysis, logistic regression analysis and artificial neural network analysis. This Euclidean distance analysis is a representation of the factors that influence land use change. These factors focus on the magnitude of the distance between a location and the growth center where each factor has a high correlation with the growth center. The results of the Euclidean distance analysis that contain distance information from each factor that affects land use change have different intervals. These different intervals have several drawbacks when analyzed statistically. The difference in the value of the upper and lower limits of each result of the Euclidean distance analysis significantly affects the reduction in the level of validation of the model to be analyzed. Therefore, in this study, the standardization method will be used using fuzzy set analysis, namely by equating the upper and lower limits of each factor analysis result.*Euclidean distance* to 0 (lowest) and 1 (highest). If correlated with*Euclidean distance*

the closer to the center of growth or factors that affect land use change, the higher the value. Fuzzy can homogenize data values from the range 0 (low) to 1 (high) so that in data analysis there is no need to do a Z-score to make the data standard. In this study, the fuzzy set used is the sigmoidal type (monotonically decreasing).

This monotonically decreasing type is formed on the driving factors of urban development because each factor has a function as a growth center. The center of activity has a tendency, the closer it is to the growth center, the higher the potential for an area to develop and vice versa, the farther from the growth center, the lower the potential for an area to develop. In determining the values of c and d in the sigmoidal equation, c is the distance o from the factor and d is the farthest identified distance from the factor.

The results of this fuzzy analysis are then used in logistic regression analysis and neural network analysis. Specifically for logistic regression analysis, factor analysis was performed again, while in the analysis of artificial neural networks, the results of factor analysis using v-cramer's were directly used in the analysis of artificial neural networks in the formulation of probability maps of land use change.

Based on the results of logistic regression analysis and the artificial neural network used to formulate the land use probability map, the next step will be to analyze the prediction of land use change using the cellular automata method. In the modeling phase of land use change prediction, the cellular automata method is used with the Idrisi 17.0 analysis tool. In this analysis using three data, the following are the three data used in this analysis.

a. Land use base map: as for this research is the land use map of the early years as the last multitemporal data.
b. Land use probability map: map of the probability of land use change from the spatial results of logistic regression and neural network analysis.
c. Number of land pixels that changed: the predicted result of pixel changes from each land use class at the end of the prediction. The maps that are used as a reference for predictions are the 2002 and 2022 maps.

1.8 Conclusion

Based on the explanation of the mindset above, the following are the conclusions from the above study:

1. Conceptually, historical disasters have a negative correlation with the acceleration of development or the development of a city. By using the perspective in this study, it is expected to be able to identify response anomalies from historical disasters to urban

development. In addition, by using this mindset, spatial phenomena can really be analyzed spatially (raster data) using data, analytical tools and outputs that are able to explain spatial phenomena quantitatively and measurably.

2. In conceptual analysis, the study is directed to use spatial analysis tools using raster basic data which has a basic analysis pattern similar to matrix analysis. So that each component of the spatial data and spatial characteristics can be explained in detail spatially
3. Conceptually, this study aims to determine the balance point that is formed as a result of the driving factors that lead to the economic aspect and the limiting factors that lead to the ecological aspect.

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