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Adaptation and Mitigation Model for Flood Disaster Resilience in West Malangke District, North Luwu Regency, Indonesia

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ABSTRACT

World climate change in the last decade has resulted in annual seasonal changes, especially in tropical geographical areas due to changes in land use in watershed areas, and has increased the risk of flash floods in downstream areas. This study aims to analyze the factors that have a dominant effect (leverage) on disaster adaptation and mitigation, as well as the resilience of flash flood disaster areas, and find a model of adaptation and mitigation relationships in the form of the resilience of flash flood-prone areas. The research method uses an ex post facto quantitative approach with an explanatory design that is analyzed by multivariate statistics based on structural equation modeling (SEM-PLS). Data collection was done using observation, interviews, documentation, and a survey. The results showed that aspects of disaster management and spatial planning are the dominant factors influencing disaster mitigation and adaptation, while aspects of flood technology and disaster mitigation are also the dominant influences on the resilience of flood disaster areas. The potential sustainability of flash flood-prone areas indicates two main pathways of direct relationship models based on disaster management and spatial planning that encourage the resilience of flash flood disaster areas in West Malangke District, North Luwu Regency. This research helps formulate a model of development and sustainability in the flood disaster area in the downstream area.

1. INTRODUCTION

With the pace of global climate change accelerating in this century and predicted to accelerate in the next, current anthropogenic climate change is likely to continue for centuries [1], [2]. The main source of global climate change is human-induced changes in atmospheric composition. These disruptions result primarily from emissions associated with energy use, but at local and regional scales, urbanization and land use change are also important. While progress has been made in monitoring and understanding climate change, many scientific, technical, and institutional barriers remain to appropriately plan for, adapt to, and mitigate the impacts of climate change [1].

Changes in the world's climate are also related to annual seasonal changes in certain geographical areas over a period of time. These seasonal changes are linked to the production of carbon dioxide and other greenhouse gases by various anthropogenic sources such as industrial development, urbanization, land use, and so on [3]. Furthermore, the main issue of climate change that has penetrated into various regions of the world has a detrimental impact on important sectors such as agriculture, food supply, water sources, social aspects, and ecological systems [4]. As well as increasing flood risk, this increase depends on the degree of warming and implies the need for adaptation before significant warming occurs. [5].

Indonesia is a country prone to natural disasters and hazards formed by geological processes, such as land subsidence, seawater inundation, floods, volcanic eruptions, earthquakes, tsunamis, and landslides [6]. North Luwu Regency is one of the districts that has a large risk of natural disasters such as floods, especially in West Malangke District. This natural phenomenon has a serious impact on the local community and environment. West Malangke Sub-district is an area that is vulnerable to flood disasters due to topographic conditions that tend to be flat with a slope of 0-8% and some swamp areas located downstream of the Rongkong watershed area that have undergone land use changes. In 2020, there was a major natural disaster caused by flash floods upstream that impacted the central region in Masamba, South Baebunta, Baebunta, and downstream areas in West Malangke and Malangke Districts. Other areas are mostly categorized as floods with high inundation. The impact of this flood disaster damaged infrastructure and public facilities and caused casualties [7].

Flood risk assessment based on geospatial analysis according to the characteristics of the Lower Rongkong watershed area is a flood area with low (not vulnerable), medium (vulnerable), and high (very vulnerable) flood vulnerability conditions. Some areas of West Malangke Sub-district have a high level of vulnerability to flooding, with an area of 913.9329 hectares in Pombakka Village, and another area has a medium level of vulnerability with an area of 5.473202 ha, which is prone to flooding, namely the Waelawi Village area [7].

The various references above explain several indications of factors that encourage flooding such as climate change, spatial planning, irregular land use, and rapid population growth can exacerbate the risk of flash floods. Therefore, in the context of this research, flash flood mitigation and adaptation efforts are crucial in providing a construction development model that provides implications for the sustainability of flash flood prone areas so as to provide benefits in protecting lives, property and environmental resources.

2. CONCEPTUAL FRAMEWORK: STRUCTURAL MODEL OF ADAPTATION AND MITIGATION IN THE FORM OF DISASTER AREA RESILIENCE

Conceptually and theoretically, the development of this research is based on the fact that mitigation and adaptation strategies are closely related to urban resilience, and these two factors are aspects of more resilient urban development [8]. Kajian Mitigasi studi bibliometric belum banyak menyentuh isu lainnya. Konteks adaptasi dan ketangguhan memiliki visibilitas yang lebih tinggi. Kecenderungan terjadi perpecahan dasar dari tiga dekade lalu antara mitigasi dan adaptasi-dan marjinalisasi strategi adaptasi masih terjadi hingga saat ini [9].

Several factors in this study include the selection of available technologies to assist in flood risk reduction in the disaster management cycle. New technologies offer great potential to engage communities and facilitate knowledge production [10]. Implementation of IOT (technology) as a disaster mitigation effort [11]. In the aspect of disaster resilience, engineering has shown its benefits in the design and operation of technological systems in general and flood-resistant technology. Building disaster area resilience (socio-ecological resilience) in flood risk management strategies requires an adaptive approach to look at short-term and long-term adaptation strategies. Furthermore, ecological and socio-ecological resilience provide guidance for building a more resilient flood risk management system, resulting in an approach that includes flood protection, prevention, and preparedness [12].

The conceptual terotitis explains that successful disaster management requires high adaptability to the living environment. Disaster management involves culture, traditions, and customs. This means that local wisdom is an important factor in disaster management [13]. Another perspective is that local wisdom as social capital in natural disaster management derives from the substantive meaning of community, local wisdom, and natural disaster management [14]. Environmental, disaster management, socio-economic, and institutional challenges such as flood resilience and climate adaptation need to be considered. Furthermore, spatial planning encourages evidence-based resilience, limited financial resources, flood damage, managing community interests and divergent interests, improving resilience coordination across sectors, and utilizing knowledge and values embedded in local history and traditions [15].

The spatial form of cities has a significant impact on climate change and is important in implementing adaptive responses within a resilience framework [16]. In the development of spatial planning aspects through local regulations in Indonesia, many regions have accommodated traditional knowledge (local wisdom) with community involvement in the spatial planning process [17]. Some of Indonesia's local wisdom can be utilized in disaster risk mitigation, such as forest conservation, spring conservation, and soil and water conservation [18].

The theoretical perspective above has not yet provided the reality of theory and reality, which has not yet described the simultaneous factors of technology in the relationship between mitigation and resilience. Technology is also related to flood disaster management. Disaster management factors have a relationship with local wisdom and adaptation. Local wisdom factors have a relationship to adaptation and spatial planning, and spatial planning factors have a relationship to adaptation and regional resilience. From the research problems above, an adaptation model is needed for the resilience of flood areas based on the construction of theoretical concept flows. This research intends to answer the following research questions:

1. Factors that have a dominant effect on disaster adaptation and mitigation and the resilience of flash flood disaster areas?
2. What is the adaptation and mitigation model in the form of resilience in flash flood-prone areas in West Malangke Sub-district, North Luwu Regency?

What are the adaptations and mitigations? This research is important to fill and develop theoretical gaps in the development model in constructing phenomena in the case of flood disaster areas with novelty in formulating disaster adaptation and mitigation models for the form of resilience of flash flood areas with multivariant analysis methods based on structural equation modeling (SEM-PLS) with the case of the downstream area of the Rongkong watershed in West Malangke District, North Luwu Regency. The urgency of this research is that it will strengthen or form regional resilience by preparing communities and regional systems that are resistant to flood disasters. In addition, it will address regional problems and challenges to face the threat of flash floods in the North Luwu Regency area. This research will analyze and formulate measurement and structural models from the point of view of flood technology, disaster management, local flood wisdom, and spatial planning towards adaptation and mitigation efforts for flash floods to realize the resilience of disaster-prone areas. model in the form of resilience in flash flood-prone areas in West Malangke Sub-district, North Luwu Regency

3. MATERIALS AND METHOD

3.1 Research Approach

This research uses a quantitative research design with an explanation-based ex post facto. The definition of this research design is to trace back the events that trace back to find out the causal factors. Explanatory research is used to test the relationship between hypothesized variables [19]. PThe process of explanation begins with exploring theories and concepts that are in accordance with the subject matter under study. The research approach uses a positivism paradigm [20], which emphasizes identification and quantification to measure the variables under study and collection and analysis using multivariate statistical analysis.

3.2 Studi Area

The research location, which is the population location, is in West Malangke Sub-district, North Luwu District, South Sulawesi Province, which consists of 13 villages as observation locations and 5 villages affected by floods as the main focus of observation, interviews, and surveys (Figure 1). The approach in sampling research amounted to 300 respondents with sample conditions that are known to the total population, which is divided into 5 villages, namely Cenning, Waelawi, Limbong Wara, Wara, and Pombaka.

The selection of the research site was based on several basic considerations, as follows: (a) has the genesis characteristics of flood events such as the rise in water level as a result of overflow of surface flow (run-off) in the watershed; (b) is a Flood Prone Area (KRB), the intensity of flood events and the magnitude of the impact caused, or relatively high disaster risk; (c) the area has a risk of flash floods; (d) the research location can be replicated model handling in the area and typology of problems from the impact of flooding in the downstream area with the potential of tidal water supported by local uniqueness of the physical characteristics of coastal land and socio-economic agrarian communities.

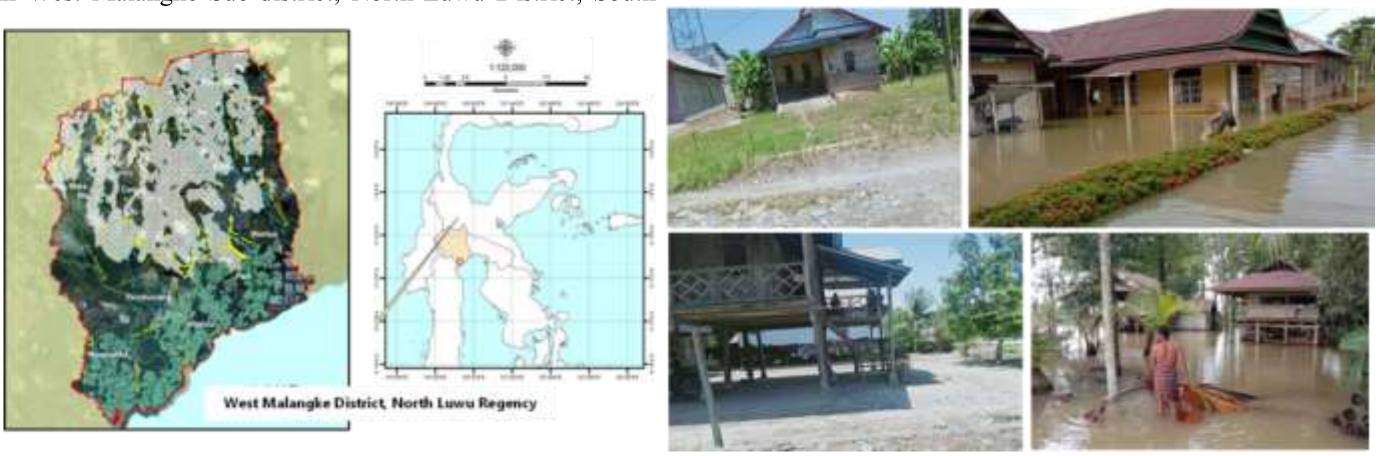

Figure 1. Research Area

3.3 Method of Collecting Data

Data sources in the study were obtained through field observations, documents, surveys, and interviews. The data sources are as follows: (a) observation and documentation in this study were used for data needs on land conditions around the river, physical conditions of buildings, and social, cultural, and economic conditions of the community; (b) respondent surveys and interviews, distributing questionnaires and interviews, were conducted to obtain data on the physical condition of the area, community and government adaptation activities, and spatial policies. Indicators were measured with a Likert scale through questions in the questionnaire and scored: (1) strongly disagree; (2) disagree; (3) disagree and disagree; (4) agree; (5) strongly agree.

3.4 Data analysis method

The analysis method uses quantitative descriptive analysis of the data collected from the survey, which is then examined and integrated into Smart-PLS 3. The Structural Equation Modeling (SEM-PLS) process is carried out simultaneously with measurement and structural processes to build a model [21]. This concept is a relationship model of adaptation in the form of disaster resilience. The variables in this study are flood technology (X_1) as independent or exogenous variables, disaster management (X_2), local wisdom (X_3), spatial arrangement (X_4), disaster mitigation and adaptation (Y) as intervening variables, and flood disaster area resilience (Z) as dependent or endogenous variables. The following equation model is as follows:

$$Z = X_1 + X_4 + Y + e \quad (1)$$
$$Y = X_1 + X_2 + X_3 + X_4 + e \quad (2)$$
$$X_2 = X_1 + e \quad (3)$$
$$X_3 = X_4 + e \quad (4)$$

The following is a conceptual proposal of the relationship model and variables and their indicators, and the analysis process is carried out using path equations with the Partial Least Squares Structural Equation Modeling method (SmartPLS 3); see Figure 3.

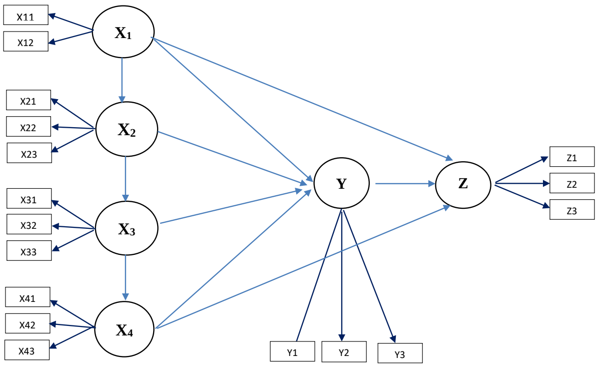

Figure 2. The concept of the proposed research model

4. RESULT AND DISCUSSIONS

4.1 Factors influencing disaster adaptation, mitigation, and resilience in flood disaster areas

4.2.1 Measurement Model Analysis (Outer Model)

The results of checking the convergent validity of all indicators already have criteria for the outer loading value to be ≥ 0.7, meaning that the indicator is a valid construct. Furthermore, the assessment of discriminate validity based on the latent construct of flood technology has an AVE square root value of 0.917, the AVE value of the disaster adaptation and mitigation variable is 0.840, the AVE value of the flood area resilience variable is 0.876, and local wisdom has an AVE value of 0.838, where the latent construct correlation value has a high value compared to the disaster management value, which only has an AVE value of 0.799. The results of discriminant validity through the Fornell-Lacker criteria for latent constructs of flood technology, disaster adaptation and mitigation, flood area resilience, local wisdom, and disaster management have good discriminant validity values.

Table 1. Internal consistency reliability

Variable	Cronbach's Alpha	rho_A	CR	AVE
Disaster adaptation and mitigation	0.789	0.792	0.878	0.706
Resilience of flood areas	0.849	0.899	0.908	0.767
Local wisdom	0.786	0.783	0.876	0.702
Disaster management	0.722	0.731	0.841	0.639
Space arrangement	0.820	0.825	0.893	0.735
Flood technology	0.810	0.811	0.913	0.840

Notes: Loading Factor >0.70, CR>0.70, AVE>0.50 [21]

4.2.2 Structural model analysis (Inner model)

The value of determination in the endogenous construct of disaster mitigation can be supported as a link between variables, with a strong relationship reaching 33.7%. The adjusted R2 value on the endogenous construct of disaster resilience shows that this construct can be supported by exogenous variables, with moderate reaching 14.1%. The R2 adjusted value of the endogenous disaster management construct shows that the exogenous construct is strong enough to reach 26.1%. Furthermore, the adjusted R2 value on the endogenous construct of spatial planning shows that this exogenous construct can be supported by a fairly strong variable, only reaching 29.1%.

Table 2. Results of path coefficient values and p values

Path	Sample Mean (M)	T Statistics	P Values	Effect/Sig
Disaster adaptation and mitigation -> Resilience of flood areas	0.161	2.249	0.025	Positive/Significant
Local wisdom -> Disaster adaptation and mitigation	0.084	1.120	0.263	Negatif /Not significant
Local wisdom -> Spatial arrangement	0.537	9.096	0.000	Positive/Significant
Disaster management -> Disaster adaptation and mitigation	0.260	2.981	0.003	Positive/Significant
Disaster management -> Local Wisdom	0.261	4.262	0.000	Positive/Significant
Spatial arrangement -> Disaster adaptation and mitigation	0.448	4.758	0.000	Positive/Significant
Spatial arrangement -> Resilience of flood areas	0.058	0.717	0.474	Negatif /Not significant
Flood technology -> Disaster adaptation and mitigation	-0.065	1.036	0.301	Negatif /Not significant
Flood technology -> Resilience of flood areas	0.290	4.646	0.000	Positive/Significant
Flood technology -> Disaster management	0.513	10.319	0.000	Positive/Significant

Notes: **t-value is below 1.96 and *p<0.05. Source: Author elaborator

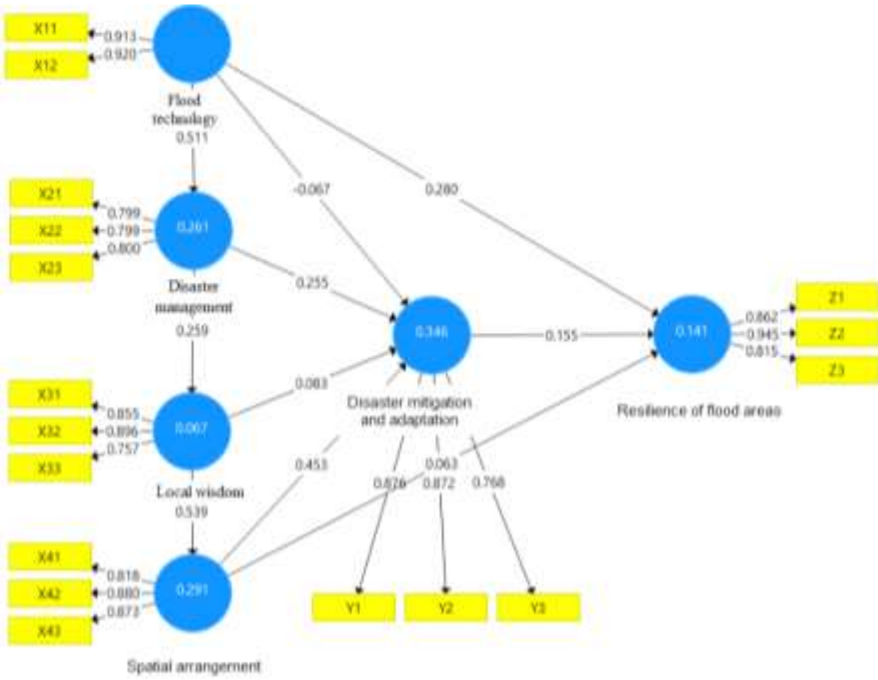

Figure 1. Results of tests of the influence between variables and the influence of indicators on variables

In Table 2 and Figure 3, the path coefficient results show that of the ten hypotheses proposed, all are acceptable. The path coefficient results show that disaster adaptation/mitigation has a significant effect on flood area resilience, local wisdom has no significant effect on disaster adaptation/mitigation, local wisdom has a significant effect on spatial planning, spatial planning has a significant effect on disaster adaptation/mitigation, spatial planning has no effect on flood area resilience, disaster management has a significant effect on disaster adaptation/mitigation, disaster management has a significant effect on local wisdom, flood technology has no effect on disaster adaptation/mitigation, flood technology has a significant effect on disaster management and flood technology has a significant effect on flood area resilience.

4.2 Adaptation and mitigation model in the form of resilience in areas prone to flash flood disasters

The relationship between adaptation and mitigation has an effect on resilience, and this finding is in line with the research of Leichenko [8], Einecker & Kirby [9]. The findings of this study reveal that disaster mitigation and adaptation is a community response to the importance of community mitigation and adaptation to their environment, supported by the importance of technical guidance (disaster training), early warning to face disasters, disaster posts, and disaster insurance, which will support the occurrence of flood area resilience marked by good economic activity, the occurrence of post-flood social and economic changes, and infrastructure conditions that remain good. This relationship encourages social, economic, and cultural changes in the community in West Malangke Subdistrict to occur in stages of change that lead to hereditary values, both stilt house buildings that are maintained in flood adaptation and new adaptation values in changes in agricultural activities from brown farming to paddy field farming. Changes in old adaptations to new adaptations will encourage communities to become resilient to environmental conditions at risk of flooding.

The relationship between local wisdom and adaptation and mitigation is not in line with Simarmata's research [18] on local wisdom in conservation. The findings of this study reveal that local wisdom is carried out by the community on the riverbanks as actors who utilize the land on the riverbanks by cultivating crops such as corn and sweet potatoes in order to increase the economic value of the community. This value is only economic utilization but less on river ecology if flooding occurs, which will have an impact on damaging agricultural products. Local wisdom from the traditions of building houses on riverbanks, farming and gardening on riverbanks, and fishing in rivers does not have direct consequences for adaptation and mitigation but indirectly encourages relationships through spatial planning so that it becomes a good relationship model for regional sustainability.

The relationship between local wisdom and spatial planning has an influence; this finding is in line with Ahyar & Kristiyanto's research [17]. The findings of this study reveal that local wisdom, marked by the tradition of building houses on riverbanks, the tradition of farming and gardening on riverbanks, and the tradition of catching fish in the river, is a driving force for the creation of spatial planning with local wisdom that utilizes the riverbank environment wisely. The relationship between spatial planning and the spatial utilization of riparian areas is also determined by the value of good local wisdom that is still maintained by the community in West Malangke Subdistrict, which will have a positive impact, especially the use of rivers for cage cultivation, fishing, and well-contained crop farming, which has an impact on the sustainability of riparian areas.

The relationship between disaster management and adaptation and mitigation has an influence, and this finding is in line with Kusumasari & Alam's research [13]. The survey results illustrate that 10.54% of respondents do not have early warning facilities or the availability of disaster posts, only the sub-district office as a temporary post in the event of a disaster. Aspects of disaster mitigation and adaptation where the knowledge and experience factors of flood disasters are still weak from the survey results, as many as 49% are only high school graduates, as many as 20% are junior high school graduates, and as many as 15% are elementary school graduates, this will affect the knowledge factors and adjustments to disaster mitigation and adaptation both before and after flooding. The physical mitigation aspect through flood control buildings is also still partial where physical policies are still prioritized, characterized by flood control buildings in the form of river management that are only temporary and will be damaged in the event of a flash flood, so the findings of this study can explain why these two factors are very important where community information and knowledge in disaster management and mitigation and adaptation are minimal, which can hinder the process of sustainability in disaster-prone areas. The condition of the community, with limitations in technical guidance and training for disasters, the absence of early warnings and disaster posts, and disaster insurance, indicates that the community and the government are still alert to various disaster events marked by physical damage and disaster victims. This indicates that the downstream community has experienced a phase of attitude development from the problem of flooding in their environment, so that there are local values that occur in efforts to understand the disaster.

The relationship between disaster management and local wisdom has a significant effect on local wisdom. This finding is in line with Kusumasari and Alam's research [13] and explains the new theoretical development of Hariadi et al [14]. The findings of this study illustrate that the community has knowledge of the ecosystem that occurs in their place of residence and seeks to avoid various safety threats from flood disasters. The local wisdom aspect should be interpreted as the knowledge of the community that already knows the environment and its environmental conditions, or regional wisdom, which is the knowledge of the community in finding answers that occur and have been maintained until now. A disaster management plan needs to clarify the position of the community in Malangke Sub-district with social and cultural capital in the form of local wisdom.

The relationship between spatial planning and disaster adaptation and mitigation has a significant effect, and this finding is in line with Meng et al.'s research [15]. The findings of this study illustrate that the government and community members consider spatial aspects important in promoting disaster mitigation and adaptation. The results of the respondents illustrated that 78.33% of the community considered the importance of planning, utilizing, and controlling disaster-prone areas. Meanwhile, 78% of respondents surveyed said that the increase in the area of flood areas from year to year was due to weak spatial control. In the aspect of disaster mitigation and adaptation, where the knowledge and experience factors of flood disasters are still weak, this will affect the knowledge and adjustment factors of disaster mitigation and adaptation both before and after flooding. The combination of spatial knowledge and good mitigation and adaptation in the community will have a positive impact on minimizing the physical and non-physical impacts that occur due to flood disasters. The importance of information on disaster-prone conditions in the aspect of spatial planning encourages the balance of ecosystems and the carrying capacity of the environment, so that the government and the community can be in line in the form of the sustainability of flood areas.

Spatial planning relationships have no effect on the resilience of flood areas, where the findings are consistent with Brunetta et al [16]. The findings of this study describe that spatial planning aspects do not have a significant relationship with the severity of the area of the flood disaster, but the main process requires disaster mitigation and adaptation aspects so that the relationship is disaster severity. This is due to the relationship of mediation through mitigation and adaptation of disasters, so it can be concluded that this indirect relationship is more because of the immaturity and conditions of the area of future flood disasters, which cause the space relationship, and resilience has no direct relationship but requires a more important process that is adaptation and mitigating disaster.

The flood technology relationship has not had an influence on significant disaster adaptation and mitigation, where the findings are in line with Kurniyati et al.'s research [11]. The findings of this research illustrate that the need for weather modification to prevent flooding and technological engineering for new flood control methods is an approach that is not yet represented as an important need where this factor really requires a very large budget policy effort. The community and government do not yet have capital for flood technology, which is a burdensome factor to date. Limited budgets and political support from the government budget in flood problems result in efforts to mitigate and adapt to disasters with limited budgets, so community knowledge and experience are needed in flood disaster management.

Flood technology has a significant impact on disaster management, and the findings are in line with McCallum et al.'s research [10]. The findings of this research illustrate that the technological aspect of flooding is a serious aggravating factor, so that disaster management efforts are needed that do not have large budget costs in the form of strengthening management information, technical guidance (disaster training) down to the community level, and early warning facilities to deal with disasters in the form of hotspots. information points at density centers, worship facilities, health, and government to provide information, as well as social media information and disaster posts. The condition of the community and government with limited budgeting capital in fulfilling flood technology is where this factor is the toughest factor in the resilience of flood disaster areas, so disaster management is needed with community knowledge and wisdom in flood disaster management.

Flood technology has a significant impact on flood disaster resilience. These findings develop and explain the research of Wahyuni et al [22]. The findings of this study describe that flood technology has a significant influence on the durability of flood disasters. This is due to budget capital constraints, but social capital becomes an important factor in the existence of a society, becoming an environment that is resilient with gotong royong efforts in improving facilities. The relationship is not only formed by the aspects of flood technology and the severity of the flood area, but there is also a mediation relationship in the efforts of regional resilience through disaster mitigation and adaptation.

5. CONCLUSIONS

Changes in the world's climate in the last decade have caused annual seasonal changes, especially in tropical geographical areas, especially in the North Luwu district, where there have been massive land use changes in upstream areas dominated by protected forest areas and have had an impact on the condition of degradation of watershed areas with the risk of flash flood disasters in downstream areas.

The relationship between the influence of disaster management and spatial planning has a significant influence on disaster mitigation and adaptation; this relationship also forms an indirect influence through local wisdom until the relationship to spatial planning occurs. While the relationship between the influence of flood technology and adaptation is both direct and indirect, This relationship model is a perspective of the reality experienced by the community and government in the occurrence of flash floods, especially aspects of disaster adaptation and mitigation in the form of disaster area resilience, which can be divided into two aspects, including the direct relationship model based on disaster management and spatial planning, which causes it to be a controller of the impact of disaster damage and encourages the resilience of disaster areas in West Malangke District, North Luwu County.

This research strengthens and develops the dynamics of the development of flood-prone areas in Malangke sub-district, which continues to occur in the rainy season, and the condition of rising sea water that encourages river overflow. The community and the government become actors in the development and sustainability of flood-prone areas, so that the development and sustainability model is considered with aspects of the limited real conditions of the community supported by the value of local wisdom. This research helps formulate a model of development and sustainability in flood disaster areas in the downstream area.

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