OPTIMIZED LAND SURFACE LOW POINT DETECTION USING THE D8 ALGORITHM IN A GEOGRAPHIC INFORMATION SYSTEM (GIS) FRAMEWORK

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ABSTRACT
Hydrological analysis in urban areas often suffers from inaccuracies in Digital Elevation Model (DEM) interpretation, especially in detecting micro-depressions and small-scale surface flow patterns. Previous studies typically relied solely on the automatic D8 algorithm in GIS without manual verification, resulting in flow directions that do not fully represent actual surface conditions. This study aims to compare manual D8-based flow direction calculations with automatic ArcGIS processing using DEMNAS data for Langsa City. The DEM (8.1 m resolution) underwent sink filling, hydrological conditioning, slope and aspect processing, followed by field validation using GPS measurements. The results show that the manual method identified 23 flow paths, whereas ArcGIS detected only 11. The differences stem mainly from micro-topographic variations that the automatic algorithm failed to capture in flat areas or anthropogenically modified surfaces. Field validation confirmed that 8 of the 11 ArcGIS-derived paths matched the actual drainage patterns, while the additional manual paths better represented subtle elevation gradients. This research contributes by offering a systematic comparison between manual and automatic D8 approaches, highlighting the importance of manual verification in low-slope urban terrains. The findings are valuable for micro-scale flood mitigation planning and urban surface hydrology analysis.
Keywords : *Digital Elevation Model (DEM), D8 Algorithm, Geographic Information System (GIS), Lowest Point*

1. Introduction

In the era of globalization and the rapid development of information technology, the use of technology in various fields is very important. One of the rapidly developing technologies is Geographic Information System (GIS) (Raihan, 2024; Akindele et al., 2025; Villacreses et al., 2022). Geographic Information System (GIS) is an important tool for spatial analysis, geographic data management, mapping and data visualization. Geographic Information System (GIS) allows users to integrate various types of data, perform complex spatial analysis, and visualize the results in the form of maps and graphs that are easy to understand. The utilization of Geographic Information System (GIS) in the field of hydrology, especially the identification of the lowest point on the earth's surface by determining the direction of water flow, is becoming increasingly important given the challenges of water resources management and natural disaster mitigation. The D8 algorithm is one of the algorithms used in hydrological analysis to determine the direction of water flow within each cell in a data network.

The water flow from each cell is directed to one of the eight nearest cells with the lowest elevation value, which is how it works(Doe, 2023). As a result, it is possible to estimate water flow and identify the lowest point in an area using the D8 algorithm. Although the D8 algorithm has a lot of potential, further research is needed to guarantee its accuracy and efficacy in various geographical settings before it can be used in Geographic Information Systems (GIS).

Research that has been done before in finding the lowest point on the ground using the D8 algorithm, including: Implementation of the D8 Algorithm for Lowest Point Search on the National Digital Elevation Model (DEMNAS)(Nirwana et al., 2022), previous research conducted a search for the lowest point using the D8 algorithm obtained from searching using ArcGIS and the data used using the National Digital Elevation Model (DEMNAS) data. However, in previous research, the determination of the direction of water flow was not only carried out in ArcGIS, but the determination of the direction of flow was also carried out using a system made by researchers using the Java language. However, the previous research also explained that the search for the direction of water flow was carried out for the needs in the process of finding the lowest point of land surface in a certain area using data from the National Digital Elevation Model (DEMNAS). In this context, the study of the application of Geographic Information System (GIS) to find the deepest point using the D8 algorithm is very relevant and important. In addition, climate change and rapid urbanization are increasing the frequency and intensity of natural disasters such as floods. In such a situation, the ability to identify low points and water flow to predict and manage flood risks becomes increasingly important. Therefore, this research also aims to provide practical solutions for better and sustainable spatial planning and natural resource management.

Surface flow direction modeling is fundamental in hydrological analysis, particularly in urban areas with flat topography and complex surface modifications. Although the D8 algorithm has been widely applied due to its simplicity and integration within GIS platforms, several studies report that it performs poorly in detecting micro-depressions and subtle slope variations (Smith et al., 2020; Rahman, 2022). Furthermore, most existing studies rely solely on automated GIS tools without critically comparing them against manual calculations. In the context of Langsa City, previous hydrological mapping efforts focused primarily on automatic GIS outputs with limited field validation. This leaves a clear research gap: the absence of a systematic comparative analysis between manual D8 computation and ArcGIS automatic processing using the DEMNAS dataset. The novelty of this research includes: (1) a direct quantitative comparison between manual and automatic D8-based flow direction methods; (2) analysis of micro-depression effects on flow pattern detection; and (3) field-based validation of flow direction accuracy. This study aims to improve the reliability of urban hydrological mapping and support better decision-making in drainage and flood mitigation planning.

The application of Geographic Information System (GIS) and the D8 algorithm not only provides benefits in the field of hydrology, but also has wide applications in urban planning, environmental engineering, and natural resource protection. The ability of Geographic Information System (GIS) to process large-scale data and provide detailed and accurate analysis makes it a very useful tool for researchers, planners, and policy makers. Therefore, this research aims to develop a Geographic Information System (GIS) application that utilizes the D8 algorithm as well as DEM data to find the lowest point on the earth's surface. This research is expected to make a major contribution to the development of Geographic Information System (GIS) technology and the D8 algorithm and provide practical solutions in water resources management and natural disaster mitigation.

Astronomically, Langsa City is situated between 04024'35.68" - 04033'47.03" North latitude and 97053'14.59" - 98004'42.16" East longitude. East Aceh Regency and the Malacca Strait border the city to the north, Aceh Tamiang Regency borders it to the east, East Aceh Regency and Aceh Tamiang Regency borders it to the south, and East Aceh Regency borders it to the west. Langsa City is also home to lowlands, rivers, and undulating terrain. It receives an average of 1,850 to 4,013 mm of rainfall annually, has an average air temperature of 28 to 33 degrees Celsius, and is located between 0 and 29 meters above sea level. The average humidity in Langsa City is 75%. In terms of topography, Langsa City is situated on a coastal alluvium plain that ranges in elevation from 8 meters above sea level in the southwest and south, where it is surrounded by slightly sloping folded mountains that reach a height of roughly 75 meters, to a swampy plain that stretches extensively in the east(Figures, 2024). Between 0 and 25 meters above sea level is the elevation of the Langsa City region.

Langsa City consists of 5 sub-districts, namely Langsa Barat, Langsa Kota, Langsa Lama, Langsa Baro and Langsa Timur. Langsa Barat is divided into 13 villages/subdistricts. Langsa Kota is divided into 10 villages/subdistricts. Langsa Lama is divided into 15 villages/subdistricts.

Langsa Baro is divided into 12 villages/subdistricts. Langsa Timur is divided into 16 villages/subdistricts.

An image of the earth's surface presented on a level surface is called a map. As a planning expert and policy maker, the government can use the map's appearance as a source of information to make judgments during the development process. In order for local government programs to be seen as having integrity, maps created in the most recent year or updated with the most recent data will undoubtedly offer factual and up-to-date data or information(Luis et al., 2021). Maps serve the purpose of methodically documenting the locations of both physical and predetermined cultural facts on the surface of the earth. When created with certain goals in mind, maps can be used for a wide range of purposes and provide a simplified description of geographical phenomena(Donya et al., 2020). With the advancement of technology, maps now depict not just items on the surface of the globe but also objects below and above it (in the air)(Ginantra et al., 2023). In general, maps are used to store information, evaluate spatial data, communicate information, and help with design projects such housing roadways, transit routes, and more. Based on the content of the data presented, the map is divided into 2 parts, namely:

A general map is a map that depicts all topography on the earth's surface, including natural elements (rivers, forests, etc.), man-made elements (housing, buildings, bridges, etc.), and the shape of the earth's surface (mountains, valleys, slopes, heights, etc. And, thematic maps are maps that depict information on the surface of the hill with certain or special themes. For example, geological maps, land mountain maps, tourist attraction distribution maps, weather maps, population density maps, statistical maps and so on.

A Digital Elevation Model (DEM) represents a 3D model of the earth's surface shape using a regular grid of uniform-sized cells (such as squares or triangles). Each cell embodies a specific elevation value (z) and has spatial coordinates of the form (x, y). Typically, the height value can be found in the middle of the cell. The size of the cell reflects the resolution that defines the detail level of the DEM. A smaller cell size increases the resolution and detail of the DEM, thereby more accurately depicting the actual shape of the earth's surface. DEM essentially denotes a digital model that depicts the earth's surface morphology in three dimensions (3D). Polyliterature contains research and publications on DEM. A Digital Elevation Model (DEM) is a digital representation of the geometry of the earth's surface or a portion of it. It consists of a collection of coordinate points obtained through sampling, which defines the surface using these points. Computer applications can be utilized in DEM processing to produce water flow directions and delineate catchment areas (Wood, 2023). A catchment area refers to a unit of water system area that is formed either naturally or artificially, primarily bounded by ridges and/or the highest elevation of the segment being examined.

The height of a land area in relation to sea level is known as land elevation. Regions situated at a low altitude will pose an issue, as water runoff will naturally aim for lower ground, leading to automatic inundation of these areas(Amin et al., 2022).

Algorithm flow direction is an algorithm used to determine the direction of flow by knowing the value of the surrounding pixels. According to Geoscience Australia, there are 8 main directions, namely east, southeast, south, southwest, west, northwest, north, northeast which indicate the direction of surface flow from one pixel to the surrounding pixels. The direction is encoded based on the convention standardArc/Info with 1=East, 2=South East, 4=South, 8=South West, 16=West, 32=North West, 64=Northand 128=North East. In the D8 algorithm, only one stream is used based on the lowest pixel value around it. Algorithm flow direction is a method used to determine the direction of water flow moving on the ground surface which is simulated from each pixel using DEM data. Each pixel in the DEM has a unique height value, so you can determine the direction of flow by knowing the values of the surrounding pixels. There are two main rules of the algorithm water flow direction, namely the algorithm Single Flow Direction (SFD) or commonly called D8 and the algorithm Multiple Flow Direction (MFD). In the method single flow direction, Flow direction work is carried out by considering the direction of water flow based on the height of a land surface obtained from digital data. Digital Elevation Model (DEM). For the SFD method it self, there is only one flow used based on the lowest pixel value around it. While in the MFD algorithm, it allows more than one flow direction based on the lower pixel value around it. The D8 algorithm, also known as the eight directions of water flow, has been widely used in analysis. Geographic Information System (GIS). In this algorithm, there is only one flow direction taken which is determined by means of comparing the height difference between the surrounding pixels. The algorithm commonly used in the process of determining the flow direction is D8 method. The flow direction refers to the smallest pixel value of the review pixel values. The Flow Direction algorithm serves to establish the water flow direction at every pixel within a Digital Elevation Model (DEM). With various elevation values, DEM is utilized to ascertain the water flow based on the pixel values in its vicinity; one of the algorithms for this purpose is D8(Adirinarso, 2023). The D8 algorithm is a method of computation that allows for eight distinct flow directions in a defined review area. It determines the lowest value among the pixel values in the vicinity (Ariana et al., 2023). A pixel is chosen as the direction of the water's movement if its value or height is less than that of the original pixel(Firgiawan et al., 2024). The next figure illustrates the working scheme of the D8 algorithm.

Surface water flow, a key element of the hydrological cycle, happens when rainwater or water from other sources moves over the land surface and transports soil particles. This phenomenon significantly affects the environmental context and everyday human life(W. Firgiawan et al., 2022). To comprehend surface water flow, it is crucial to be able to forecast the direction of flow. This capability affects many different facets of human life in a major way.

Surface water flow can be modeled using spatial data, which serves as the primary information source for water flow methods like the D8 (eight-way) algorithm(Halal et al., 2022). Spatial data refers to geographic information that characterizes objects on Earth with a geographic reference(Ezzat et al., 2021)(Hawkins, 2022). This spatial data is typically derived from maps that include interpretations and projections of all phenomena on Earth, encompassing both natural and human-made events (Ginantra et al., 2021). Spatial data refers to information that has a geographic connection to objects on the surface of the Earth. Maps are the primary means of displaying information contained in spatial data, illustrating representations and projections of various phenomena on Earth, including both natural and human-made occurrences. At the outset, every piece of data and information depicted on the map corresponds to objects located on the surface of the Earth(Nirwana et al., 2022).

Geographic Information System or Geographic Information System (GIS) is a computer-based information system, designed to work with data that has spatial information (spatially referenced). This system takes, checks, integrates, manipulates, analyzes, and displays data that spatially references the condition of the earth. GIS technology integrates common operations database, like query and statistical analysis, with the unique visualization and analysis capabilities of mapping. These capabilities are what distinguish GIS from other information systems, making it useful for a variety of groups to explain events, plan strategies, and predict what will happen. Today’s technological advancements allow GIS to be more interactive, enabling users to view detailed information about a location on a map. Geographic Information System (GIS) is now utilized across multiple domains, including health, transportation, tourism, education, and more. Various fields have also adopted GIS. Platforms including desktop, web-based, and Android(Perrina, 2021).

ESRI (Environmental Science & Research Institute) developed ArcGIS as a platform technology that assists users in creating, sharing, and accessing maps, applications, and data. ArcGIS offers contextual mapping and spatial analysis tools, enabling users to investigate location-based data. The primary offering of ArcGIS is ArcGIS Desktop, which comprises four fundamental applications: ArcMap, ArcCatalog, ArcGlobe, and ArcScene, along with the ArcToolbox(Sukmawati & Rahmah, 2022).

A systems flowchart illustrates the comprehensive workflow of a system. There are two types of flowcharts: system flowcharts and program flowcharts. System analysts often utilize system flowcharts to depict the flow of data or file structures within a system. This book does not cover such flowcharts. A program flowchart, as defined in(Arthalita & Hidayat, 2021), is a type of flowchart that programmers typically use to elucidate the steps involved in a task. There are five types of flowcharts: system flowcharts, document flowcharts, schematic flowcharts, program flowcharts, and process flowcharts(Malabay, 2016).

2. Literature Review

Geographic Information System (GIS) has become an essential tool in spatial data analysis, particularly in fields that require the integration, management, and visualization of geographic information. GIS enables users to combine various datasets and perform complex spatial analysis efficiently, making it highly valuable for researchers, planners, and policymakers. In recent years, GIS has been widely applied in multiple domains, including hydrology, environmental management, transportation, and urban planning. Its ability to present spatial data in the form of maps and visualizations allows for better understanding and interpretation of geographic phenomena, thereby supporting more informed decision making processes.

A fundamental component in GIS-based spatial analysis is the Digital Elevation Model (DEM), which represents the Earth's surface in a three-dimensional form using a grid of elevation values. Each cell in a DEM contains specific height information, allowing researchers to analyze terrain characteristics such as slope, elevation, and surface flow. The resolution of DEM plays a significant role in determining the accuracy of the analysis, as higher-resolution data provides more detailed representations of the terrain. DEM is widely used in hydrological studies, including watershed analysis, flood modeling, and surface water flow simulation, making it a critical data source for understanding environmental processes.

Surface water flow is a key aspect of hydrological analysis, as it describes how water moves across the Earth's surface due to gravity. This process has significant implications for environmental conditions, land use, and disaster management. Accurately predicting the direction of water flow is essential for identifying flood-prone areas, managing water resources, and mitigating natural disasters. Spatial data derived from DEM is commonly used to model water flow behavior, enabling researchers to simulate how water travels across different terrains and identify areas that are likely to accumulate water.

One of the most widely used methods for determining water flow direction in raster-based terrain analysis is the D8 (Eight Direction) algorithm. This algorithm operates by assigning flow direction from each cell to one of its eight neighboring cells based on the steepest descent. In other words, water is assumed to flow toward the adjacent cell with the lowest elevation value. The D8 algorithm follows the Single Flow Direction (SFD) approach, which simplifies the modeling process by allowing only one flow direction per cell. Despite its simplicity, the D8 algorithm is highly effective in identifying drainage patterns and locating the lowest points on the land surface.

In addition to the D8 algorithm, other methods such as the Multiple Flow Direction (MFD) algorithm have been developed to model water flow more realistically by allowing flow to be distributed to multiple neighboring cells. However, the D8 algorithm remains widely used due to its computational efficiency and ease of implementation. It provides clear and straightforward flow paths, making it particularly suitable for applications that require precise identification of drainage networks and lowest surface points. As a result, many studies continue to rely on the D8 algorithm for hydrological and spatial analysis.

Previous research has demonstrated the effectiveness of the D8 algorithm in identifying flow direction and lowest points using DEM data. For instance, studies utilizing DEMNAS (National Digital Elevation Model) and GIS software such as ArcGIS have shown that the D8 algorithm can accurately model surface water flow. Some researchers have also developed custom systems, such as Java-based applications, to enhance the calculation and visualization of flow direction. These studies highlight the potential of combining GIS tools with algorithmic approaches to improve the accuracy and efficiency of spatial analysis.

GIS software, particularly ArcGIS developed by ESRI, plays a significant role in supporting hydrological modeling and spatial analysis. ArcGIS provides various tools, such as flow direction analysis and raster processing, which enable users to automate complex calculations and generate visual outputs in the form of maps. These capabilities simplify the analysis process and allow users to focus on interpreting results rather than performing manual computations. The integration of GIS software with algorithms like D8 enhances the overall effectiveness of spatial analysis and supports a wide range of applications.

Identifying the lowest points on the land surface is particularly important in the context of flood risk management and environmental planning. Low-lying areas are more susceptible to water accumulation, making them vulnerable to flooding and other related hazards. By accurately detecting these points, planners and decision-makers can develop strategies to mitigate risks, improve drainage systems, and optimize land use. This becomes increasingly important in the face of climate change and rapid urbanization, which contribute to the rising frequency and intensity of natural disasters.

Furthermore, the integration of GIS with web-based platforms, commonly referred to as WebGIS, has enhanced the accessibility and usability of spatial data. WebGIS allows users to interact with maps and spatial information through online interfaces, making it easier to share and disseminate research findings. This technology supports collaborative decision-making and enables stakeholders to access real-time information for planning and management purposes. The combination of GIS, DEM data, and algorithms such as D8 within a WebGIS framework provides a comprehensive solution for spatial analysis and environmental monitoring.

Despite the widespread use of the D8 algorithm, there is still a need for further research to evaluate its performance across different geographic conditions and data resolutions. Comparing results obtained from automated GIS tools with manual calculations can provide deeper insights into the accuracy and reliability of the algorithm. Therefore, studies that integrate both approaches contribute significantly to the advancement of spatial analysis methods and offer practical solutions for real-world problems, particularly in hydrology and disaster mitigation.

3. Research Methods

3.1 D8 Algorithm

Preprocessing of the DEMNAS dataset included sink filling, hydrological conditioning, raster snapping, and slope–aspect computation to ensure surface continuity. These steps are essential to reduce artificial depressions and noise before flow direction modeling. The manual D8 method was computed by calculating pixel-to-pixel elevation differences, while the automatic method used ArcGIS Flow Direction and Flow Accumulation tools. Field validation using GPS measurements was conducted at selected points to confirm the actual flow directions. In the process of determining flow direction using the d8 algorithm there are several processes which will be explained in the form flowchartin figure 3 below:

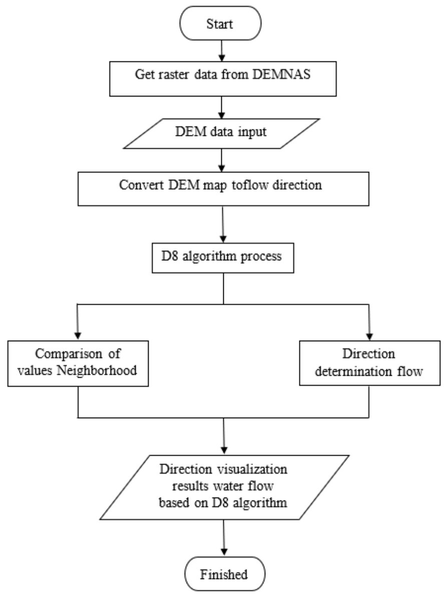


Fig. 1. Flowchart of D8 Algorithm

The following is an explanation of the use of the water flow direction algorithm, namely the D8 algorithm in the search for flow over the surface based on DEM maps.

1. The data source that the author uses in this thesis research is from DEMNAS, Geospatial Information Agency which can be downloaded at the link tanahair.indonesia.go.id. This research uses ArcGIS software as a system used to process data from DEMNAS or Geospatial Information Agency. The DEMNAS dataset used in this study has a spatial resolution of approximately 0.27-0.3 arc seconds (8-10 meters), integrating SRTM,

TERRASAR Xm and local IFSAR data. Dataset provides a vertical accuracy ranging fro 2 to 6 meters, which is adequate for hydrological and flow path modeling in urban areas such as Langsa City.

2. In this case, after downloading the raster data from DEMNAS, the DEM data is then input into ArcGIS, and then converted into a flow using the flow direction tool in ArcGIS. Then the result of the flow direction is converted into an arrow symbolized flow that is arranged based on a 45º angle comparison in each respective grid cell.

In the process of determining the flow direction, the comparison of neighboring values is calculated using the formula:

$$Slope = \frac{\mathrm{elv_a} - \mathrm{elv_b}}{\mathrm{distance}}$$

Compare the elevation values on each grid, look for the highest elevation which then the surrounding elevation value is lower so that it can be calculated using the formula above, then to determine where the flow direction is, it can be seen from the steepest slope results. The biggest or highest slope is the steepest slope. The steepest slope is generated from the search using the formula above. So that towards the cell that produces the steepest slope calculation result, the water will flow.

In the D8 algorithm used in this study, there are two methods in determining the direction of water flow and finding the lowest point of land surface in Langsa City. The method or method is used by using ArcGIS and using the D8 algorithm formula (manual calculation).

3.2 Flow Direction and Lowest Point With System

The rotation used in determining the direction of water flow in this thesis uses the arithmetic direction as follows:

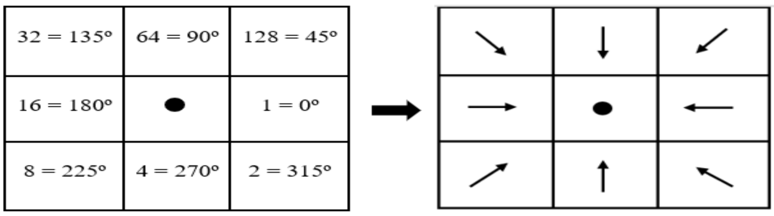


Fig. 2. Arithmetic Direction

By determining the direction of flow using a system that has flow direction tools, the flow direction will automatically come out eight directions that flow towards 1 point based on the arithmetic flow direction as shown in Figure 2.

To ensure methodological transparency, the manual D8 analysis considered micro-topographic variations that may not be captured by the DEM resolution. The flow direction generated by ArcGIS was compared systematically with the manually derived pathways. The distinction between these methods allows the assessment of how DEM resolution limitations affect flow path detection.

3.3 Flow Direction and Lowest Point with D8 Algorithm Formula

Basically, water flows from a height towards a low area. So to determine the 8 points of flow direction intended by the D8 algorithm, a comparison of the values of each elevation is carried out.gridfirst to get the arrow direction results with the following search formula. The Flow Direction tool was executed using the standard D8 deterministic mode with the cell size set to match the native DEM resolution. Snap raster was activated to maintain grid alignment, and hydrological conditioning settings were enabled to improve flow path accuracy.

$$Slope = \frac{\mathrm{elv_a} - \mathrm{elv_b}}{\mathrm{distance}}$$

Information:
Slope: Slope
$\mathrm{elv_a}$: First height
$\mathrm{elv_b}$: Second height

Notes:
If the distance is straight horizontally and vertically then the distance = 1.
If the distance is diagonally then the distance = 1.41

For an example of a comparison of elevation values owned in each cell and the search for the flow direction that the author takes here is one of the 8 flow directions in West Langsa District. The lowest point based on the eight flow directions used as case samples is in the Kuala Langsa area. With the elevation that can be seen in figure 3 below.

1,104722	0,768535	0,394113
1,252697	-3,21554	-2,0302
-1,159584	1,035513	0,021758

Fig. 3. Elevation on West Langsa DEM

The solution to determine the direction of flow is to compare the elevation value with the following slope search formula, and the elevation value can be seen in Figure 4 below:

1,104722	0,768535	0,394113
1,252697	-3,21554	-2,0302
-1,159584	1,035513	0,021758

Fig. 4. Comparison of Neighborhood Values 1

$$Slope\ 1 = \frac{-2{,}2302 - (-3{,}21554)}{1} = 0{,}98534$$

So, the flow direction obtained based on the largest slope obtained in the calculation of the elevation value which is smaller than the elevation -2.2302, namely elevation -3.21554 with a flow direction of 0º can be seen in Figure 5 below:

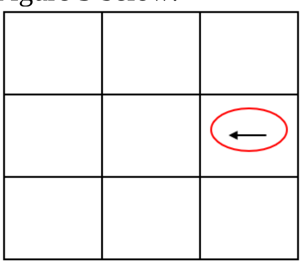


Fig. 5. Flow Direction 1

The following flow direction search with the neighboring values can be seen in Figure 6 below, there is 1 neighboring elevation value that is lower compared to the elevation value of the cell where the flow direction will be determined:

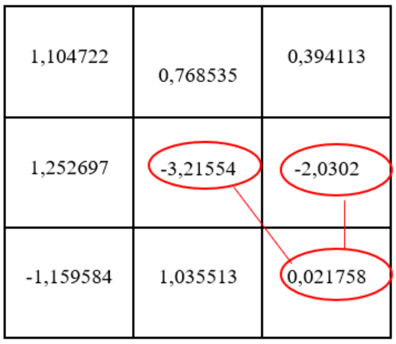


Fig. 6. Comparison of Neighborhood Values 2

$$Slope\ 1 = \frac{0{,}021758 - (-2{,}0302)}{1} = 2{,}051958$$

$$Slope\ 2 = \frac{0{,}021758 - (-3{,}21554)}{1} = \frac{3{,}237298}{1{,}41} = 2{,}2959560283687$$

Calculations in the direction of the second arrow are inslope2nd because it has a higher slope value. So the direction of the flow can be seen in the following figure 7.

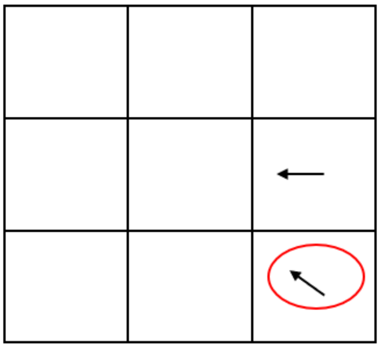


Fig. 7. Flow Direction 2

Do the next calculation like the calculation above until it produces the final flow direction, as shown below.

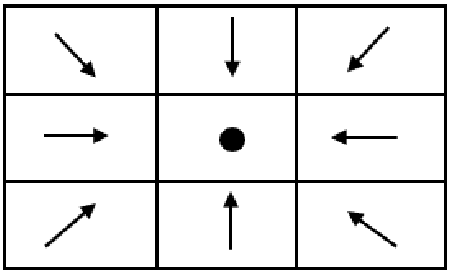


Fig 8. Flow Direction Visualization

The slope search is carried out to ensure that the flow direction is correct or not. The calculation to find the steepest slope serves to determine where the flow is headed. The visualization results of the flow direction are presented using a map via ArcGIS can be seen in Figure 9 below.

Fig. 9. Example of Case Study

To ensure the reliability of the D8-derived flow paths, field verification was conducted at several loe lying areas identified by the model, including Kuala Langsa, Gampong Jawa, and Pondok Pabrik. Observations were compared with flood prone locations documented by BPBD Langsa. The field survey confirmed that the majority of modeled low points correspond with actual drainage patterns and frequently inundated zones.

4. Results and Discussions

The final result of this research is the mapping of the lowest point resulting from the search for flow direction using ArcGIS and the search for flow direction using manual calculation.

4.1 Map Layout

The results of the research to find the lowest point on the land surface using the D8 algorithm in the Langsa area using DEM can be seen in layout the following map:

4.1.1 Initial Lowest Point Layout Map

For the lowest point of processing results using the system, namely ArcGIS with flow direction tools the lowest point results were obtained as many as 11 points from 5 subdistricts in Langsa City. For areas that are included as the lowest points based on real data before manual calculations using the D8 algorithm formula, the data amounted to 11 points that can be categorized as the lowest points because these points are closer to the concept flow direction with the D8 algorithm. And the following in figure 4.1 is layout from data based on system results using ArcGIS. This point was obtained before manual calculations were implemented with the D8 algorithm formula.

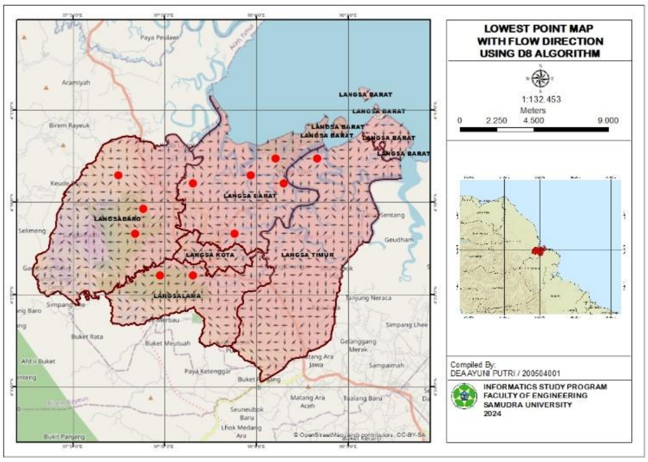


Fig .10. Initial Lowest Point Map

From the following figure 10, it can be concluded that the points obtained are 11 points, data from the five subdistricts can be seen in the table below.

Table 1. Initial Lowest Point Data

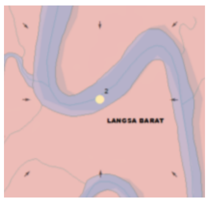
No.	Subdistrict	Lowest Point Count	Village
1.	Langsa Baro	3	Timbang Langsa, Pondok Kelapa (2)
2.	Langsa Lama	2	Pondok Pabrik (2)
3.	Langsa Kota	0	-
4.	Langsa Barat	5	Kuala Langsa (3), Seuriget, Sungai Pauh
5.	Langsa Timur	1	Sungai Lueng

Although ArcGIS detected 11 initial loe points, this outcome is strongly influenced by automated sink-filling processes, cell resolution, and the internal implementation of the Flow Direction tool. Emphasize that single flow algorithms like D8 tend to generalize depressions, causing some subtle topographic variations to be unrecognized. Therefore, the 11 points generated represent only major depressions, while smaller micro depressions may remain undetected without manual verification or algorithmic refinement.

4.1.2 Lowest Point Layout Map with Manual Calculation

Before becoming the final map result, it is necessary to carry out a map processing process using tools provided by software ArcGIS. Some tools used in making this map include raster tools, mosaic, clipping, dislove, and others. The data from the lowest point resulting from the search for the direction of flow can be seen in table 2 below. The results of this study produced 23 lowest points from 5 sub-districts in the Langsa area with each subdistrict having the lowest point.

Table 2. Lowest Point Data of D8 Algorithm

No.	Location	Arithmetic Direction	Flow Direction	Elevasi	Map
0.	Kuala Langsa, Langsa Barat Subdistrict	1	←	-2,2302	
		2	↖	0,021758	
		4	↑	1,035513	
		8	↗	-1,159584	
		16	→	1,252697	
		32	↘	1,104722	
		64	↓	0,768535	
		128	↙	0,394113	
1.	Alue Dua, Kecamatan Langsa Baro	1	←	1,434017	
		2	↖	1,122375	
		4	↑	1,828684	
		8	↗	1,341776	
		16	→	1,407752	
		32	↘	1,423439	
		64	↓	1,073253	
		128	↙	1,147287	
2.	Simpang Lhee, Langsa Barat Subdistrict	1	←	0,358921	
		2	↖	0,522622	
		4	↑	0,901232	
		8	↗	0,957594	
		16	→	0,651642	
		32	↘	0,43088	
		64	↓	0,345407	
		128	↙	1,041552	

In table 2 above is the data of the flow direction based on the D8 algorithm obtained from processing using ArcGIS. The flow directions in the table are based on the arithmetic directions that have been explained in the previous chapter. In table 2 there are 23 lowest points on the ground surface, with serial numbers starting with 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22. With different elevations or surface heights.

From the 23 lowest points obtained through DEM data, the elevation values of the 23 points obtained can be seen in table 3.

Table 3. Lowest Point Elevation Value D8

No	Lowest Point (D8 Algorithm)
0	-3,21554
1	0,687231
2	-0,167546

The comparison shows that the manual D8 method detected 23 flow paths while ArcGIS identified only 11. This discrepancy is mainly due to micro-topographic depressions and subtle slopes (<10 cm) that are not captured by the 8.1-meter DEM resolution. Manual calculation is therefore more sensitive to local variations, particularly in low-slope urban zones. These findings demonstrate that automated GIS processing tends to oversimplify flat areas, leading to underestimation of potential flow paths.

Seen from layout in Langsa Barat and Langsa Timur Districts there are many lowest points based on eight (8) flow directions. The lowest points are identified by a colored circle symbol. Cream which is surrounded by 8 arrow symbols as an illustration of the direction of the flowing water. The lowest point is presented on the lowest point layout map in Figure 11 below:

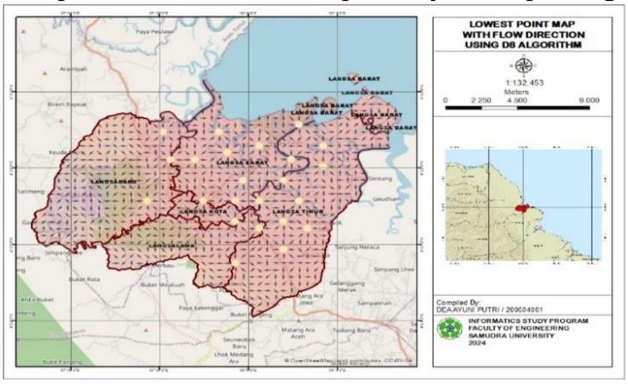


Fig. 11. Lowest Point Layout Map

From the results of this study, the lowest areas in several subdistricts were produced, which can be seen in the data in table 4 below. The data produced 23 points which can be said to be the lowest points from the search results using the formula above and based on the D8 algorithm. The lowest points produced are in each subdistrict in Langsa City.

Table 4. Lowest Point Results

No.	Subdistrict	Lowest Point Count	Village
1.	Langsa Baro	3	Alue Dua, Birem Puntong, Karang Anyar
2.	Langsa Lama	2	Baroh Langsa Lama, Sukarejo
3.	Langsa Kota	0	Alue Berawe
4.	Langsa Barat	10	Kuala Langsa (2), Simpang Lhee (2), Sungai Pauh (4), Seuriget, Matang Seulimeng
5.	Langsa Timur	8	Sungai Lueng (5), Cinta Raja, Alue Pineung, Buket Meudang Ara

So, it can be seen that between the real data (which is close to the D8 flow) or in other words the lowest point results using a system like ArcGIS with tools flow direction compared to the data that has been processed based on manual calculations with the D8 algorithm formula to determine the direction of flow as well as the lowest point, there are similarities in Langsa Baro District, namely that they both have 3 points as the lowest points. The increase from 11 to 23 low points following manual D8 calculation indicates that ArcGIS's automatic detection likely filtered out several micro-topographic depressions. Hydrologically, these additional points may represent minor storage areas where runoff can accumulate; however, without field verification, some may also represent false depressions caused by DEM noise or interpolation artifacts. Previous research notes that 8–10 m DEM resolution can introduce artificial sinks, particularly in flat landscapes such as Langsa Barat and Langsa Timur.

Moreover, D8's limitation in representing divergent flow on gentle terrain may lead to oversimplification of surface flow paths, contributing to potential false positives. Validation through ground truthing, GPS observation, or comparison with hydrological models is therefore necessary to confirm hydrological relevance.

These findings also suggest that terrain complexity, land cover, and drainage infrastructure significantly influence flow accumulation patterns, which are not captured in DEM-only analysis. Thus, the identified 23 points should be considered preliminary indicators rather than final flood-prone zones.

4.2 Webgis View Flow Direction Langsa Region

When compared with previous international studies on DEM-based hydrological modeling, such as those by Prodanović et al., (2009), Zaidi et al., (2018), Yao et al., (2022), the number of detected low points in Langsa aligns with trends observed in flat urban watersheds where micro-depressions dominate runoff behavior. However, the reliance on a single-flow algorithm (D8) places this study closer to earlier hydrological approaches and may benefit from integration with multi-flow algorithms in future phases. The results have practical implications for flood risk management, as the identified low points can function as indicators of potential water pooling, drainage blockages, or priority areas for infrastructure improvement. City planners and disaster management agencies can use these findings to enhance drainage design, early warning systems, zoning decisions, and climate resilience strategies. In this study, a GIS based web or commonly called webgis is also used. The following figure 12 shows the display. Home page from the webgis lowest point of Langsa City. In this menu there are several button options such as about and maps. Where when choosing about will enter the window about which contains a little description of the webgis that has been created, and there is a picture of the administrative boundary map of 5 subdistricts in Langsa City. While for map menu, when selecting the map menu, a map window will appear showing the lowest points in Langsa City which are located in each of the 5 subdistricts.

Fig. 12. Menu View Home

Next, in Figure 13 is a display of the lowest point map in Langsa City. The map includes the final results of the study with the case of finding the lowest point on the ground surface using the D8 algorithm with the data used coming from DEMNAS and the Geospatial Information Agency. The map shown in Figure 13 is a map that has been made into a web using the Qgis application. In other words, in Figure 13 is a web GIS display of the lowest point map in Langsa City with results in 5 sub-districts in Langsa City, such as Langsa Baro Subdistrict, Langsa Barat Subdistrict, Langsa Kota Subdistrict, Langsa Lama Subdistrict, Langsa Timur Subdistrict.

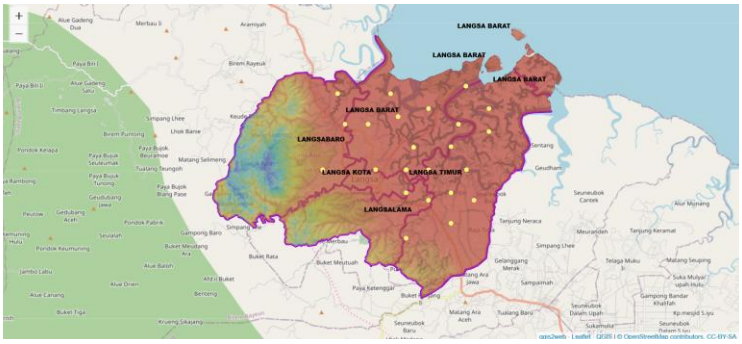


Fig. 13. Webgis View of Lowest Point Map

Figure 13 is a web GIS of the lowest point mapping using the D8 algorithm which was previously processed using ArcGIS, and determines the flow direction first before finding the lowest point in Langsa City. For the final results listed in the webgis image above, the cream-colored circle symbol is a symbol of the location of the lowest point in Langsa City with 5 Districts. Each District has a lowest point with a different number. The maroon border line on the edge of the Langsa City map is the administrative line or boundary of the Langsa City area, so that with this line you can see the shape of each subdistrict in Langsa City. Meanwhile, the base map used in this lowest point web GIS uses a basemap Open Street Map.

These results align with findings from recent hydrological studies suggesting that DEM resolution critically affects flow modeling accuracy, particularly in flat terrains. The inability of ArcGIS to detect several micro-scale flow paths indicates the need for manual verification in urban hydrological mapping. This has practical implications for drainage planning, as reliance solely on automatic GIS outputs may overlook critical pathways that contribute to localized flooding.

5. Conclusion

Based on this research, the following conclusions can be drawn:

1. Finding the location of the lowest point on the land surface in the Langsa City area based on 5 sub-districts.
2. Comparison of the lowest point map generated from ArcGIS with the map resulting from manual calculations using the D8 algorithm formula.
3. The final result of this study obtained that the number of the lowest points of the land surface in the Langsa City area based on 5 Districts produced by ArcGIS was 11 points. While the results of manual calculations with the D8 algorithm formula amounted to 23 lowest points.

This study provides a comparative analysis of manual and automatic D8-based flow direction modeling in Langsa City using DEMNAS data. The manual method revealed more detailed flow paths (23) compared to ArcGIS (11), emphasizing the limitations of automated algorithms in flat and modified urban terrains. Field validation confirmed that manual interpretation improves the accuracy of micro-scale flow mapping. Future work should utilize DEMs with resolutions below 5 meters or LiDAR data to further improve accuracy in capturing micro-topographic variations.

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