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RESEARCH ARTICLE

MORPHOMETRIC AND HYDROLOGICAL CHARACTERIZATION OF THE LOTIO WATERSHED AT LONGORALA IN THE SIKASSO-MALI CIRCLE

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ABSTRACT

For better watershed control, protection, water resource planning and seabed development; it is important to aquire master the its physical environment. The aim of this study is to understand the hydrological functioning of the watershed through its physical environment in order to successfully manage it. The data from the 30 m resolution Shuttle Radar Topographic Mission (SRTM) and the 1/200,000 scale urban mapping of the study area were used. The description of the watershed showed that it is an elongated and covers an area of 498.78 km^2. It is characterized by an old relief with a very low slope with an average drainage density of about 0.67 km/km^2. The shallows cover an area of 1981 ha. This study shows the sensibility of the catchment to run-off and consequently to develop it in order to ensure its sustainable exploitation.

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INTRODUCTION

In Mali, agriculture is the main economic driver, employing 80% of the population and accounting for more than 35% of GDP (Nkuingoua and Pernechele, 2022). The agricultural sector in Mali is performing poorly because of climate change, land degradation, conflict and inadequate infrastructure (NCEA, 2017). As a result, the high sensitivity of the agricultural sector to climatic uncertainties gives the development of hydro-agricultural developments (AHA) a decisive role in sectoral policy (Ministry of Rural Development and Water, 1999). Therefore, to increase food production, the main focus is on developing irrigation systems along flood-prone areas of the Niger River (NCEA, 2017). The same strategy has been extended to wetlands such as the Lotio tributary of the Banifing in the Sikasso Circle. In southern Mali, floodplains cover an area of about 3000 km2 (PIRL, 1999). They cover 8% of the rice-growing areas in Mali and over 17% of the arable land in southern Mali (Bariau, 1992). They are a significant asset in addressing food and nutrition insecurity because the lowlands have land and water conditions that are favorable to improving agricultural and livestock production (Consortium bas-fond, 1997). However, the exploitation of lowlands reveals many constraints, including the failure to consider factors characteristic of the functioning of lowlands and the limits they impose on crop intensification (Lidon and Simpara, 1991). These constraints require appropriate responses to ensure sustainable exploitation of the lowlands.

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They involve knowledge of the hydrological functioning of the watershed through its characterization. This is the context of the present study; whose purpose is to facilitate the hydraulic development of the Lotio to Longorala lowland.

MATERIALS AND METHODS

Presentation of the study area: The Lotio watershed at Longorala is located between latitudes 11°5'47'' and 11°25'45'' north and longitudes 5°37'45'' and 5°55'30'' west in the Sikasso Circle (Figure 1). The climate of the area is tropical Sudanese (Traoré *et al.*, 2021). The Lotio is a major permanent streamthat crosses 17 municipalities in the Sikasso Circle. The floodplain and lowland areas within the Lotio watershed occupy 33% of the potential of the Sikasso Circle (Ministry of Energy Mines and Water, 2007).

Extraction of the watershed and its hydrographic system: Geographic information system tools and teledetection were used to determine morphometric characteristics (Nadjla, 2016). The Tarboton *et al.,* (1991) method integrated into ArcGIS 10.3 has been highlighted (Figure 3) for processing data. These are the SRTM image of the study area at a resolution of 30 m pixels uploaded to www.earthexplorer.usgs.gov and the urban mapping at 1/200,000 scale collected at the Geographic Institute of Mali (2016). This methodology consists of exploiting the DTMas a basic product on which an algorithm is applied in order to extract the hydrographic network, point altitudes and to delineate and characterize the watershed. Indeed, the DTMare representations of altitude based on the topography of a given geographic area (Hocine *et al*., 2007 and

Beskri *et al.*, 2009). The first step in processing was to correct anomalies to eliminate holes and abnormal exaggerations on the SRTM to obtain the digital field model (DTM). Then the hydrographic network was created from the DTM. This required the creation of two raster files (flow direction: flowDir and flow accumulation: FlowAcc). Finally, a threshold (Con) of 1500 has been set to obtain the hydrographic network. The resulting network was classified using the Strahler (Strahler, 1957) method integrated into ArcMap. The watershed was defined from the flow direction file and the geographic coordinates of the basin outlet (Figure 2). The shallows within the basin were cut from the wetlands of the Geographical Institute of Mali urban mapping.

Calculation of morphometric parameters: The parameters involved in watershed characterization are calculated using empirical formulas. These are summarized in Table 1.

RESULTS

Geometric characteristics: Table 2 gives the geometric characteristics of the basin. It has an area of 498.78 km^2 and a compacticity index of Kc of 2.5. The length of the basin is almost ten times its width.

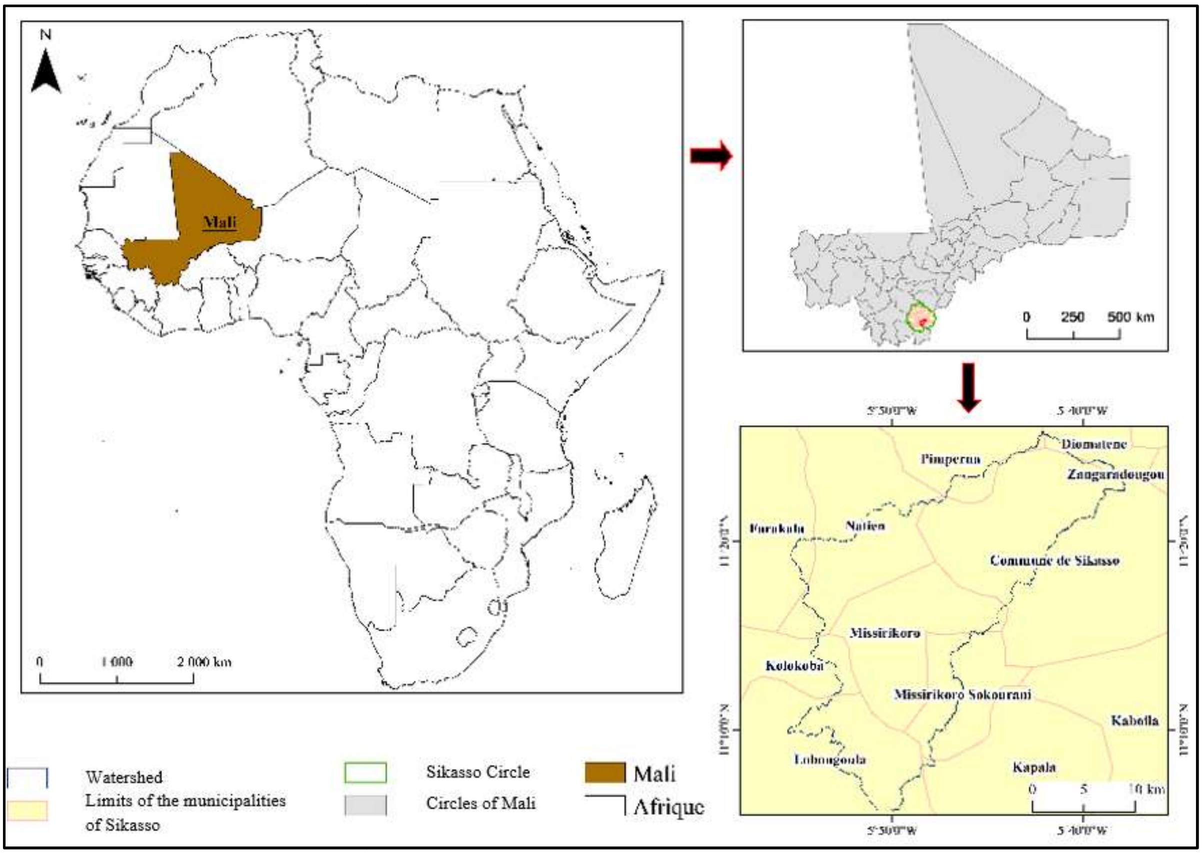

Figure 1. Location of the Lotio watershed at Longorala

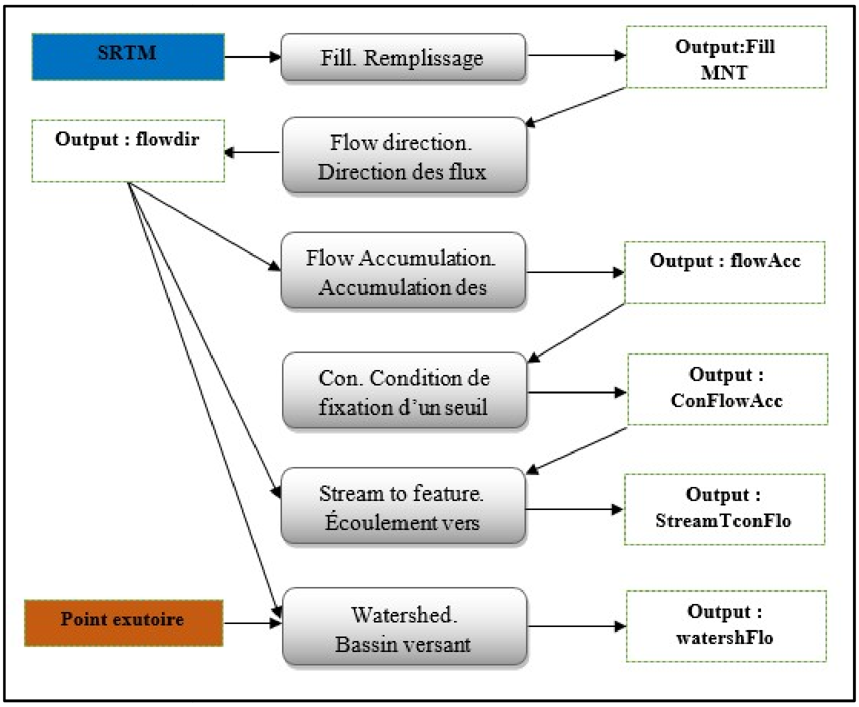

Figure 2. Drainage and watershed extraction

Table 1. Summary of the formulas for the calculation of morphometric and hydrological parameters

N°	Parameter	Formula	Abbreviation
1	Graveliuscompacticity index K_c	$K_c = \frac{P}{2\sqrt{\pi A}} = 0.28\frac{P}{\sqrt{A}}$	P: basin perimeter [km], A: catchment area[km²]
2	Equivalent rectangle	$\frac{K_c\sqrt{A}}{1,12}\left[1+\sqrt{1-\left(\frac{1,12}{K_c}\right)^2}\right]$	L: length of the rectangle [km], l: width of the rectangle [km], A: area of the catchment [km²], K_c:Graveliuscompacticity index
3	average altitude (H_{moy})	$H_{moy} = \sum\frac{A_i \cdot h_i}{A}$	A_i: area between two contour lines [km^2], h_i: mean altitude between two contour lines [m], A: total catchment area [km^2]
4	Indice de pente globale (I_G)	$I_G = D/L$	D: vertical drop, D = H5% – H95%, H5% = altitude corresponding to 5% of the total area of the basin, H95% = altitude corresponding to 95% of the total area of the basin, L: length of the rectangle [km]
5	Pente moyenne (Pmoy)	$P_{moy} = \frac{\Delta H_{max}}{L}$	ΔH_{max}: maximum difference in level of the river [m], L: length of the main watercourse [m]
6	Densitéde drainage (D_d)	$D_d = L_i/A$	L_i: Total length of rivers [km], A : catchment area [km²]
7	Bifurcation ratio (R_b)	R_b ou $R_c = n/n+1$	n: number of streams of order n, n+1 :number of streams of order n+1
8	length ratio (R_L)	$R_L = L_{n+1}/L_n$	L_n: mean length of water courses of order n, L_{n+1}: mean length of n+1 order river
9	Frequency of water courses (F_c)	$F_c = N/A$	N: number of watercourses of order 1, A:area of the catchment
10	Torrentiality coefficient (C_t)	$Ct = D_d{*}F_c$	D_d: drainage density, F_c: frequency of 1 order watercourses

Table 2. Lotio Basin Geometry at Longorala

Parameter	Résults
Area	498,78 km²
Périmeter	201,16 km
Gravelius compacticity index K_c	2,5
Length of equivalent rectangle	96,14 km
Width of equivalent rectangle	5,19 km

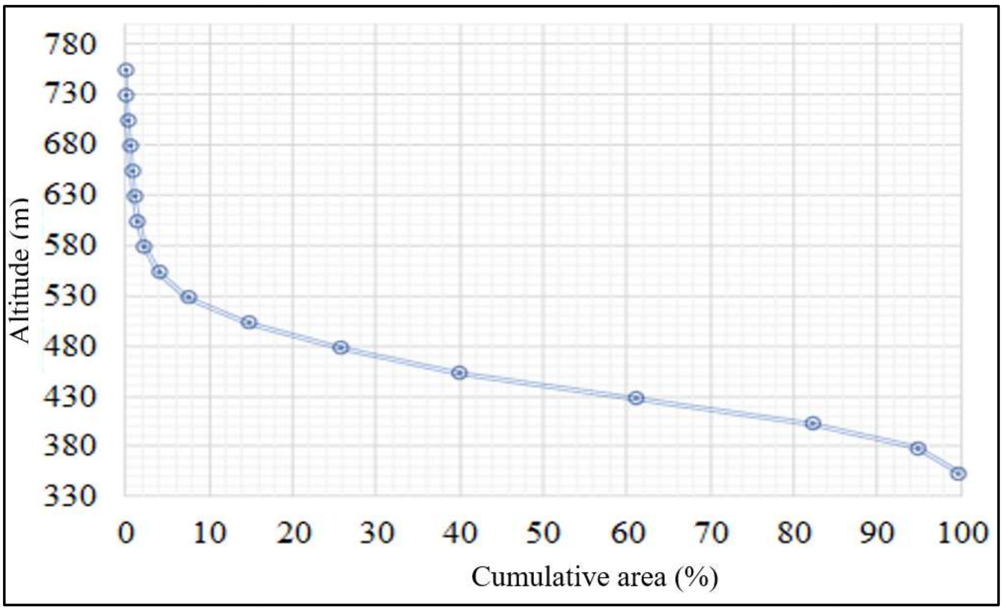

Figure 3. Hypsometric curve

Hypsometric curve: This curve and the hypsometric map are shown in Figure 3 and 4 respectively. Analysis of the curve shows a high concavity of 0 to 40% of the cumulative areas, followed by a low concavity up to 80% before ending with a convex shape. The overall trend of the curve is concave. The ridgelines are above 578 m. The dominant elevations in its upstream portion occupy 69.1% of the total area of the basin. They are between 353 m and 453 m and represent the flank. The lowest altitudes that represent the shallows are below 353 m or 4.9% of the basin surface. They are concentrated in the NE of the watershed.

Altitudes and Slopes: The values for the altitudes of the Lotio to Longorala watershed are shown in Table 3. It shows that the altitudes are between 753 m and 330 m. The values for the mean altitude and the median altitude are close. The overall slope index (IG) is 0.18% with an average slope of 0.43%.

Hydrographic system: The hydrographic system (Figure 5) of the study area is composed of four orders according to the Strahler classification (Strahler, 1957).

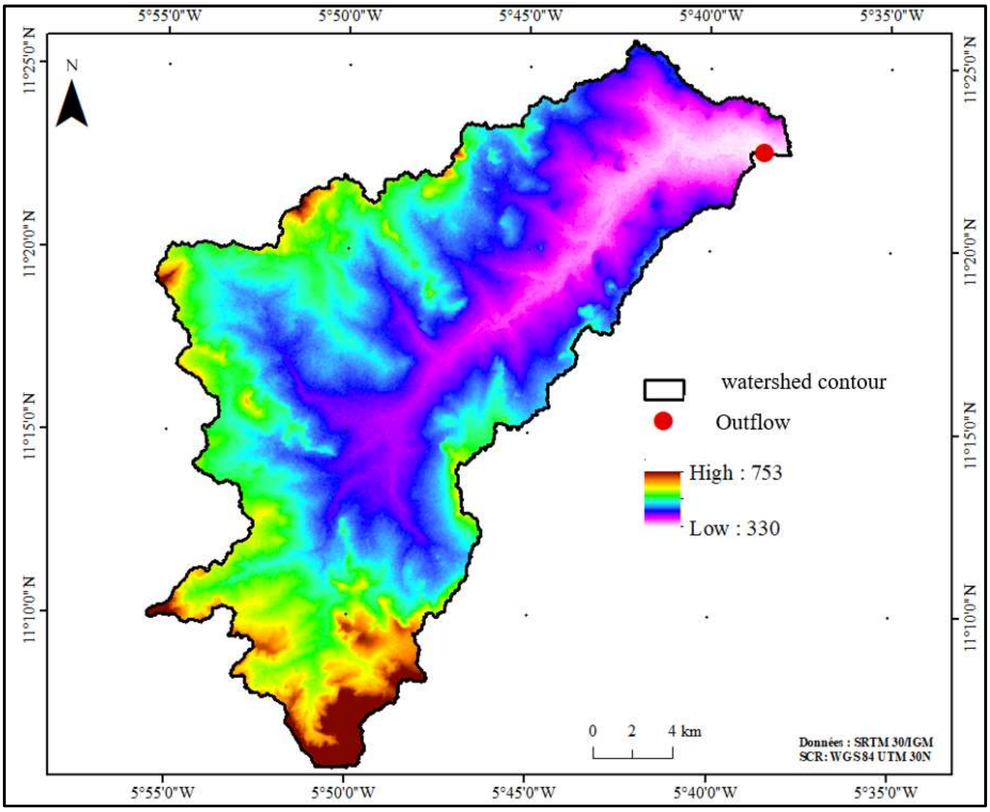

Figure 4. Hypsometric map of the Lotio watershed at Longorala

Table 3. Typical altitudes of the Lotio at Longorala

Parameter	Results (m)
maximum altitude	753
minimum altitude	330
average altitude	424,21
Altitude read at 50% of the basin surface	442

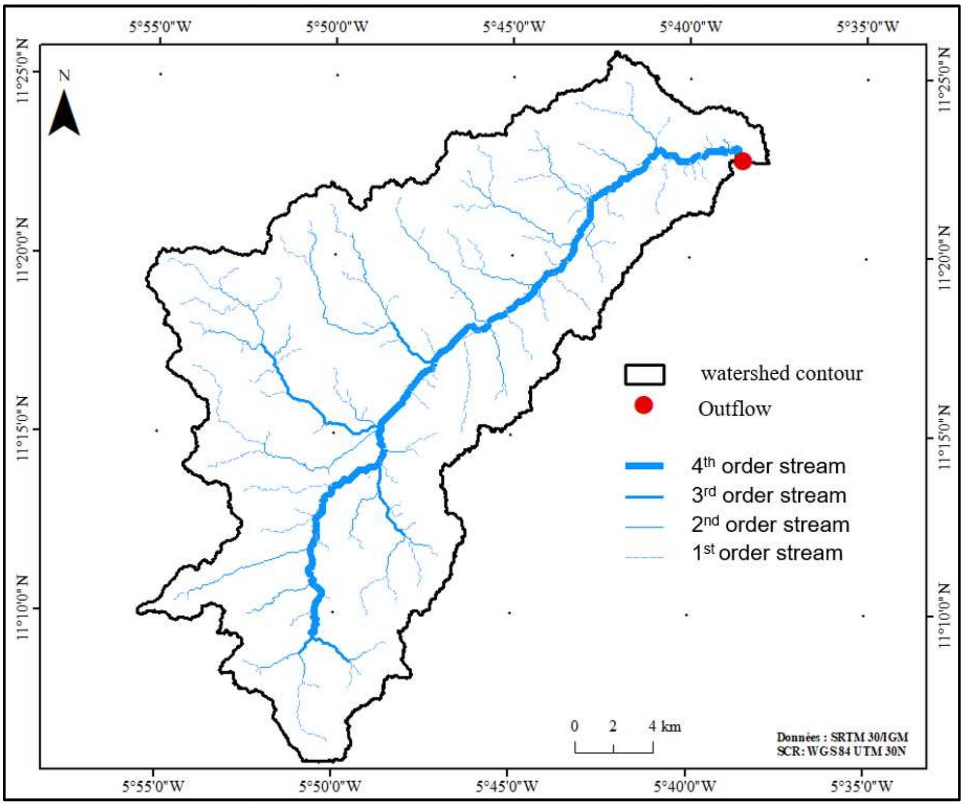

Figure 5. Organization of the hydrographic system according to Strahler (1957)

It is characterized by an average drainage density value of about 0.67 km/km^2. Bifurcation ratio varies between 0.37 and 2.16 (Table 4). Length ratio (LR) shown in Table 5 varies between 0.98 and 1.04. The values of the frequency and torrentiality coefficient for the Lotio basin at Longorala are 0.17 and 0.11 respectively.

Table 4. Bifurcation ratio

Water course of order n	Nomber	Bifurcation ratio
1	132	-
2	61	2,16
3	22	2,77
4	59	0,37

Table 5. Length ratio

Water courses order n	Nomber	total length	average length	length ratio
1	132	335,03	1,22	0,98
2	61	322,43	1,20	1,04
3	22	163,10	1,25	0,99
4	59	301,19	1,24	

The low-water areas: The lowland is a wetland in which agricultural practices are intense. In the Lotio at Longorala, the bottom is located in the NE part of the basin from its outlet. Its section covers an area of about 1981 ha (Figure 6).

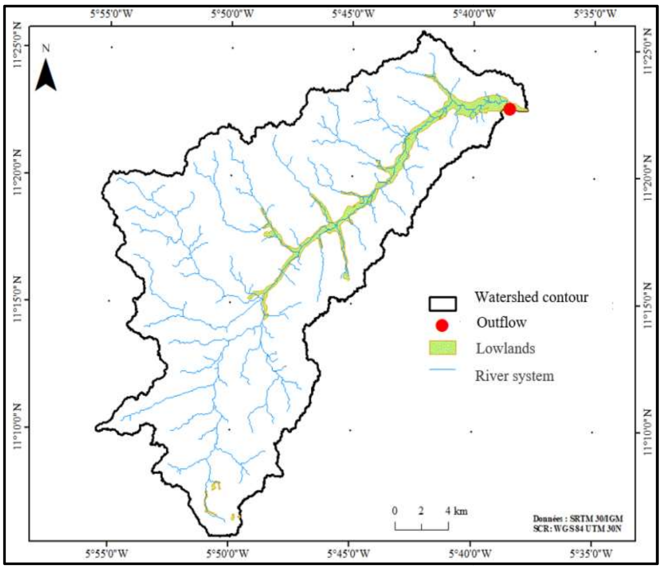

Figure 6. Lowland areas in the Lotio watershed at Longorala

DISCUSSIONS

The geometric parameters obtained are related to the hydrological behaviour of the basin studied. The high value of the compacity index gives the basin an elongated shape (Gravelius, 1914). This form suggests a strong infiltration including a high response time (Camara *et al*., 2018). It affects the flow and the evolution of the flow as a function of time in the basin (Ahmed *et al*., 2016). The elongated shape of the watershed generates low peak flood flows because remote areas are slow to influence outflow at the outlet. The basin is then characterized by low peak flow rates due to high concentration time. The mean and medium altitudes give a regular slope to the hypsometric curve. In addition, the concavity of the hypsometric curve of the Lotio watershed indicates its state of old age (Brahim*et al*., 2019; Bannister, 1980 and Amil, 1992). Referring to the ORSTOM classification, the value of the overall slope index shows that the basin is characterized by very strong relief. The hydrographic network is defined as all hierarchical linear streamdraining a water basin (Crave, 1995). According to Strahler (1964), the Rb varies from 3 to 5 for a region where geology has no influence. The high RL values indicate rapid sediment removal because higher order streams are important (Gravelius, 1914). With a drainage density of 0.67 km/km^2, the watershed is fairly well drained as evidenced by Hamed and Bouanani (2016). This value of the hydrographic network density can be explained by the medium permeability of the substrate and by a less rugged terrain. The value of the torrentiality coefficient reflects this permeability. However, drainage density may vary because according to Riad (2003) it is influenced by the geology of the topographical features of the watershed and to some extent by climatic and anthropogenic conditions. The Lotio is part of an arid climate with irregular rainfall (Traoré *et al.*, 2021), which has effects on its hydrological behaviour. The shallows are flooded during the rainy season by overflowing waters of the Lotio. Because of this favourable hydrology, these areas are exploited practically all year round.

CONCLUSION

This study shows the interest of physical characteristics in understanding surface flows within the Lotio basin at Longorala. The results show an area of 498.78 km^2 and a perimeter of 201.16 km. The Lotio watershed upstream of Longorala is characterized by an elongated shape. Its hydrological network is dense and branched, the geology of the region influences surface flows. Knowledge of the physical environment of the watershed is essential information in solving issues of development, development of the lowlands. With these results, this study facilitates the choice of type of development and their location in the watershed. However, it must be supplemented by hydrological studies.

REFERENCES

Ahmed L., Abdellah El. H., Lahcen G., Mourad El. A., 2016.Contributions of the digital terrain model MNT to the modelling of the relief and physical characteristics of the middle Beht watershed upstream of the El kansera dam (Sillon Sud Rifain, Morocco). *European Journal of Scientific Research*, 262 p.

Amil M., 1992.Nekour Watershed, Sedimentation Sources of the M.B.A El Khettabi Dam (Morocco). Doctoral thesis, Cheikh Anta Diop University, Faculty of Science and Technology, 209 p.

Bannister E. N., 1980.Hypsometries of Michigan's Southeastern Lake Plain. Journal of Great Lakes Research, Vol. 6, Issue 2, 154-163,

Bariau, O., 1992.Socio-economic study of a rural village near Sikasso (South-Mali). Importance of rice in production systems. *Institut Supérieur d'Outre-Mer (ISTON),* Cercy-Pontoise.

Beskri Y., Belhadj A. M., Hocine F., 2009.Extraction of geomorphological indices from watersheds from the NTM. Application: The Oued M'zab watershed, Algeria. *Journéesd' Animation Scientifique* (JAS09) of the AUF. Alger, 5 p.

Brahim B., Abdallah D., Larbi B., Driss S., and Brahim B., 2019.GIS input and remote sensing for the assessment of physical characteristics of the Oued Inaouene watershed (North-east Morocco) and their uses in the field of natural risk management. Am. J. innov. res. appl. sci. 8 (4)120-130

Camara O. M., Dembélé N. J., Diallo A. B., Tessougue M. M., and Traore D., 2018. Hydrological behaviour of an urban-peri-urban watershed: the Kalabancoro river in Bamako, Mali. Studies in Mali N°85.

Consortium bas-fond, 1997. The Layout of Low Lands. Bulletin du Consortium bas-fonds, 11p.

Crave A., 1995.Quantification of the organization of hydrographic networks. PhD thesis, University of Rennes I, 209 p.

Gravelius H., 1914.Grundriβ der gestamtenGewasserkunde, Band 1: Fluβkunde (compendium of hydrology), vol. 1: Rivers in German. Gůschen Berlin Germany.

Hamed B. H., and Bouanani A., 2016.Characterization of a watershed by statistical analysis of morphometric parameters: Case of the Tafna watershed (North-west Algeria). Geo-Eco-Trop., 40 (4) 277-286,

Hocine F., Belhadj A. M., Haddoud A., 2007.Extraction of the Hydrographic System from an NTM and use of GIS for watershed studies. *Proceedings of JSIRAUF,* Hanoi, 6p.

Institut Géographique du Mali., 2016.Cartographie Urbaine du Mali version 3.1.

Lidon B., Simpara M., 1991.Constraints of the natural environment and the value of seabed development: a case study of southern Mali. Low-lying areas and rice cultivation Antananarivo,451-467.

Ministry of Energy Mines and Water., 2007. National Action Plan for the Integrated Management of Water Resources (Part 2). Republic of Mali, 65p.

Ministry of Rural Development and Water., 1999. National Strategy for Irrigation Development. Republic of Mali, 50 p.

Nadjla B., 2016.Using a GIS to assess the physical characteristics of a watershed and their influence on water flow (Oued El Maleh watershed, Northwest Algeria. National Space Technology Centre, Remote Sensing Laboratory. Arzew, Algeria.

NCEA., 2017 Food security and employment under changing climatic conditions in Mali: What are the options? 27 p.

Nkuingoua, J., and Pernechele, V., 2022. Monitoring agricultural and food policies in Mali 2022 - Policy analysis report. Agricultural and Food Policy Monitoring and Analysis (AAPSA). FAO, Rome, https://doi.org/10.4060/cb8952en

PIRL, 1990. Regional Summary BDPA-SCET-AGRI-CTFT-SYSAME. Direction Nationale des Eaux et Forêts. Bamako. Mali, 320 p.

Riad S., 2003.Typology and hydrological analysis of surface waters from some representative watersheds of Morocco. Doctoral thesis, University of Science and Technology of Lille and University Ibnou Zohr of Agadir, 127p.

Strahler A. N., 1957. Quantitative analysis of watershed geomorphology. Trans. Am. Geophys. Union. 1957; (38) 913-920.

Strahler A. N., 1964. Quantitative Geomorphology of Drainage Basins and Channel Networks, VT Chow (ed), Handbook of Applied Hydrology. McGraw Hill Book Company, New York, pp. 4–11,

Tarboton D. G., Bras R. L., Rodriguez I. I., 1991. On the Extraction of Channel Networks from Digital Elevation Data. Hydrological Processes 5, 81–100,

Traoré S. M., Bengaly S., Cissé Y., Diarra S., Guindo A. M., 2021. Dynamics of Landscape Signatures in the Lotio Watershed 1990-2019. 133-139.

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