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Article

Water Quality Pollution Control and Watershed Management Based on Community Participation in Maros City, South Sulawesi, Indonesia

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Abstract: Increases in the number of urban residents have significant impacts on spatial pressure, affecting the utilization of river basins. The purpose of this study is to analyze (1) the increase in population and changes in spatial use as determinants of the complexity of the watershed ecosystem; (2) the effect of housing development, urban activity systems, and land use changes on the degradation of the environmental quality of the watershed; and (3) the direct and indirect effects of changes in spatial use, land reclamation, and community behavior on water pollution and the sustainability of watershed management in Maros City. The research method used is a sequential explanatory design combining quantitative and qualitative research methods. Data were obtained through observation, in-depth interviews, surveys, and documentation. The study findings show that land use change, complexity of spatial use, and community behavior have a negative impact on the environmental quality of the watershed. Housing development, urban activity systems, and changes in land use had a significant effect on environmental quality degradation, with a coefficient of determination of 73.9%. Furthermore, the influence of spatial use, land reclamation, and community behavior on water pollution in the watershed was 72.82%. This study may serve to assist the decision-making of and policy formation by the Maros Regency Government in the framework of controlling the use of watersheds, working towards their social, economic, and environmental sustainability.

Keywords: spatial use; city activities; ecosystem complexity; people's behavior; water quality pollution

1. Introduction

Urbanization is synonymous with the growth of large and medium cities. Increasing populations and rural-to-urban migration have accelerated urbanization globally, permanently transforming natural systems to a large extent [1]. Urbanization is dominant in the main cities of countries, due to the accumulation of capital and economic growth (which are the main attractions

for the rural population). The processes of industrialization, rural–urban migration, absolute and relative urban population growth, and increasing national prosperity are similar in rapidly urbanizing developing countries [2,3]. Furthermore, the rapid growth of the population accompanies significant industrial and agricultural development that impacts the environment with all its components, and thus impacts the surface water [4]. Furthermore, the world's water resources are stressed due to high demand and limited availability. The need for drinking water, food production, and environmental protection are increasing as the world population increases [5].

Cities in East Asia and the Pacific have consistently been the locations with the fastest-growing urbanization rates in the world. Continuous urbanization has occurred over the last century and is still evolving under the differential influence of population growth and migration [6–10]. In 2019, it was recorded that 58.9% of the Indonesian population lived in urban areas. As this transformation is ongoing, there are still opportunities to shift the course of urbanization towards a more sustainable and equitable path [11]. Indonesia has become one of the countries with the largest urban population in the East Asia and Pacific region. This rapid rate of urbanization has opened up a number of opportunities for Indonesia. On one hand, economic growth has been steadily promoted while, on the other hand, the problems of poverty and unemployment have increased [12]. Thus, urbanization not only has an impact on urban growth but also contributes positively to social and economic disparities. Cities, as the focus points of the regional economy, politics, culture, and transportation, attract people from the surrounding areas, due to their numerous employment opportunities, improved infrastructure, and good educational environments [13,14].

A river is a channel or container of natural and/or artificial water, in the form of a water drainage network and the water in it (i.e., upstream of an estuary), bounded to the right and left by boundary lines. Furthermore, a river is a flow of water on the ground that flows into the sea, which is physically divided into three parts: the upstream, the middle, and the downstream [15]. The roles and functions of rivers in the history of human civilization, in relation to the process of city formation, are basically strategic (e.g., as a basis for urban growth, for the fulfillment of clean water needs, and as a means of water transportation). Rapid urban expansion often has a violent impact on the regional landscape, mainly due to the conversion of a large amount of agricultural land into construction land and other urban land types [16]. The provisioning of improved water infrastructure technologies and innovation can address several challenges posed by water shortages to environmental sustainability [17]. Furthermore, an empirical hydrological model is a practical tool that can easily be used to identify and measure the effects of land use change on water catchments for water resource management decisions [18].

The research results that support this study include: first, research conducted by Twisa, S. et al., [19]. The focus of this study was to examine changes in land use/land cover to the environment, towards changes in patterns of ecosystem services and their effects on water supply services. The results showed that shrubs, forest, cultivated land, and grasslands were significantly correlated with water point characteristics in the watershed. Furthermore, the study concluded that changes in land use/cover affect the water ecosystem in the watershed. Second, the study conducted by Rodríguez-Romero, A.J. et al., [20]: this study assessed spatial and seasonal variations in water quality, and the relationship between water quality and land use change in the Bobos-Nautla river, which crosses a patch of tropical cloud forest upstream. The study found the impact of land use change on the quality of river water flowing through cloud forests in the tropical zone, which is currently an endangered ecosystem.

Third, a study conducted by Ding, J. et al. [21], the focus of which was to examine the impact of land use in the catchment on water quality during the dry and wet seasons in the Dongjiang river basin, using remote sensing, geographic information systems, and multivariate statistical techniques. The results showed that 83 sites could be divided into three groups representing different land use types: forest, agriculture, and urban areas. The results of this study found that the use of forested land has a stronger impact on water quality in the dry season than in the wet season. However, use of agricultural land has no significant impact on water quality. This study shows that urban land use is a key factor influencing changes in water quality and limits the disposal of point source waste in

urban areas during the dry season, so it is very important to improve water quality in urban areas. The three results of this study are at a meeting point by emphasizing that land use change has a significant impact on increasing water quality pollution in the watershed. Therefore, the study is more focused on analyzing changes in land use and community behavior towards environmental quality degradation and water quality pollution, as well as their impact on the sustainability of the Maros City watershed. Furthermore, the focus of the study is more specific on water quality pollution control and watershed management based on community participation. Thus, the affirmation of this study is that the increase in development activities in the benefit areas of the river due to the ease of licensing followed by the complexity of space utilization has a positive contribution to the increase in the pollution load of river water quality. Then, controlling water quality pollution and watershed management requires conservation efforts through community participation, changing community behavior, and utilizing local wisdom in sustainable watershed management.

The complexity of spatial use in the watershed has been identified as having an impact on the disruption of the ecosystem which leads to a decrease in environmental quality and river water pollution. Watershed management has a strategic value and urgency to be addressed immediately to ensure the stability of the watershed ecosystem and the distribution of the fulfillment of clean water services for Maros City, Makassar City, and Mamminasata Metropolitan urban area. Furthermore, an increase in environmental pollution in the watershed of Maros City is positively associated with the condition of the urban ecosystem in general. Thus, the focus of this study is aimed at answering the following research questions: (1) How do increases in population and changes in space use function as determinants of the complexity of the watershed ecosystem of Maros City? (2) How do housing development, urban activity systems, and land-use change affect the environmental quality of the Maros City watershed? and (3) Are there direct and indirect impacts of changes in spatial use, land reclamation, and community behavior on water pollution and the sustainability of the management of the Maros City watershed?

2. Conceptual Framework

Watersheds play important roles in the human life cycle and, so, a comprehensive approach is required when dealing with environmental degradation and water pollution. Integrated watershed management is a holistic approach to land and water resource management, with multiple roles and points of contact with land tenure issues [22,23]. A comprehensive approach to watershed management demands an open management system which ensures the continuity of the coordination process between related institutions. In this decentralized management approach, stormwater runoff and pollution are primarily controlled by measures located near the source, striving towards well-integrated measures that perform multiple functions including flood protection, pollution removal, and groundwater recharge, as well as recreation, biodiversity, and urban aesthetics [24].

Watershed management is highly dependent on the nature of the watershed; namely, its soil, climate, rivers, hills, and community activities. Furthermore, the consideration of technology selection is oriented towards achieving targets for land-use, water conservation, and improving the welfare of communities located in watershed areas. Soil erosion is a major threat to the stability of the ecological environment and the harmonious development of communities, providing a major cause of disturbance of natural characteristics and land development. Soil and water conservation are scientific measures that can co-ordinate contradictions between economic development, ecological protection, and the prosperity of citizens [25]. Furthermore, wetland assessment using dynamic hydrological and hydrogeological data sets can provide important insights into wetland level variations, so analysis and interpretation is needed to assess responses to natural/anthropogenic stresses and decision choices for ecological, social, scientific value, and Mitigation measures to secure wetland biodiversity in the catchment basin [26]. The conceptual framework of this study is presented in Figure 1, below.

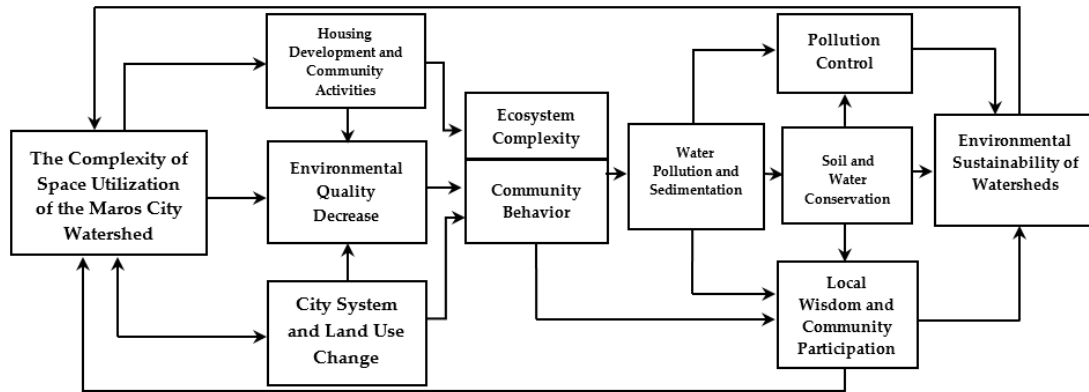


Figure 1. Conceptual framework: land use change, community behavior towards the environment, and environmental sustainability of the Maros City watershed. Source: Author's elaboration.

2.1. Watershed Conservation Based on Local Wisdom

Conservation through integration involves the concept of land and forest rehabilitation by integrating soil and water conservation techniques physically/mechanically and vegetatively, as well as through sociocultural changes in community land management, in order to maintain the function of and to preserve watershed ecosystems. Soil is a precious natural resource that covers Earth's land surfaces, which contributes to basic human needs such as food, clean water, and clean air, as well as being a major carrier for biodiversity [27]. Transboundary river basins are under increasing pressure due to population growth, agricultural and industrial developments, and climate change, as well as river pollution [28].

Two factors influence sociocultural change in society in relation to local values; namely external and internal factors, which move simultaneously. External factors are influenced, among others, by globalization; in this case, political ideologies at the global level, developments in information and communication technologies, and neocapitalism and neoliberalism, which spur pragmatic, consumptive, and individual lifestyles. Internal factors are influenced by transformations which cause the loss of traditional and local values. The modernization of urban development is assumed to have an impact on the fading of traditional values which have long been adhered to and obeyed by the community. At present, watershed management around the world generally does not take into account the land's capacity of use and recovery and prevention potentials [29].

2.2. Land Use Change and Community Behavior towards the Environment

Land use change is the shift in land use, from one use to another, followed by a reduction in the former type of land use from one time to the next, or changes in the function of land at different periods of time [30]. For example, the conversion of agricultural land occurs when agricultural land changes its function from that of the agricultural sector to that of the non-agricultural sector. Change in land use is basically a change in the function of land, from one certain designation to another. Land use and land cover changes have been shown to drive unprecedented changes in ecosystems and environmental processes at different scales [31]. Thus, changes in land-use in a given area typically indicate that it is experiencing developments, especially in terms of the number of physical facilities and infrastructure, in the form of the economy and roads, among other infrastructure types. Such development illustrates that land use change has a tendency to be distributed in certain places; in this case, in addition to the distribution of land use changes, there will also be land use change patterns. The factors that have the greatest influence on land use change are economic activity and population growth, in relation to the provision of housing facilities [32]. Furthermore, watershed environments are fragile and highly threatened due to changes in land use and human behavior [33].

The management of the Maros City watershed environment has a direct relationship with community behavior. Accordingly, several things need to be considered, among others: (1) people with higher education and income (i.e., having a better quality of life) tend to have better behavior;

(2) the pro-environmental behavior of the community towards rivers can be put into five categories of actions, namely (i) being able to carry out waste management with a good system, (ii) caring about river water quality, (iii) managing river boundaries as open spaces and water catchments, (iv) maintaining clean drainage channels such that the urban drainage system (including the rivers in them) can flow smoothly, and (v) sensitivity to the environment in order to manage the river environment collectively by relying on community participation, such that the river can function properly; and (3) public behavior in general, which tends to change when there is an intervention due to the implementation of policies, as well as due to economics and information. Behavioral change interventions based on social norms have been proven to be a popular and cost-effective way, in which both researchers and practitioners attempt to transform behavior in order to increase environmental and social sustainability in real-world contexts [34].

2.3. Community-Based Watershed Sustainability

Ecology is the study of the relationships between living things and their environment [35]. In accordance with the definition of ecology, river ecology limits the “environment” to the environment around the river area. There are two categories of approaches that can be used namely, the “natural physiological ecological approach” and the “urban development approach”. The natural physiological approach examines the ecology of the river from physical and natural environmental aspects. Meanwhile, the urban development approach examines the cultural aspects (or the behavior of people) [36]. Combining these two approaches can facilitate the balancing of humans and their environment from various aspects (e.g., demographic, economic, social, and environmental aspects) in the ecological steps taken [37].

Sustainable development using the concept of integrated watershed management is part of the environmental integration. Thus, it requires continuous watershed management efforts and periodic evaluations from the aspects of relevance, performance, efficiency, and the impact on the objectives of the activity to be achieved. Thus, development does not only see humans as independent individuals, but also considers the impact of development in relation to the position of humans as social beings who care about the sustainability of natural resources. Sustainable development is concerned with economic growth in relation to the environment, which is considered to have an instrumental function, as a means for the satisfaction of human needs without neglecting those of future generations [38,39].

3. Material and Method

3.1. Research Design

The research method used was a sequential explanatory design combining quantitative and qualitative research methods. Referring to the focus and objectives of this study, the emphasis of the study was directed at assessing the increase in population and changes in the use of working space as determinants of the complexity of the watershed ecosystem of Maros City. Thus, this research is naturalistic, rationalistic, holistic, cultural, and phenomenological [40,41]. The aim was to describe the object of the study in a deep, detailed, and holistic way. Thus, the choice of approach for this study was a case study. For the case study, the following considerations were made: (1) the intensity of land use change in the watershed of Maros City is very complex; (2) the nature of the case has a very prominent pattern, consistency, and sequence, in relation to the degradation of the environmental quality of the watershed and its impact on the urban conditions of Maros City; and (3) the context of the Maros watershed case has a direct connection with the socio-economic dynamics of the community. The combination of qualitative and quantitative research is shown in Figure 2.

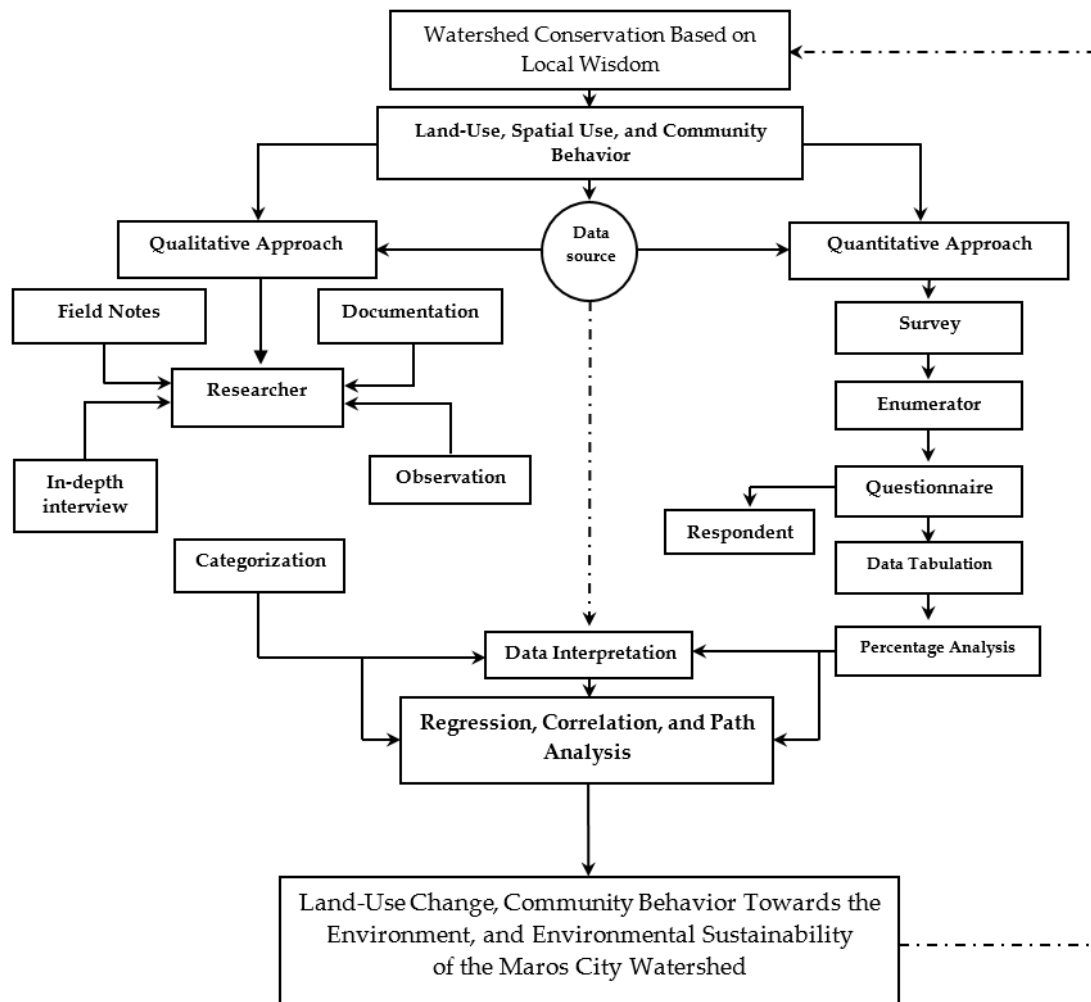


Figure 2. Research process implementation flow. Source: Author's elaboration.

3.2. Study Area

The characteristic of the watershed area of Maros City is that it has a river channel in the upstream part of the forest area while, in the downstream part, it empties directly into the Makassar Strait. The river length is 78.07 km. The basic physical conditions of nature and natural resources which are discussed in this sub-section include: geographical position, climatic and weather conditions, conditions of soil and rock structure, and land use. Physically, the Maros river watershed is lowland, with an altitude between 0–500 m above sea level (a.s.l.). Furthermore, the topography is generally relatively flat, with an altitude of 5–15 m above sea level and a slope range of 0–2%. The development of the population of Maros City serves as a determinant of the factors that cause changes in land use towards the use of river benefit areas. This condition is marked by population increases concentrated in two sub-district locations and 15 villages which are part of the urban development area of Maros City. Data showed that, for five years (2015–2019), there has been a population growth of 0.8% per year. Furthermore, the increase in population has contributed positively to the complexity of spatial use in the watershed area, reducing land cover. This condition is characterized by the existence of several functions of urban activities namely, housing and settlements, commercial functions, and social functions. Their populations are listed in Table 1, and their geographic locations in Table 2.

Table 1. Population growth in chosen districts of Maros City from 2015–2019.

Year	District				
	Maros Baru	Turikale	Lau	Mandai	Simbang
	Total Population (Soul)	Total Population (Soul)	Total Population (Soul)	Total Population (Soul)	Total Population (Soul)
2015	12,628	35,596	9896	15,298	3203
2016	12,628	35,877	10,030	15,508	3245
2017	12,628	36,084	10,034	15,510	3245
2018	12,772	41,038	10,918	15,819	3645
2019	14,138	41,319	10,971	18,690	3793

Source: Reference [42].

Table 2. Geographical location of Maros City based on district.

District	Altitude (Meters from Sea Level)	Slope (Degree)	Geographical Location
Maros Baru	−4.56–20.72	0–0.32	119°31'42.383" E; 4°59'47.002" S
Turikale	−7.34–22.35	0–0.28	119°34'33.587" E; 5°0'51.562" S
Lau	−7.35–12.05	0–4.09	119°33'39.878" E; 4°57'43.978" S
Mandai	−0.49–164.17	0–27.36	119°33'41.038" E; 5°4'40.523" S
Simbang	−18.31–666.23	0–69.27	119°40'45.572" E; 5°2'57.899" S

Source: Reference [42].

The role of the river in Maros City in supporting urban development is utilized for two functions, namely: (1) utilization as a means of transportation for the community that connects rural areas to Maros City; and (2) utilization of raw water sources to fulfill the distribution of clean water services for residents of Maros City and Makassar City. Thus, the function and role of the Maros City watershed is very strategic to meet the basic needs of the community for drinking water services and is very important in supporting the sustainable development of the Mamminasata Metropolitan area. Research locations are shown in Figure 3.

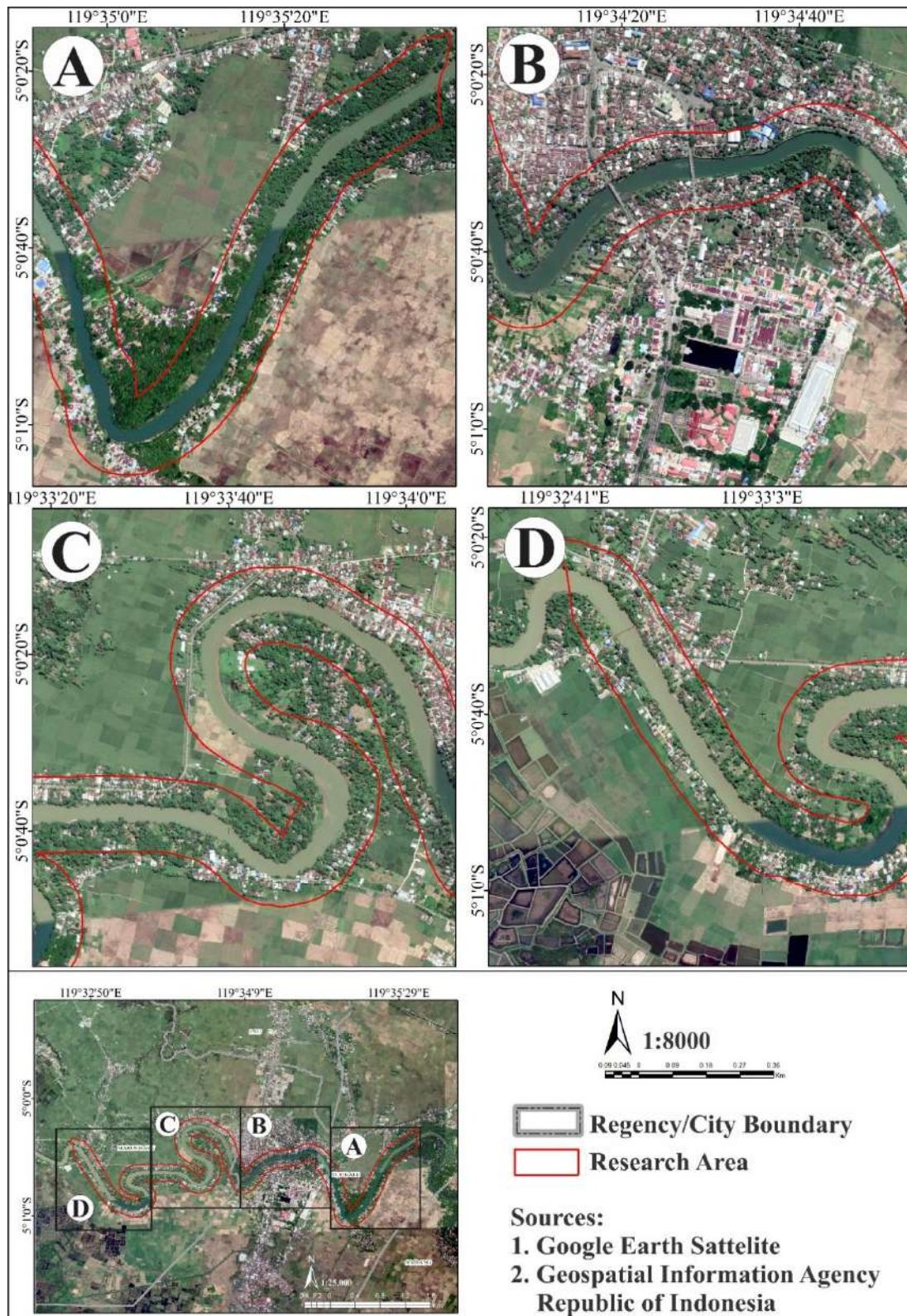


Figure 3. The watershed of Maros City as the object of research. (A) River basins with land use dominated by scrub and swamp vegetation. (B) Riverbanks with dominant land use for dense settlements, commercial, and offices. (C) The location of the river flow is dominated by shrubs, settlements, and agricultural areas. (D) Riverbanks with dominant residential land use. Source: Author's elaboration.

Figure 3 shows the watershed characteristics of the City of Maros. The Maros City watershed is part of the Tanralili sub-watershed of South Sulawesi and is one of the sources of clean water supply for drinking water for the people of Maros City, Makassar City, and Mamminasata Metropolitan City, as well as water sources for the development of the people's agriculture and fisheries sector. The population of Maros City, which tends to increase in line with the increase in socio-economic activities of the community, has a positive contribution to the decline in the quality of the Maros City watershed. The decline in environmental quality is marked by an increase in quality pollution caused by development activities, namely housing and settlements, shops, offices, and other activities by utilizing the benefit areas of rivers.

3.3. Method of Collecting Data

In accordance with the focus and research objectives to be achieved, the data collection methods needed in this study included three main aspects: (1) increases in population and changes in the use of working space as determinants of the complexity of the watershed ecosystem of Maros City; (2) the effects of housing development, urban activity systems, and land use changes on the degradation of the environmental quality of the Maros City watershed; and (3) the direct and indirect effects of changes in spatial use, land reclamation, and community behavior on water quality degradation and the sustainability of the watershed management of Maros City. Thus, the data sources in the study were observation, in-depth interviews, surveys, and documentation.

3.3.1. Observation

Observations in this study were carried out to observe the conditions and characteristics of the watershed, namely spatial use, land use changes, settlements, and socio-economic activities that develop in the river benefit areas of the Maros City. Furthermore, observation was also used to observe the behavior of people located in the benefit area of the river continuously for a certain period, by observing and listening to individual behavior for some time without manipulating or controlling, and recording findings that allow or qualify for use in analysis. The instruments used in the observation were field notes, periodic notes, and checklists. The aim was to observe a situation/situation or event related to the focus and problem being studied, including: (a) capturing the natural social (context) situation in which observed behavior occurs, (b) capturing meaningful events or events that affect changes in the use of space in the benefit area of the Maros City river, (c) determining the reality and norms of society that are relative to each individual and community group, observing the dynamics of natural behavior of the community, and values based on perspectives in the management of the Maros City watershed, and (e) identify regularities and recurring phenomena in people's lives for the purpose of comparing and seeing differences from the data obtained with actual environmental conditions. The process was carried out by researchers for the purpose of providing an overview of the increase in population and changes in space use as a comprehensive determinant of the complexity of the Maros City watershed ecosystem and to feel the atmosphere of the social situation under study.

Furthermore, the observations made by the researchers were related to two things, namely those of information and context. In this case, the researcher noted what happened in the socio-economic dynamics of the community in relation to the utilization of the Maros City river benefit area and associated these events with certain dimensions of time and place. From the information and context observed, the researcher then drew a meaning to the events that occurred in the field. Furthermore, the results of observations obtained in the field were then linked to local activism which is still maintained in relation to the role of community participation in the management of the Maros City watershed. The results of these observations then allow the researcher to give meaning to every event that occurs. The meaning given by the researcher concludes the incident by using assumptions and referring to the theory used.

3.3.2. In-Depth Interviews

In this study, in-depth interviews were used to extract information from informants regarding the conditions and socio-economic characteristics of the community, in relation to the use of river benefit areas, as associated with environmental quality degradation and water pollution in the watershed of Maros City. The information obtained by researchers through in-depth interviews related to various community activities relating to the utilization of watersheds and their relationship to reducing land cover, land reclamation, community behavior, and the potential for flood disasters (which are often experienced by the community due to overflowing of the Maros River). The results of the in-depth interviews were then used to determine the focus and research objectives. In-depth interviews in this study were used to explore the community's reasons for occupying the river's benefit areas and the efforts made to preserve the environment of the Maros City watershed. In-depth interviews in this study were used to explore information based on previously obtained quantitative data, including: (1) how the community's efforts to obtain permits to build housing facilities and socio-economic activities in the river benefit areas of Maros City; (2) land reclamation carried out; (3) efforts made in disaster management; and (4) community understanding in relation to local activism in the management of the Maros City watershed. In-depth interviews in this study used tools, namely a tape recorder, location map, and interview guides which were equipped with loose notes and a checklist.

3.3.3. Questionnaire

The questionnaire used in this study had two functions: (1) description, used to describe the conditions and situations of land use change, and spatial use of the Maros City watershed; and (2) measurement, used to assess changes in land use, changes in space use, community behavior, and socio-economic dynamics of communities located in the benefit areas of the river in relation to a decrease in environmental quality and pollution of water quality in the watershed of Maros City. The purpose of using a questionnaire was to describe some characteristics of an individual or group [43]. Questionnaires were used for the data tracking of education level, social stratification, type of work, income level, community roles and participation in environmental management, community behavior towards the environment, management and control of watershed based on local wisdom, patterns of individual relationships in community groups, community institutions, land ownership status, and socio-economic dynamics of the community, among other aspects. The questionnaire was distributed to five sub-districts within Maros City which were in direct contact with the river basin.

Structured interviews using a questionnaire were conducted by researchers by asking questions to respondents based on the questions set out in the questionnaire. Filling in the questionnaire was not submitted to the respondent but was guided by the researcher. Furthermore, the selection of respondents was carried out by field workers who were also enumerators. Completion of the questionnaire was facilitated by the enumerators who had been previously selected. The enumerators selected were based on considerations, namely (i) the local population selected and had the ability to collect data, (ii) understanding the situation and socio-economic conditions of the local community, and (iii) understanding the field situation and understanding well the cultural conditions of the communities located in the benefit area of the river. Furthermore, before carrying out their duties in the field, the enumerators were given instructions and exercises in filling out the questionnaire as well as techniques for conducting interviews with respondents.

The questionnaire was distributed to five sub-districts within Maros City which were in direct contact with the river basin. The location was determined based on field conditions, in this case the change in the use of the river's use area was quite significant and the land use change was quite intensive and was used by the community to build shelter, social activities, and economic activities. Furthermore, the criteria for the participants who filled out the questionnaire (respondents) were residents who lived in the river's benefit area, were married, and lived permanently or did not leave the place for a period of five years.

3.3.4. Documentation

The documentation in this study used various documents relating to the situation and conditions of the Maros City watershed. Data collected through documents included, among others: land ownership status in the benefit area of the river, population data, community socio-economic profile, data on watershed handling, and control activities that have been carried out by the local government. Furthermore, the documents used in this study include: (a) Maros City Spatial Planning, obtained through the Maros Regency Spatial Planning and Settlement Service; (b) data on the total population of Maros City in 2019 were obtained through the Central Statistics Agency of Maros Regency; (c) data on housing development activities carried out by the community, obtained through the Spatial Planning and Settlement Service and the Village Office; and (d) other documents related to our research objectives. All of these documents were used to support in-depth interview data and observations as well as to make research questionnaires.

3.3.5. Research Instruments

In qualitative research, the researcher acts as the main instrument. The qualitative approach in this study served to determine the focus of the research, select key informants as data sources, collect data, assess data quality, interpret data, and draw conclusions [40]. The steps that the researchers took in the field were: (1) increasing sensitivity through interactions with environmental stimuli based on field data; (2) involving themselves in the process of interaction with the local community for the purpose of understanding, feeling, and exploring how the community behaves towards its environmental conditions by referring to the theories used; (3) making conclusions based on the data collected, in order to obtain confirmation of the situation and conditions on the ground, in relation to environmental quality degradation and water pollution; (4) enhancing trust by responding to the social phenomena that occur, especially those related to increases in the population and changes in space use as determinants of the complexity of the watershed ecosystem of Maros City, which was the focus of the research.

The quantitative approach in this study used a questionnaire instrument. The questionnaire was used to measure: (a) the effect of housing development, urban activity systems, and land-use changes on the deterioration of the environmental quality of the watershed of Maros City; and (b) the direct and indirect effects of changes in spatial use, land reclamation, and community behavior on environmental degradation and water pollution in the watershed of Maros City.

3.3.6. Triangulation

Triangulation is defined as a data collection technique that combines different data collection techniques with the same source. The study was carried out by combining observation, in-depth interviews, and documentation for data sources simultaneously, for the purpose of testing the credibility of the data and understanding and interpreting the increase in population and changes in spatial use as determinants of the complexity of the watershed ecosystem of Maros City, such that consistent, complete, and certain data could be obtained. Triangulation of data in this study was carried out by: (1) extending the observation time; (2) source triangulation; and (3) technical triangulation by checking data with the same source with different techniques. Triangulation in the study was used for the purpose of testing data credibility, confirming data, and data validity. The types and techniques of research data collection are listed in Table 3.

Table 3. Summary of research data and data collection methods.

Number	Research Question	Research Variable	Indicator	Method of Collecting Data	Instruments and Tools Used
1	The increase in population and changes in the use of space as determinants of the complexity of the Maros City watershed ecosystem.	Total population	The population was measured by the following indicators: birth, death, and migration.	Observation, survey, and documentation	Field notes, base map of location, questionnaire, and data notes at District office
		Space utilization	Spatial use was measured by indicators: spatial function, socio-economic activity patterns, and permits issued by the local government.	Observation, survey, and documentation	Field notes, location base map, and permit records issued by the Maros City Spatial Planning Office
		Ecosystem complexity	Ecosystem complexity was measured by the following indicators: ecological conditions, spatial pressure, population activity, community response, and spatial activity patterns.	Observation, survey, and in-depth interviews	Field notes, questionnaires, location base maps, cameras, and voice recording devices
2	The effects of housing development, urban activity systems, and land use changes on the degradation of the environmental quality of the Maros City watershed.	Housing development	Housing development was measured by the following indicators: land-use, space allocation, land used, and building ownership.	Observation, surveys, and in-depth interviews	Field notes, questionnaires, location base maps, cameras, and voice recording devices
		City activity system	City activity system was measured by the following indicators: spatial function, built area, movement system, and facilities and infrastructure.	Observation and survey	Field notes, base maps of location, questionnaires, and cameras
		Land use change	Land use change was measured by the following indicators: land use change, land use, and land use patterns.	Observation and survey	Field notes, base maps of location, questionnaires, and cameras
3	Direct and indirect effects of changes in spatial use, land reclamation, and community behavior on water pollution and the	Environmental quality decrease	Environmental quality degradation was measured by the following indicators: pollution load, pollution level, and environmental carrying capacity.	Observation, survey, and measurement of river water quality	Field notes, location base maps, questionnaires, cameras, TSS AMTAST TB200, Digital Water TDS EC, DO Meter HI98193, and Chemical Oxygen Demand COD571
		Change in space use	Spatial use change was measured by the following indicators: population growth, land availability, land ownership status, space allocation,	Observation, survey, and documentation	Field notes, base maps of the location, permit records issued by the Maros City Spatial Planning Agency

sustainability of watershed management of Maros City.		space capacity, spatial function, and spatial use control.		and Maros City Spatial Plan
	Land reclamation	Land reclamation was measured by the following indicators: differences in land elevation, reclamation treatment, and land use.	Observation, survey, and in-depth interviews	Field notes, questionnaires, location base maps, cameras, and voice recording devices
	Community behavior	Community behavior was measured by the following indicators: knowledge, educational background, care, awareness, and community participation.	Observation, survey, and in-depth interviews	Field notes, questionnaires, location base maps, cameras, and voice recording devices
	Water pollution	Water pollution was measured by the following indicators: pollution management and water pollution index.	Observation, survey, and measurement of river water quality	Field notes, location base maps, questionnaires, cameras, TSS AMTAST TB200, Digital Water TDS EC, DO Meter HI98193, and Chemical Oxygen Demand COD571
Sustainability of watershed management	The sustainability of watershed management was measured by the following indicators: water pollution index, watershed management, community participation, and protection of river benefit areas.	Observation, survey, and water quality status	Field notes, location base maps, questionnaires, cameras, TSS AMTAST TB200, Digital Water TDS EC, DO Meter HI98193, and Chemical Oxygen Demand COD571	

3.3.7. Research Informants and Respondents

The determination of informants in this study was carried out using the snowball method. The snowball method in this study was used to obtain clear information from informants regarding the determinants of environmental quality degradation and water quality pollution in the watershed of Maros City. This means that researchers determined who was interviewed based on information provided by the local community. Furthermore, the informants were selected from several respondents who had been previously interviewed. This determination was aimed at exploring some of the questions that had been answered in the questionnaire, but which required a more detailed explanation. The informants were considered, by the researcher, as the actors in the phenomenon being studied. The number of informants was 20: 10 from outside the respondents and 10 from among the respondents. The determination of the 10 informants from outside the respondents was determined based on information obtained from the village office. Furthermore, informants who came from respondents were determined through the following considerations: (1) residing in the river's benefit area; (2) understanding the social situation of the local community; (3) understanding the conditions and characteristics of the watershed and their impact on urban flooding; (4) ability to provide good information about the environment in which they live and the condition of the watershed of Maros City; and (6) ability to provide good information about local activism and community behavior towards their environment.

Quantitative data were collected from respondents or research samples. The sample was determined using stratified random sampling. Stratified random sampling is based on dividing the population into strata and selecting simple random samples from each stratum, then combining them into a sample to estimate population parameters [43]. This method was used in this study with the consideration that the study population was not homogeneous and proportionally stratified; in this case, the research sample was differentiated based on educational background and income level. Sampling referred to Isaac and Michael [44], as follows:

$$s = \frac{\lambda^2 N P Q}{d^2(N - 1) + \lambda^2 P Q} \quad (1)$$

where s is the number of samples, N is the population, λ^2 is Chi Square, and $dk = 1$. The error rates were 1%, 5%, and 10% and, so, $d = 0.05$ and $P = Q = 0.5$. The number of samples in this study was 350.

3.4. Data Analysis Method

The analysis in the study was carried out by combining the qualitative and quantitative data analyses. The steps of the qualitative analysis, at the same time, used the quantitative analysis. When we arrived at the interpretation step, the data were reduced; namely, for the qualitative data, categorization was carried out while, for the quantitative data, statistical calculations were performed. Furthermore, the two datasets were interpreted by means of triangulation. This merger was used to strengthen the validity of the study results. The process of data analysis using a qualitative approach was used to answer the question regarding the increase in population and changes in the use of working space as a determinant of the complexity of the watershed ecosystem of Maros City. The analysis was carried out in three steps, namely data reduction, displaying data, and drawing a conclusion. Furthermore, quantitative analysis was carried out using descriptive, associative, and correlational statistics. The standard of water quality status uses the pollution index method according to the Decree of the State Minister for the Environment of the Republic of Indonesia. No. 115 of 2003. The analytical formulation used was as follows:

$$P_{ij} = \sqrt{(C_i/L_{ij})2M + (C_i/L_{ij})2R/2} \quad BPS = (Cs)_j \times Q_s \times F \quad (2)$$

where P_{ij} is the pollution index for the designation (J), L_{ij} is the concentration of water quality parameters listed in the water quality standard (J), C_i is the concentration of water quality parameters in the field, $(C_i/L_{ij}) M$ is the maximum C_i/L_i value, and $(C_i/L_{ij}) R$ is the average C_i/L_{ij} value; (2) BPS is the river pollution load (kg/day), $(Cs)_j$ is the measured level of pollutant element j (mg/l), Q_s is the river water discharge (m^3/day), and f is a conversion factor. Furthermore, the pollutant index method uses various water quality parameters. This means that its use requires an average value of the entire C_i/L_{ij} value as a measure of pollution (C_i/L_{ij}) with a value > 1 . Thus, the index value includes the maximum C_i/L_{ij} value. The river is more polluted for a designation (J) if the values of $(C_i/L_{ij}) R$ and $(C_i/L_{ij}) M$ are greater than 1.0; when the values of $(C_i/L_{ij}) R$ and $(C_i/L_{ij}) M$ are higher, the level of pollution of the water body will be higher. The relationships between the pollution index (IP) values and water quality status are shown in Table 4.

Table 4. Relationship between pollution index (IP) values and water quality status.

Number	IP Value	Water Quality
1	0–1.0	Good condition
2	1.1–5.0	Lightly polluted
3	5.0–10.0	Moderately polluted
4	>10.0	Heavy Polluted

Source: Reference [45].

The multiple linear regression method was used to answer the question of the effect of housing development, urban activity systems, and land use changes on the degradation of the environmental quality of the Maros City watershed. The variables measured were X_1 (housing development), X_2 (city

activity system), X_3 (land use change), and Y (environmental quality degradation). Furthermore, for the correlation coefficient test, we used the Pearson correlation coefficient. We took into consideration two things; namely, (i) the characteristics of the research data were interval-scaled data and (ii) the correlation between two or more variables was linear, meaning that the distribution of the data obtained showed a direct relationship. Path analysis was used to answer the research questions; namely, the direct and indirect effects of changes in spatial use, land reclamation, and community behavior on water pollution and the sustainability of the watershed management of Maros City. Application path analysis was based on the following variables: (i) X_1 exogenous independent variable (change in space use), (ii) X_2 exogenous independent variable (land reclamation), (iii) X_3 exogenous independent variable (community behavior), (iv) Y endogenous dependent variable (water pollution), and (v) Z endogenous dependent variable (sustainability of watershed management). We tested the effects between variables with multiple linear regression methods, correlation, and path analysis using the following equation:

$$Y = a + b_1X_1 + b_2X_2 + \dots + b_nX_n \quad (3)$$

$$r_{xy} = \frac{\sum x \cdot y}{\sqrt{(\sum x^2)(\sum y^2)}} \quad (4)$$

$$Y = PYX_1 + PYX_2 + PYX_3 + \varepsilon \quad (5)$$

Y is the dependent variable (predicted value), X_1 , X_2 , and X_3 , the independent variable, a is a constant (the value of Y if $X_1, X_2, X_3 \dots X_n = 0$), and b is the regression coefficient (value of increase or decrease. Furthermore, r_{xy} is the correlation coefficient between the variables X and Y , X is the deviation from the mean for the value of variable X , y is the deviation from the mean for the values for variable Y , $\sum x \cdot y$ is the product of the x and Y values, x^2 is the square of the x values, and y^2 is the square of the y values. Path analysis was used with consideration of: (1) the interval-scale research metric data used; (2) endogenous dependent variables for multiple regression models and intermediate variables for mediation models, as well as combined mediation and multiple regression models and complex models; (3) patterns in the relationship between variables occurring in only one direction; and (4) the causal relationships based on theory; namely, urban activity systems, transportation systems, and the origin–destination patterns of movement against environmental quality degradation and air pollution indices. The application of the multiple regression and path analyses is shown in Figure 4.

Figure 4 shows the multiple linear regression analysis, where the explanatory variable Y is the dependent variable, X_1 and X_2 are the independent variables, r_{12} is the relationship between X_1 and X_2 , r_{1Y} and r_{2Y} are the correlation values between the respective X variables and Y , and t_{1Y} and t_{2Y} are the corresponding significance values. In the path analysis model, several things can be explained as follows: (1) the magnitude of the relationships is expressed by the correlation coefficients (r_{12}), (r_{13}), and (r_{23}), where (r_{ij}) indicates the correlation or relationship between X_i and X_j ; (2) the variables X_1 , X_2 , and X_3 act as independent variables affecting the dependent variable (Y); (3) the independent variable X_1 and the dependent variable Y are connected by the regression coefficient (p_1); (4) the independent variable X_2 and the dependent variable Y are connected by the regression coefficient (p_2); (5) the independent variable X_3 and the dependent variable Y are connected by the regression coefficient (p_3); (6) the magnitude of the direct effect of X_1 on Y is the square of the regression coefficient (p_{12}), the direct effect of X_2 on Y is the square of the regression coefficient (p_{22}), the direct effect of X_3 on Y is the squared of the regression coefficient (p_{32}); (7) the magnitude of the total influence is the coefficient of determination with the R^2 symbol, which is the value of the total effect of the influence of the independent variables under study on the dependent variable: (i) R^2 is the total effect (i.e., the direct effect + the indirect effect), (ii) ($p_{12} + p_{22} + p_{32}$) is the direct effect of X_1 , X_2 , and X_3 on Y , (iii) (p_1, r_{12}, p_2) is the indirect effect of X_1 through X_2 on Y , (iv) (p_2, r_{12}, p_1) is the indirect effect of X_2 through X_1 on Y , (v) (p_1, r_{13}, p_3) is the indirect effect of X_1 through X_3 on Y , (vi) (p_3, r_{13}, p_1) is the indirect effect of X_3 through X_1 on Y , (vii) (p_2, r_{23}, p_3) is the indirect effect of X_2 through X_3 on Y , and (viii) (p_3, r_{23}, p_2) is the indirect effect of X_3 through X_2 on Y ; and (8) epsilon (ε) indicates the amount of residual effect (i.e., the residue), which is the magnitude of the influence of the independent variables that are not examined.

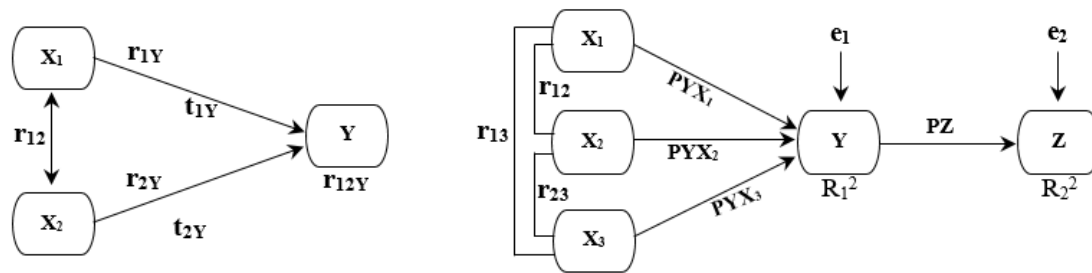


Figure 4. Model of multiple regression analysis and path analysis.

4. Results

4.1. Determinants of the Complexity of the Maros City Watershed Ecosystem

The population, which tends to increase with the dynamics of the development of Maros City, is positively associated with changes in land use. This was typified by the conversion of productive agricultural land and semi-natural ecosystems into built-up areas, accompanied by the negative ecological impacts of habitat deterioration and fragmentation [46]. Furthermore, the dominant urban development orientation toward economic growth was in line with the increasing demand for housing and settlements. The results of field observations illustrated that the dominant and developing spatial use in the watershed was marked by the presence of several city activities: namely, housing and settlements covering an area of 611.2 hectares, commercial areas occupying 69.47 hectares, offices occupying an area of 53.63 hectares, education occupying an area of 33.66 hectares, and health facilities occupying an area of 4.66 hectares. These figures confirm that the intensity of spatial use located in the benefit areas of the river contributed positively to the complexity of the watershed ecosystem and increased pollution of the river water of Maros City from time to time. Human activities pose a significant threat to the water quality of rivers when their pollution exceeds a certain threshold [47].

The field data indicated that the tendency to use the watershed of Maros City for housing development had direct impacts on reducing land cover, utilizing water catchment areas, and reducing river vegetation (which functions as land erosion prevention). Water treatment is very important to maintain the quality of drinking water [48]. Furthermore, the influence of humans on nature can have detrimental effects leading to disruption of the ecological balance [49,50]. Thus, changes in land cover and the utilization of water catchment areas had a positive contribution to the difference in land elevation in the watershed of Maros City. Development activities in the benefit areas of the river are shown in Figure 5 below.



Figure 5. Development activities in the watershed area of Maros City. Source: Primary data.

Figure 5 shows the tendency of the community to use the land in the benefit areas of the Maros river. Interpretations that can be proposed are related to development activities carried out by the community, including: (1) in the upper reaches of the river, the dominant land use is use by the community to build residential facilities that are directly related to community activities, which still rely primarily on the agricultural sector. This condition is marked by rampant land clearing for agricultural activities; namely, for the opening of new rice fields and plantation land. Forest damage in the upstream area has a significant impact on watershed ecosystem damage, land erosion, and the silting of rivers. Agricultural land degradation in rainfed mountainous areas is a major onsite problem (i.e., due to the removal of topsoil) which also causes offsite effects, such as downstream sediment deposition in fields, floodplains, and water bodies [51]; (2) in the central part of the watershed, land use is marked by the development of urban socio-economic activities, predominantly utilized by the community to build housing, with a tendency to ignore river boundaries. This means that community housing facilities are in direct contact with the watershed and have a direct effect on environmental quality degradation; and (3) in the lower reaches of the river, in addition to being utilized by the community as an agricultural area, it is followed by housing construction. These three factors have direct impacts on the complexity of the watershed ecosystem and a decrease in environmental quality. The complexity of the Maros River watershed ecosystem has a direct impact on the urban flooding that the community experiences annually. In terms of floodwater, other contributions come from surcharged sewers and/or from minor urban watercourses, the flow capacity of which has been exceeded as a result of heavy rainfall [52,53]. The population and number of houses that have been developed in the river benefit areas of the Maros City are shown in Figure 6.

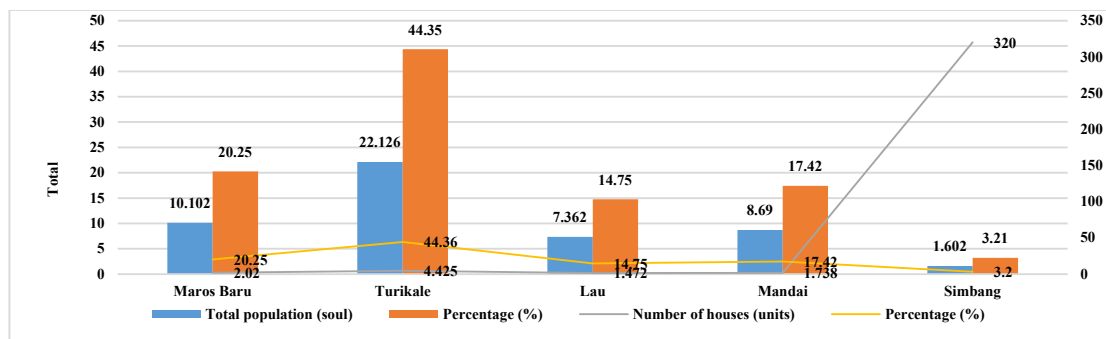


Figure 6. Total population and housing in the river benefit areas of Maros City. Source: Author's elaboration.

Figure 6 shows the total population and number of houses located in the river benefit areas of Maros City. Three interpretations can be proposed relative to these data: (i) the increase in population is in line with increases in the number of developed houses and utilized land in the river area of Maros City; (ii) the tendency of housing and settlements to increase every year causes a decrease in environmental quality with respect to the complexity of the watershed ecosystem; and (iii) population activities and the presence of housing are positively associated with community behavior towards the use and management of the watershed of Maros City. Thus, these three factors determine the complexity of the ecosystem with respect to water pollution in the watershed of Maros City. The spatial and temporal variability of human-induced hydrological changes in a river basin can affect the quality and quantity of water [54]. Therefore, in order, to assess the water quality indices in the watershed of Maros City, a water sampling location was determined, as shown in Figure 7 below.

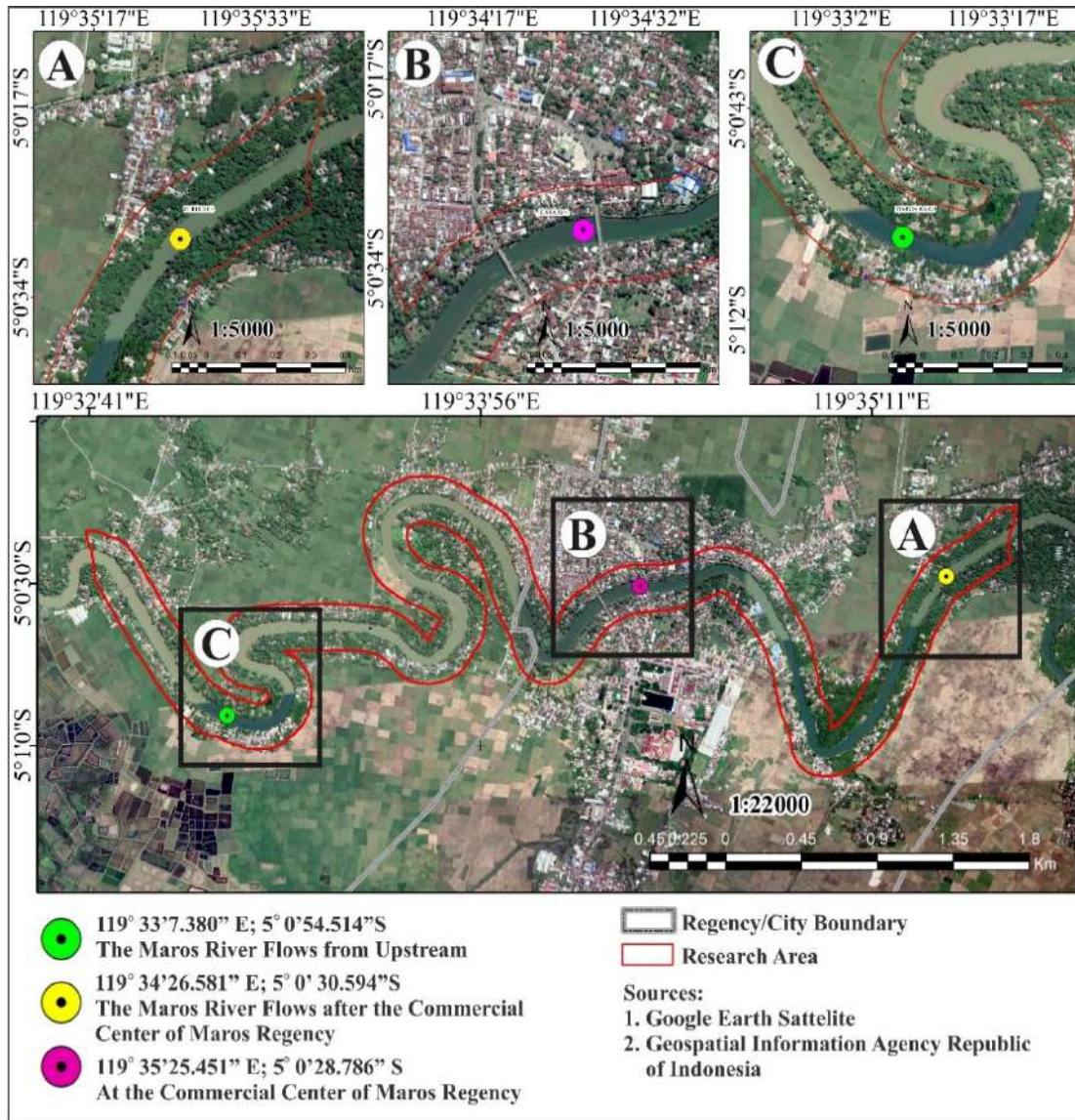


Figure 7. Water sampling locations in the river benefit area of Maros City. Source: Author's elaboration.

Figure 7 shows the three water quality sampling locations in the Maros City watershed. These sampling locations were used to compare the levels of water pollution. The location determination was based on the consideration of differences in the pattern of developing community activities, namely: (1) sample point 1 was located, in Palantikang Village (upstream of the Maros river), Maros Baru District. This location is predominantly used by the community for agricultural activities and housing; (2) sample point 2 was located in the center of Maros City (the middle of the Maros river) in Alliritengae Village, Turikale District. This location is characterized by complexity of the use of space, including housing and settlements, trade activities, education, health, and other urban activities; and (3) sample point 3 (downstream of the Maros river) was located in Boribellay Village, Turikale District. The dominant activities developed by the community are agriculture, home industry, and housing. The results of water quality measurements at the three sampling locations are given in Table 5.

Table 5. Results of analysis of water quality in Maros river.

Parameter	Unit	Water Sampling Location			Water Quality Standards			
		Point 1	Point 2	Point 3	Class I	Class II	Class III	Class IV
TSS	mg/L	28	80	34	50	50	400	400
pH	mg/L	7.6	8.5	7.8	6–9	6–9	6–9	6–9
BOD	mg/L	7.82	25	6.75	2	3	6	12
COD	mg/L	12.42	60.25	15.80	10	25	50	100
DO	mg/L	4.53	0.65	5.50	6	4	3	0
Total phosphate	mg/L	<0.0001	<0.001	<0.001	0.2	0.2	1	5
Chromium	mg/L	<0.010	<0.010	<0.010	-	-	-	-
Information	Total Suspended Solid (TSS)		Degree of Acidity (pH)			Biochemical Oxygen Demand (BOD)		
	Chemical Oxygen Demand (COD)				Dissolved Oxygen (DO)			

Source: Author's elaboration and primary data.

Table 5 shows the results of measurements of river water quality in Maros City carried out at the three sampling locations. Interpretations that can be proposed are: (1) Biochemical Oxygen Demand (BOD) concentrations at all sampling points exceeded the quality standards for classes I, II, and III; (2) sample point 2 exceeded the class IV quality standard; (3) the lowest BOD concentration value was at point 3 (6.75 mg/L), while the highest BOD value was at the second sample point (25 mg/L). Furthermore, water quality above BOD and Chemical Oxygen Demand (COD) concentrations from upstream to downstream tended to increase, from time to time; this condition is closely related to the increase of housing development activities. Organic materials are composed of carbon, hydrogen, oxygen, and nitrogen-containing compounds [55]. Organic waste is generally in the form of waste which can rot or be degraded by microorganisms; when these are discharged into the water, the BOD levels will increase [56]. Thus, it can be concluded that the increase in BOD content was influenced by household and municipal waste which was channeled directly into water bodies.

Decomposition of large amounts of organic matter will absorb oxygen in the water and, thus, decrease the amount of dissolved oxygen (DO). At sample point 2, the BOD value was 25.00 mg/L, while the DO value was 0.65 mg/L. Furthermore, the COD concentrations at sample points 1–3 were categorized as exceeding the class I quality standard: the COD concentration at point 1 was 12.42 mg/L, at sample point 2 was 60.25 mg/L and, at sample point 3, was equal to 15.80 mg/L. This confirms that the three sample point locations exceeded the Class II quality standard. Furthermore, the highest COD concentration was at sample point 2, exceeding the class III quality standard, while the lowest COD concentration was at point 1. COD values in uncontaminated waters are usually less than 20 mg/L [57,58]. Furthermore, the concentration values of Total Suspended Solid (TSS), pH, DO, phosphate, and chromium met the respective quality standards.

The pollution index was calculated based on the three sample points and the pre-determined parameters (i.e., TSS, BOD, COD, DO, pH, phosphate, and chromium). The measurement results illustrated that the status of the Maros river water quality was class II, and that the pollution index (IP) at points 1 and 3 was categorized as good. However, at sample point 2, it was categorized as lightly polluted. The highest pollution index value was at sample point 2 and the lowest pollution index was at point 3. Furthermore, for class I criteria, sampling points 1, 2, and 3 were all categorized as lightly polluted. Meanwhile, the water quality statuses for classes III and IV were still in the good category. The pollution load in the Maros river basin is listed in Table 6.

Table 6. Pollution load of the Maros river.

Point Location	Pollution Load (kg/day)		
	TSS	BOD	COD
1	2787.65	807.06	1389.69
2	5474.50	2312.90	4793.54
3	989.00	168.00	454.00

Source: Author's elaboration and primary data.

Table 6 illustrates that, from the calculation of the graph above, the pollution load of the Maros River increases and then decreases from upstream to downstream. For the category of pollution load, (i) the total TSS concentration was 9251.15 kg/day, (ii) the total COD concentration was equal to 6637.23 kg/day, and (iii) the total BOD concentration was 3287.96 kg/day. The contamination load, in terms of COD and TSS concentrations, was in the high category, due to the waste from city activities being channeled directly into the Maros river. This waste included that from commercial activities, home industries, and household waste. Thus, the pollution load of the Maros river was closely related to the existence of activities in the river benefit areas and the socio-economic activities that developed in the areas around the river. Thus, it can be concluded that the complexity of land use was positively associated with the complexity of the watershed ecosystem and water pollution.

4.2. Changes in Land Use and Deterioration of Watershed Environmental Quality

The dominant development intensity of Maros City was oriented towards the functions of commercial activities and settlement development, contributing positively to changes in land use. The growing complexity of spatial use has led to a decline in environmental quality [59]. Factors that affect land use changes in the river benefit areas of the Maros City, include: (1) an increase in the number of people who have not been matched by the fulfillment of housing and settlements; (2) preparations for community settlements that tend to prefer residential locations that are close to urban facilities and infrastructure; (3) the perspective of the Maros City community that views the river as a natural resource as well as a source of life; and (4) the watershed of the City of Maros, which is located in the city center and easy to reach in terms of transportation movement, causes changes in land use towards a decrease in environmental quality and pollution of water quality. The spatial and temporal variability of human induced hydrological changes in a river basin could affect quality and quantity of water [60,61].

The facts found in the field illustrate that the land use value that tends to increase and cannot be reached by the community is one of the reasons for people in Maros City to choose a location to live in the river's benefit area. The confirmation results illustrate that the dominant community living in that location is closely related to their life as fishermen and low-income people. This means that the welfare factor is one of the factors that causes changes in land use in the river area of Maros City. Thus, there is a relationship between the level of community income and the choice of means of living on the riverbank. The distribution of income can lead to large-scale transformations in the structure of human resources, important changes in economic outcomes through their impact on life satisfaction and work motivation, and their impact on the choice of residential locations [62]. Furthermore, differences in the interests of the community from an economic standpoint have a positive correlation with community behavior towards environmental conditions and their impact on water quality pollution in the watershed of Maros City. The universality of environment issues reduced the importance of socioeconomic and demographic factors in determining the degree of environmental awareness [63]. The land use of in the Maros City watershed is shown in Figure 8.

Figure 8 shows the land use in Maros City. There are two categories of spatial use development patterns: first, linear spatial use development. The dominant horizontal (linear) spatial development followed the regional transportation route (trans Sulawesi) from the direction of Mandai District (which is directly adjacent to Makassar City) to the Lau Sub-district towards Pangkep Regency. This road corridor is characterized by the development of urban activities, such as offices, shops, industries, and services, as well as housing and settlements. Furthermore, linear spatial development also followed along the watershed of the Maros river, from the direction of the Maros Baru District to Turikale District towards the Bone Regency. This spatial process determined the expansion of the Maros City area and its influence on the surrounding areas [64]. Furthermore, the transformation of the earth's surface from non-urban land to urban land becomes an irreversible process [65,66].

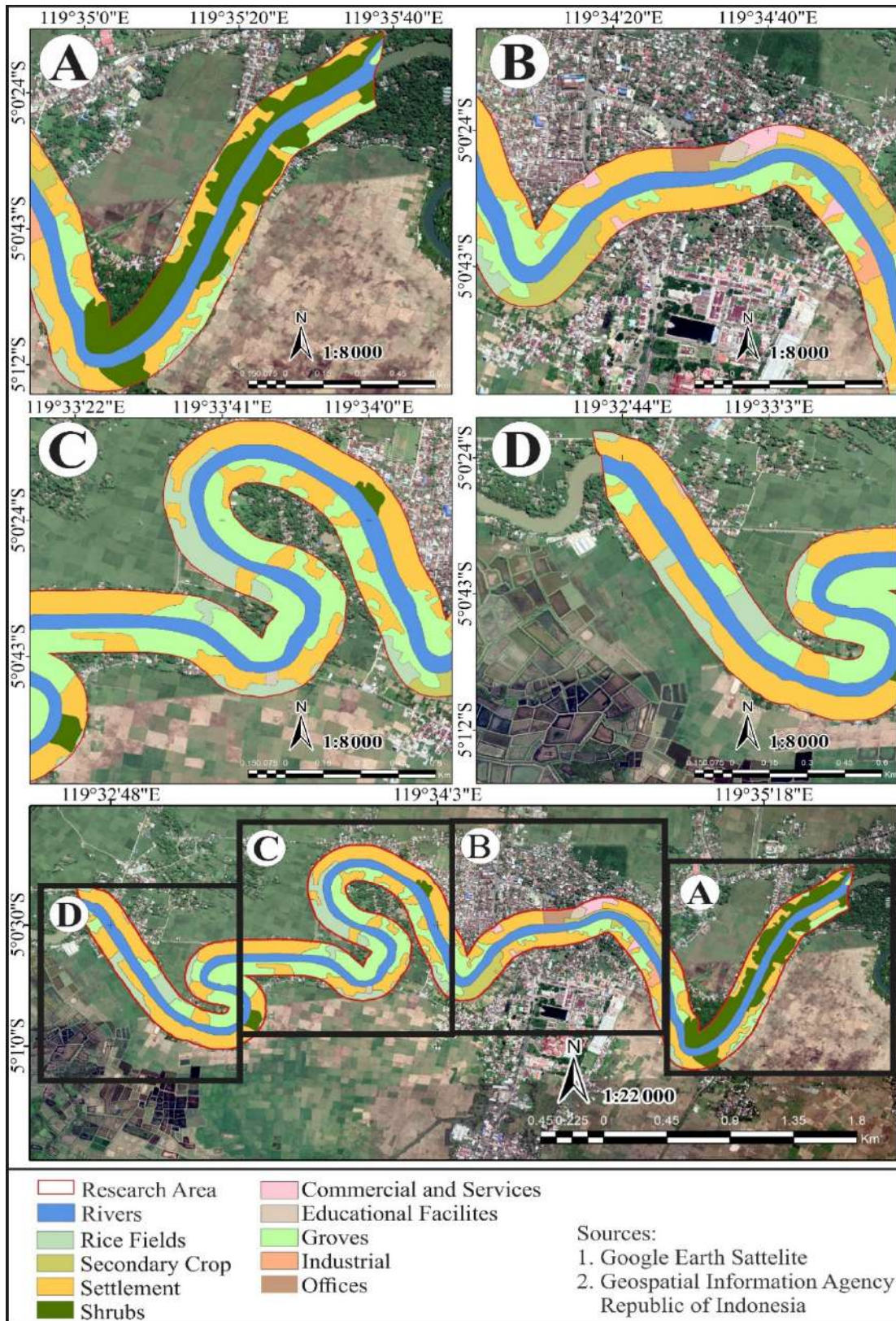


Figure 8. Utilization of the benefit area of the Maros City river. Source: Author's elaboration.

Second, concentric spatial development with a central point can be observed, marked by the existence of trade and service centers, traditional markets, office centers, education centers, hotels,

restaurants, housing and settlements, and other commercial activities. Limited land, population density, and high density of buildings at the center have resulted in dominant housing and settlement development in river benefit areas [67]. The results of field confirmation illustrated that the weak control over space utilization and the number of building permits issued by the government had an impact on the deterioration of the urban environmental quality of Maros City. Real estate is one of the largest economic activities worldwide, influencing settlement morphology and shaping built environments [68,69]. The utilization of urban space in Maros City is shown in Figure 9.

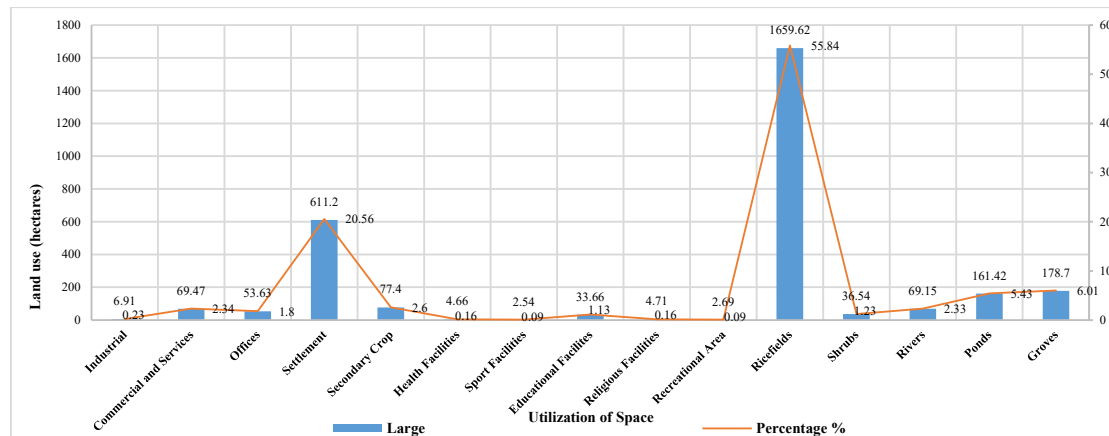


Figure 9. Utilization of urban space in Maros City. Source: Author's elaboration.

Figure 9 shows the use of urban space in the Maros City. The proposed interpretation is related to changes in land-use towards very complex spatial use: (1) the dominant spatial use was for housing and settlements, with a land area of 611.20 hectares (or 20.56% utilized); (2) the utilization of space for commercial activities and services occupied an area of 69.47 hectares (or 2.34%); (3) spatial use for office activities occupied an area of 53.63 hectares (or 1.80%); and (4) spatial use for educational activities occupied an area of 33.66 hectares (or 1.13%). Land use changes characterized by spatial use complexity cause a decrease in the quality of the urban environment [70]. Furthermore, the effectiveness of land use management serves to stop (or, at least, slow down) the negative impacts of land use on natural resources [71]. In addition, an adverse process is often understood as the degradation of soil cover under the influence of various types of erosion [72].

Space utilization complexity has a direct relationship with the high pollution load of water, soil, and air [73]. Field confirmation results illustrated that land use change in Maros City is basically inseparable from its position and function as a buffer city in the Mamminasata Metropolitan urban system [74]. Furthermore, the complexity of land use changes in the watershed of Maros City is closely related to the inability of communities to access land in the city center due to the high land value, as well as to the high conflicts in urban spatial use due to land ownership status changing over time [75]. Thus, it can be concluded that, at a close distance to the city center, the land value is high; conversely, the farther the distance from the city center, the lower the land value [76].

The field data obtained illustrated that the high level of population and building density in the city center contributed positively to the urban spatial polarization of Maros City towards the surrounding area and was positively associated with the utilization of river basins in the upstream, middle, and downstream parts of the city. Furthermore, the high demand for land in relation to the provision of facilities and infrastructure, as well as the development of new settlements, has resulted in a decrease in the quality of the environment in the river benefit areas of Maros City. Another serious problem is the insufficient capacity of technical infrastructure, such as sewerage and wastewater treatment [77,78]. Increased activity of the population in the benefit areas of the river causes silting due to high sedimentation in the Maros City watershed. This condition is characterized by community activities that take place in the upstream and downstream areas of the river. Housing development activities and land reclamation in the river benefit areas of the Maros City have

contributed positively to the decline in the quality of the watershed ecosystem. Field facts found illustrate that community housing development activities, land reclamation, land use change, and sand mining carried out by the community along of the Maros City watershed have a positive contribution to river silting, disturbed river water flow, land erosion, and sedimentation. Sand mining for the fulfillment of construction materials and human activities in the benefit area of the river has a significant effect on changes in riverbeds, degradation of environmental quality, and river morphology [79,80].

Field facts found indicate that the source of pollution to the watershed of Maros City is influenced by several factors, including: (1) domestic waste, which is generated by housing, office space, public facilities, traditional markets, and other socio-economic activities. Furthermore, the waste generated from the bathroom, soapy water, and detergent from washing activities is directly channeled to the water body; (2) household waste and urban activities located in the benefit area of rivers and channeled directly to water bodies; and (3) community agricultural activities that take place in the upper reaches of the river, in this case the irrigation canals contain chemical fertilizers, insecticides, and pesticides used to maintain crops that drain directly into the river body of Maros City. These three things have a positive contribution to the function of the Maros City watershed, namely increasing water quality pollution and disturbing the balance of the watershed ecosystem. Thus, the assessment of water quality is important in relation to the aquatic ecological environment and is the basis for the protection and utilization of river water resources [81]. The decrease in the environmental quality in Maros City is illustrated in Figure 10.

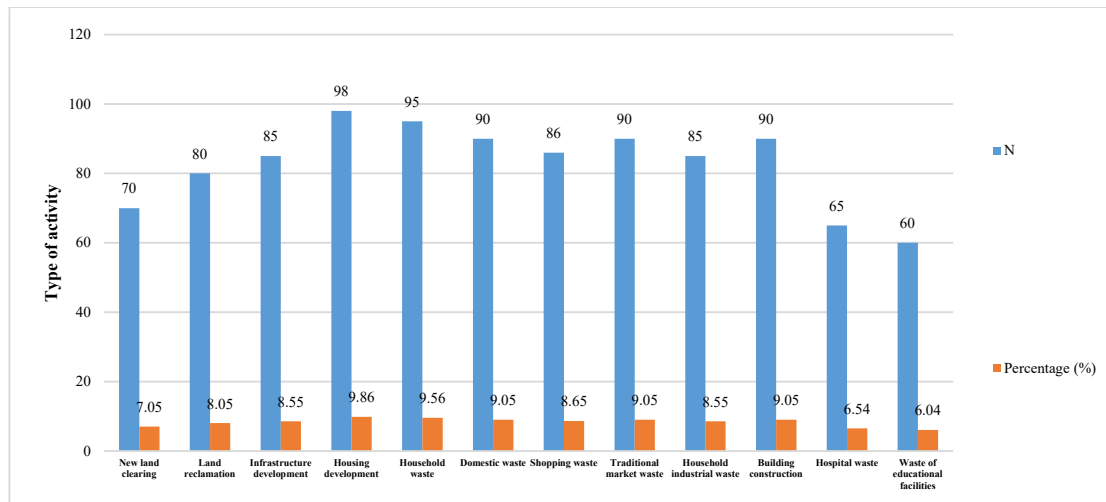


Figure 10. Decreases in the environmental quality of the river areas of Maros City. Source: Primary data.

Several factors were related to the degradation of environmental quality in the river benefit areas of Maros City (see Figure 10): (1) the highest potential for environmental degradation (with a value of 9.86%) came from housing development; (2) 9.56% was sourced from household waste; (3) 9.05% was sourced from domestic waste, traditional market waste, and building construction; (4) 8.65% was contributed by shopping centers; and (5) 8.55% was contributed by household industrial waste. This figure confirms that the complexity of land use, which was dominated by housing development, was positively associated with the complexity of the ecosystem towards decreasing environmental quality. Environmental quality degradation is a serious problem which requires government policy support to manage and control future environmental damage. Thus, public participation in environmental governance is likely to be an irreversible trend [82,83]. Furthermore, the effects of housing development, urban activity systems, and land use changes on environmental quality degradation of the watershed of Maros City, which we determined using regression methods and correlation analysis, are listed in Table 7.

Table 7. Summary of results of associative hypothesis testing.

Correlated Variables		Coefficient	T-Table	t Count	Sig.
Housing development to environmental quality degradation (ryx ₁)		0.126	1.67	4.907	0.000
City activity system to environmental quality degradation (ryx ₂)		0.136	1.67	2.987	0.004
Land use change to environmental quality degradation (ryx ₃)		0.406	1.67	4.870	0.000
Housing development, urban activity systems, and land use change together have a positive effect on environmental quality degradation (R)		F count = 74.436 > F table = 2.250			
R	R²	db1	db2	F-count	F-table
0.860	0.739	3	6	74.436	2.250

Source: Analysis results.

Table 7 shows the effects of housing development, urban activity systems, and land use changes on the degradation of the environmental quality of the Maros City watershed. The proposed interpretation of these results is as follows: (i) housing development had a positive effect on environmental quality degradation, with a coefficient value of 0.126; (ii) the urban activity system had a positive effect on environmental quality degradation, with a coefficient value of 0.136; (iii) changes in land use had a positive effect on environmental quality degradation, with a coefficient value of 0.406; and (iv) housing development, urban activity systems, and land use changes simultaneously had a positive effect on environmental quality degradation, with a determination coefficient of 73.9%, in the watershed area of Maros City.

4.3. Watershed Conservation Based on Local Wisdom

One of the triggers for environmental quality degradation and water pollution in the watershed of Maros City was the behavior of the people located in the river benefit areas. The results of field confirmation illustrated that decreases in the environmental quality of the watershed and increases in water pollution loads have an impact on the health conditions of the community. These conditions are characterized by the diseases that are predominantly experienced by the local community, such as typhus, cholera, hepatitis, and various other diseases. Thus, water pollution in the watershed of Maros City had a positive contribution to the entire ecosystem, which experienced some damage. This means that handling and controlling the current watershed of Maros City through conservation efforts is very important. Thus, it is important to maintain the sustainability of water resources, as well as to save and protect the environment, which are important tasks for all people and the government to ensure the safety of the distributed drinking water services for city residents [84,85].

Watershed conservation is understood as environmental conservation efforts based on the roles and functions of each watershed area, including the aspects of protection, maintenance, and sustainable use of ecosystems. Biodiversity is critical for the ecosystem functions and services on which humans depend, and has been directly linked to economic, social, and environmental components of sustainability [86,87]. Furthermore, uncontrolled changes in the use of natural resources affect the function and balance of the environment, including the hydrological processes in the watershed area of Maros City and the consequent impact on the balance of water, sediments, and nutrients, as well as damages to the biodiversity of habitats. Thus, assessment of the impact of change in land use with respect to ecosystem services is necessary in order to implement appropriate land use to enhance ecosystem services [88]. The behavior of the people who inhabit and occupy space in the benefit area of the river on environmental quality and water quality pollution in Maros City was reviewed based on the actions and activities undertaken, including: (1) domestic waste management; (2) management of household waste; (3) revegetation of river boundaries; and (4) water drainage control. Community participation and community behavior in relation to the management of the Maros City watershed is presented in Figure 11 below.

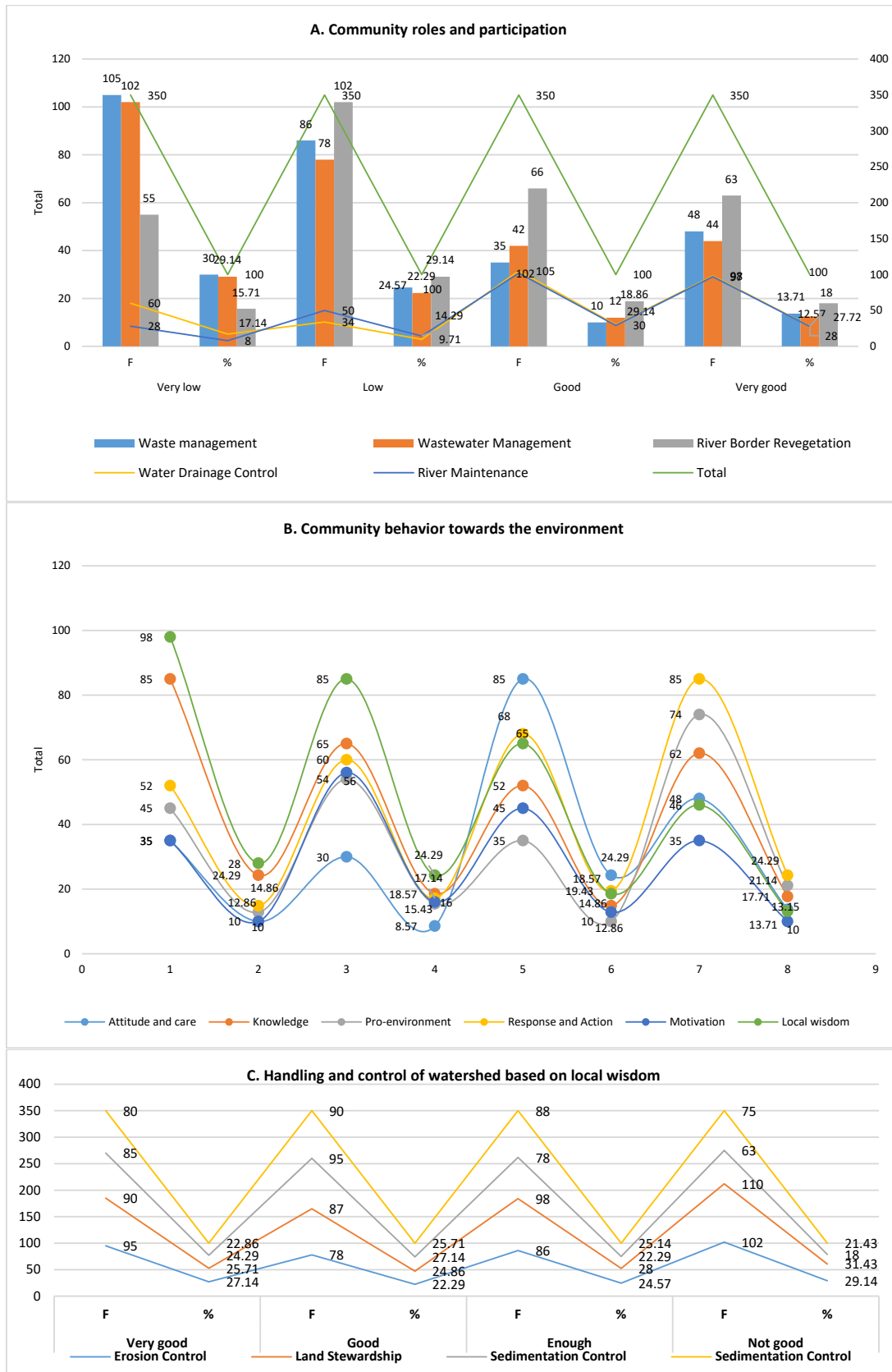


Figure 11. Decreasing environmental quality and water quality pollution in the watershed of Maros City. (A) Community participation, (B) Community behavior towards the environment, (C) Watershed control. Source: Primary data.

Figure 11A shows community participation in controlling river water quality pollution in the Maros City. The proposed interpretations related to these results include: (1) domestic waste management of 43.71% in good category and 56.29% with low category; (2) the management of household wastewater is 24.57% with a good category and 75.43% with a low category; (3) revegetation of river boundaries of 36.86% and 63.14% in the low category; (4) water drainage control by 58% with good category and 42% with low category; and (5) river maintenance is 56.86% in good category and 43.14% with low category. The five categories studied illustrate that the role and participation of the community is not optimal in the management and control of the Maros City watershed. Thus, restoration and control of urban watersheds is oriented towards improving the fluvial system, controlling flood risk, and increasing disaster resilience through active community participation [89].

Figure 11B shows community behavior in relation to the management and degradation of the environmental quality of the Maros City watershed. The proposed interpretations related to these results include: (1) public attitudes and concern for the environment by 38% well and 62% in the low category; (2) public knowledge of the function and role of watershed by 32.57% with good category and 67.43% with low category; (3) local people who are pro-environment are 31.14% in good category and 68.86% in low category; (4) community responses and actions in managing and controlling the watershed of Maros City are 43.72% and 56.28% in the low category; (5) motivation of the community to participate in maintaining the stability of the watershed ecosystem is 22.86% and 77.14% in the low category; and (6) the role of local community wisdom in maintaining watershed ecosystems is 31.72% and 68.28% in the low category. The six aspects studied illustrate that there is a relationship between community behavior towards the damage to the Maros City watershed ecosystem and the role of local wisdom is no longer the basis and consideration of the community in controlling watersheds. Thus, adaptation steps are needed based on socio-ecological aspects which are important elements and as the key to strengthening the resilience of traditional communities in facing situations that threaten the sustainability of the ecosystem [90].

Figure 11C shows the procedures carried out by the community in environmental management and land reclamation based on location wisdom in the Maros City watershed. The proposed interpretations regarding these results include: (1) control of land erosion in the bad category of 53.71% and 46.29% in the good category; (2) land use is in the bad category of 59.43% and 40.57% in the good category; (3) sedimentation control was 40.29% in bad category and 59.71% in good category; and (5) handling of land elevation with a value of 46.57% in the bad category and 53.43% in the good category. These results confirm that the food efforts made by the government and the community have not been optimal to support the preservation of the ecosystem functions of the Maros City watershed. Biodiversity is very important for the functions and ecosystem services on which humans depend, and is directly related to economic, social, and environmental components as part of the sustainability of watershed ecosystems [91]. Thus, serious efforts are needed to maintain the stability and sustainability of the Maros City watershed ecosystem through government policy support through conservation program efforts.

In its implementation, the management of the Maros City watershed is based on the principle of sustainable resource preservation. The goals to be achieved in the watershed conservation of Maros City are: (i) achieving ecological balance, (ii) ensuring the amount and quality of water throughout the year, (iii) controlling surface runoff and flooding, and (iv) controlling soil erosion. Furthermore, measures to manage the watershed of Maros City through conservation have been carried out through several actions, including: (a) not destroying trees, (b) planting trees and repairing damaged land, (c) constructing reservoirs or waiting reservoir to increase catch capacity, (d) terracing rice fields, (e) constructing infiltration wells, (f) not littering, and (g) not building along riverbanks. Sustainable development requires environmental decision-making which incorporates the intrinsic value of nature, supported by ecological modeling, additional environmental quality standards, and substance balance [92,93].

The role of the community is very important in the implementation of watershed conservation in Maros City. The role of the community is oriented towards the value systems and cultures of the

local communities. Furthermore, community empowerment actions are needed, in the form of: (1) community economic strengthening programs; (2) conservation agriculture development programs (such that it can function in the production and preservation of soil and water resources); (3) extension and technology transfer to support conservation agriculture programs; (4) increasing public awareness to participate in watershed management efforts; (5) developing various forms of incentives (stimuli), both direct and indirect, in the form of technical assistance and loans, which can spur increased agricultural production and efforts to conserve soil and water; (6) efforts to develop independence and strengthen the bargaining position of the lower classes of society, in order to expand community empowerment and develop the community's economy; (7) monitoring and evaluating the socio-economic development of the community; and (8) building public awareness about participating in the management of the Maros City watershed in a sustainable manner. Public participation is used to ensure the engagement of community actors in selecting and accepting actions and their functions in environmental management [85]. The direct and indirect effects of changes in spatial use, land reclamation, and community behavior on water pollution and the sustainability of the watershed management of Maros City are depicted in Figure 12.

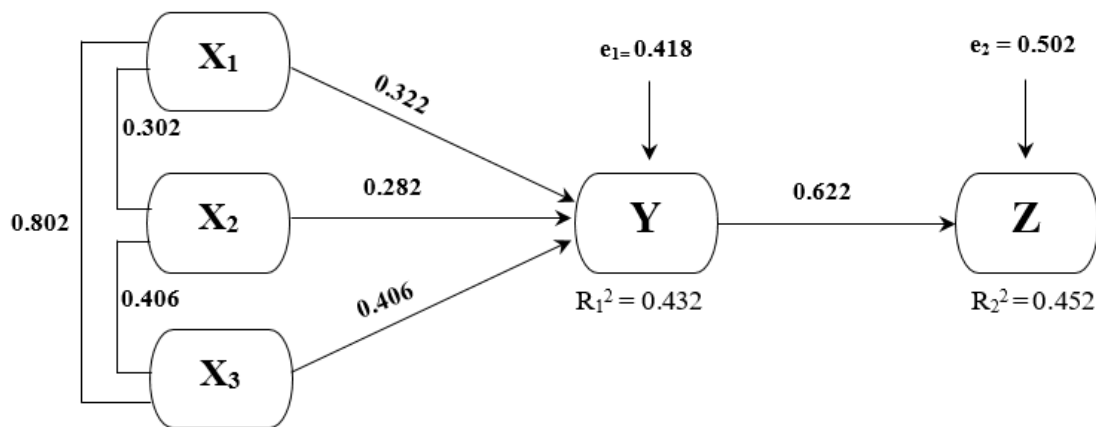


Figure 12. Effects of changes in spatial use, land reclamation, and community behavior on water pollution and the sustainability of watershed management in Maros City. Source: Analysis results.

The results of Figure 12 can be explained as follows: (1) changes in spatial use (X_1), land reclamation (X_2), and community behavior (X_3) had effects on water pollution and the sustainability of the management of the Maros City watershed; (2) the direct effect of changes in space utilization on water pollution was 0.1073 (or 10.37%); (3) the direct effect of land reclamation on water pollution was 0.0795 (or 7.95%); and (4) the direct effect of community behavior on water pollution was 0.1648 (or 16.48%). Furthermore, the indirect effects that could be explained were: (1) the indirect effect of changes in spatial use through land reclamation was 0.027 (or 2.74%); (2) the indirect effect of land reclamation through changes in spatial use was 0.027 (or 2.74%); (3) the indirect effect of changes in spatial use through community behavior on water pollution was 0.1048 (or 10.48%); (4) the indirect effect of community behavior through changes in space use on water pollution was 0.1048 (or 10.48%); (5) the indirect effect of land reclamation through community behavior was 0.0465 (or 4.65%); and (6) the indirect effect of community behavior through land reclamation was 0.0465 (or 4.65%). The total effect was 0.7082 (or 72.82%). Therefore, the remaining effect, or residue, which was not examined was 0.2718 (or 27.18%). Furthermore, the direct effect of decreasing environmental quality on the air pollution index was 0.3869 (or 38.69%). Thus, the residual effect, or residue (i.e., the influence of other variables on the decline in environmental quality that were not studied), was 0.6131 (or 61.31%).

The results of the path analysis confirmed that the behavior of people had a direct relationship to water pollution. Data found in the field illustrated that the value systems and traditions of society, which have been used as the basis and reference for acting, have decreased appreciation. This means

that the modernization occurring as a result of the development of Maros City contributed positively to the low level of public awareness of the environmental conditions of the Maros watershed. Thus, efforts to revitalize the sociocultural society are needed; this means that the value system and community traditions need to be optimized to regulate people's attitudes and behavior towards the environment. Community understanding regarding watersheds forms part of the resources that need to be preserved, which function to support the sustainability of life. This means that it is very important to restore the function of the watershed of Maros City, moving towards a balanced spatial use based on the space capacity and carrying capacity of the environment, as well as in accordance with the spatial use directions that have been stipulated in the Maros City Spatial Plan, taking into consideration that human activities pose a significant threat to the water quality of rivers when pollution exceeds the threshold limit [94]. Thus, the traditional and sociocultural values of the community play an important role, acting as an instrument for controlling water pollution in the watershed of Maros City. The ecological environments of rivers are severely affected by human activities, where small- and medium-sized rivers are facing a serious degradation of ecological function in water resource-scarce regions [95,96].

5. Discussion

5.1. Community Participation-Based Watershed Conservation

It is urgently necessary to protect the watershed ecosystem of Maros City. Various attempts have been made by the government and the general public; however, floods continue to occur. Thus, integrated watershed conservation is needed. Furthermore, the management of the Maros City watershed is oriented towards the reciprocal relationship between natural resources and the environment with human activities, towards the preservation of environmental functions and community welfare. For its implementation in the field, this requires integrated management by various sectors, from upstream to downstream, taking into account the various interests, biophysical conditions, and socio-economic conditions of local communities. Integrated watershed management is a holistic approach to land and water resources management with multiple roles and points of contact regarding land tenure issues [97,98].

Land use change is the main cause of flooding in the Maros City watershed. Changes in land use for housing needs, settlements, and other urban activities have had a significant impact, increasing the peak river discharge in the range of 6–10 times that of the previous conditions. However, river widening in Maros City is difficult due to the complexity of land use in the river's beneficial area. Furthermore, various agricultural activities in the upper watershed of Maros City illustrate that the community has converted forest vegetation into non-forest areas for yards, plantations and seasonal crops. These changes have a direct effect on river flow fluctuations and play a significant role in watershed ecosystem damage. Location-specific forms of agroforestry management can reduce problems in the forest–water–community nexus by balancing upstream and downstream interests, but social and ecological fine-tuning is needed [99,100].

Soil conservation in the Maros City watershed is oriented towards sustainable land productivity and keeping the rate of soil loss below a permitted threshold. This means that the erosion rate must be less than or equal to the rate of soil formation. Soil erosion in the Maros City watershed is caused not only by the intensity of rainfall, but also due to the large surface flow discharge. Thus, the soil conservation strategy to be implemented is, namely, (i) protecting the soil from the impact of rainwater with ground cover, (ii) reducing surface runoff by increasing the infiltration capacity, (iii) increasing soil aggregate stability, and (iv) reducing velocity runoff by increasing the surface roughness of the land. Furthermore, vegetative soil and water conservation in the Maros City watershed is oriented towards the following: (1) reducing the destructive power of raindrops that fall through the interception of raindrops by plant leaves or canopies; (2) reduction of surface runoff volume due to increased infiltration capacity by plant root activity and the addition of organic matter; (3) increased loss of groundwater due to increased evapotranspiration; (4) slowing surface runoff due to increased runoff length due to the presence of plant stems; and (5) reduction of the surface runoff

destructive force as a result of reducing surface runoff volume and surface flow velocity due to increased track length and surface roughness.

Mechanical conservation in the Maros City watershed consists of the following: (a) slowing down surface runoff; (b) accommodating and channeling surface runoff, such that it does not cause damage; (c) increasing the capacity of water infiltration into the soil and improving soil aeration; and (d) providing water for plants. Furthermore, mechanical soil and water conservation efforts require various programs, such as (i) soil processing, (ii) construction of terracing, (iii) construction of water channels, and (iv) construction of control dams.

Community participation in the management of the Maros City watershed in an integrated manner is very important, which has strategic value in the implementation of natural resource management activities in relation to social, economic, and institutional aspects, in order to achieve the goals and objectives of watershed management in Maros City. Furthermore, it is very important to maximize local wisdom in the various planning processes of the Maros City watershed, in terms of land management, land distribution, and control of the use of river benefit areas. Community participation is also oriented towards efforts to maintain soil fertility, rehabilitating land, and restoring the ecological function of the watershed by planting vegetation in the river's benefit areas, which are designated as green lines.

Local wisdom in the management and conservation of the Maros City watershed is oriented towards strengthening the institutional system. It is very important to optimize the functions and roles of social and customary institutions. Social institutions play a role in imposing social sanctions on people who commit violations of environmental destruction and water pollution. Furthermore, community leaders play a strong role in empowering, structuring, and sustaining the management of the Maros City watershed and its impact on communities. Thus, the role of community institutions in the management of the Maros City watershed is very important and strategic in regulating community behavior in the utilization and preservation of the watershed environment. Local people begin to integrate different types of knowledge through top-down interventions, subsequently implementing collaborative actions [101].

5.2. Change in Community Behavior and Environmental Sustainability

The sustainability of management of the Maros watershed is related to the functions and roles of the community. Optimizing the role of the community has a direct relationship with their knowledge, skills, and awareness in watershed management and the protection of water resources. Such knowledge and skills do not have to be directly related to efforts to tackle the problem of water resource damage and may be oriented towards matters relating to community economic efforts. Furthermore, environmental knowledge and insight need to be socialized in order to provide the same and correct concepts and views to the community about the environment and its role in the life of the community as a whole. This means that the type of knowledge and insight provided should differ, according to the location of the settlement and the type of community work undertaken. Environmental protection and restoration efforts depend not only on supervision, but also on the daily choices made by individuals—how they behave towards the environment, what they consume, or what they are willing to leave behind [102].

For people located in the core zone, efforts should be focused on increasing knowledge and insight between the local community and the use of water resources and their supervision. Increasing knowledge and insight is very important when involving village and sub-district officials and the wider community. The improvement of practical skills in environmental management in the community and government officials at the village and sub-district levels is aimed at encouraging the active participation of institutional elements in overcoming ecological and economic environmental problems which can harm the community. These skills are mainly related to ways of utilizing water resources efficiently and skills regarding efforts to deal with natural disasters caused by river overflows. Floods, droughts, and an increase in climate extremes have resulted in the loss of life and property [103].

Community capacity building is needed to participate in the policy making process, especially in the planning, implementation, and supervision processes. Community capacity building is a series of activities which emphasize the importance of community capabilities and opportunities to be able to articulate their interests through their social groups or institutions. The main goal to be achieved is increasing people's self-confidence and ability to take initiative, followed by self-development. The quality of the community in managing water resources needs to be improved to address two main challenges: (i) efforts to overcome economic problems, both to overcome the problem of meeting basic needs and to improve wider welfare; and (ii) efforts to overcome the problem of natural damage—namely, to reduce the pressure on water resources as a result of increasing community activity. Optimization tools are practical solutions to problems involving the complex and interdependent elements of a water resource system, offering the opportunity to engage with practitioners as an integral part of the optimization process [104].

The improvement of the quality of human resources hopefully encourages the diversification of employment opportunities and sources of income for the local population, leading to a reduction of the tendency of businesses to cause damage to water resources. The development of human quality can be carried out through education, training, and fostering co-operation between social and economic institutions. Furthermore, preparing the workforce to anticipate the development of development activities in the Maros City watershed and its surroundings needs to be carried out proactively, on the basis, of foresight and information technologies. The application of internet of things (IoT) technologies can address the current challenges in industrial value creation, such as shorter technology and innovation cycles, rising market volatility, and the highly dynamic environments arising from increasing competitive pressure [105,106].

Community motivation needs to be grown in order to encourage the active participation of the community in the management of water resources in the surrounding areas. For this reason, efforts to involve the community and to develop activities based on the interests of the community need to be continuously improved. Its implementation needs to be integrated with aspects that directly correspond to the interests of the community. Balancing environmental, social, and economic interests brings a strategic meaning to encouraging communities to involve themselves in efforts to protect water resources. Furthermore, traditional community values should be explored and developed. The effort to extract traditional values is important for use as a base material for the development of values prevailing in society in which operationalized norms serve as a basis for safeguarding water resources. The development of a system of values, norms, and local wisdom based on the environment encourages the use of rules or ways for people to manage water resources based on the values they believe in. Values play a key role in water management and, more generally, in natural resource management. They can be used by individuals, groups, organizations, and whole societies to judge and justify actions [107]. Furthermore, the availability and quality of drinking water resources are threatened by different natural processes and human activities, which include chemical and biological contamination from agricultural and urban activities [108–110], the direct impacts of land and ecosystem service overexploitation [111], and the direct and indirect impacts of a variety of weather-related events, such as floods and droughts [112,113]. The sustainability of the management and conservation of the Maros City watershed is illustrated in Figure 13.

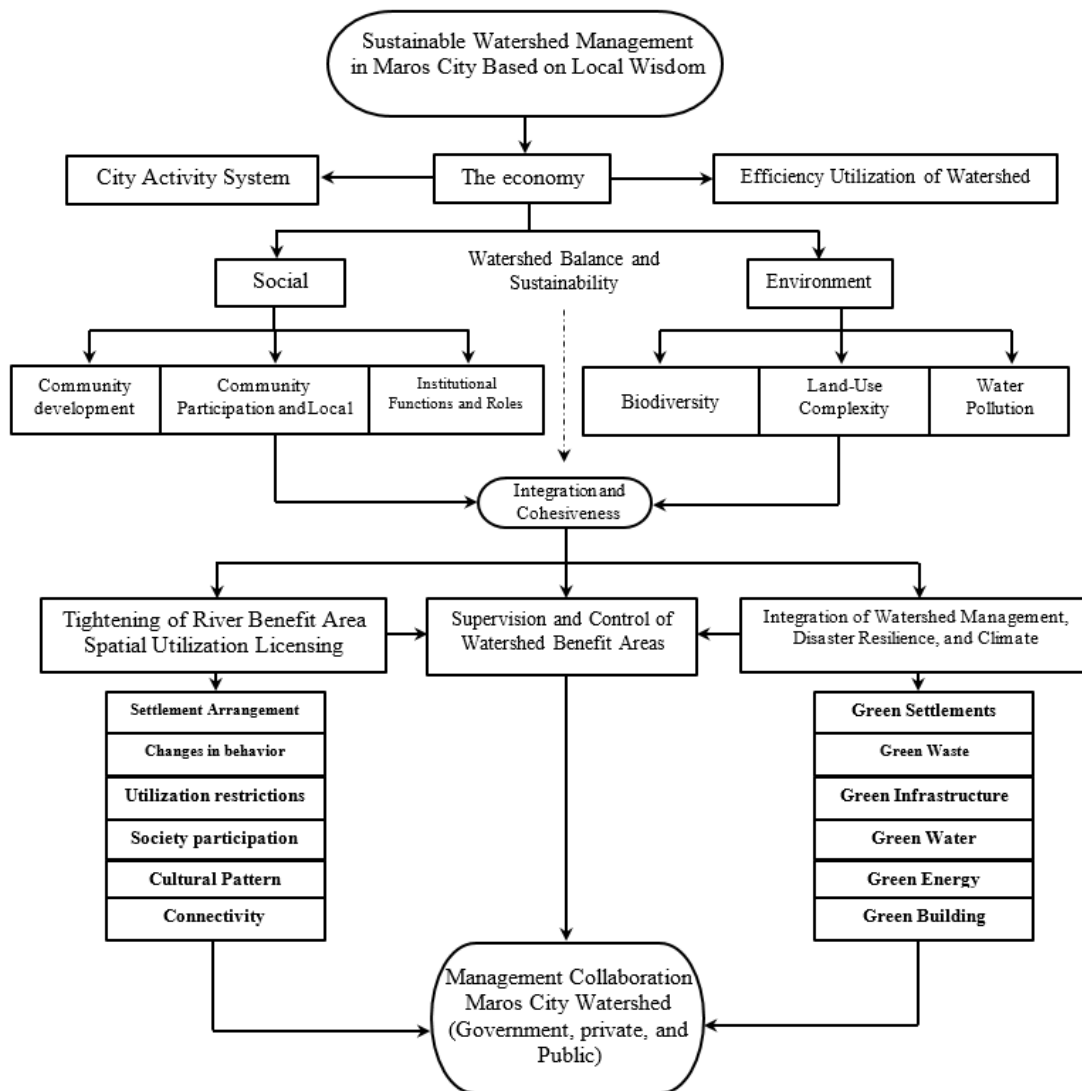


Figure 13. The sustainability of the Maros City watershed management. Source: Author's elaboration.

6. Conclusions

The annually increasing population and housing development, as well as the complexity of the activities of Maros City, were shown to be determinants of the decreasing environmental quality and increasing pollution of its watershed. Weak control over spatial use and community behaviors have led to increasing water pollution. The BOD content in the watershed, which has increased over time, was found to be dominantly influenced by household waste and municipal waste, which is channeled directly into water bodies. Changes in land cover and the complexity of utilization of water catchment areas had a positive contribution to differences in land elevation in the watershed of Maros City and their impact on urban flooding. Furthermore, the river pollution load was positively associated with the existence of activities in the river benefit areas and developing socio-economic activities in the area around the river. This means that the complexity of land-use was positively associated with the complexity of the watershed ecosystem and the pollution of river water in Maros City.

The intensity of the dominant development of Maros City is oriented towards the functions of commercial activities and settlement development, which contributed positively to changes in land use. Weak control over spatial use and the number of building permits issued by the government served to decrease the quality of the urban environment. Housing development was positively associated with the complexity of the ecosystem towards a decrease in environmental quality.

Environmental quality degradation is a serious problem which requires government policy support in managing and controlling future environmental damage. Our regression analysis results confirmed that housing development, urban activity systems, and land use changes had a simultaneous positive effect on environmental quality degradation in the Maros City watershed. Thus, community participation in watershed management, as implemented through integrated management programs, is very important and has strategic value in the implementation of natural resource management, in relation to social, economic, and institutional aspects, in order to achieve the watershed management targets of Maros City. Furthermore, it is very important to maximize local wisdom in the various processes of the Maros City watershed planning process, in terms of land use, land distribution, and control of the use of the river benefit areas. Apart from this, community participation should be oriented towards efforts to maintain soil fertility, land rehabilitation, and preserve the ecological function of the watershed.

Local wisdom in environmental management and watershed conservation in Maros City is oriented towards strengthening institutional capacities, where it is highly important to optimize the functions and roles of social and customary institutions. Social institutions play a significant role in imposing social sanctions on those people who commit violations of environmental destruction and water pollution. Furthermore, community leaders have a strong role in empowering, structuring, and sustaining watershed management and its impact on community life. Thus, the role of community social institutions in the management of the Maros City watershed should be aimed at regulating community behavior in environmental utilization and preservation. The development of a system of values, norms, and local wisdom based on the environment will encourage the community to manage these environmental resources wisely, working towards the sustainable management of natural resources and watershed ecosystems, followed by controlling water pollution.

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