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Full Length Research Article

SIMULATION OF GROUNDWATER LEVEL IN RIVER MALLAM SULE CATCHMENT AREA OF POTISKUM, YOBE STATE USING SWAT

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ABSTRACT
This study is on simulating the level of ground water in River Mallam Sule Catchment Area of Yobe State. Soil Water Assessment Tool (SWAT) was used in the study. The resistivity of boreholes, gravity data, climatic data, stream flow data, and land use and land cover change served as an input to the model. The Catchment boundary was delineated using DEM (90m resolution), while be AsterDEM (30m resolution) was used for drainage network in Arc SWAT 2012. The finding of the simulation revels that the eastern and southeastern part of the study area has the highest level of groundwater respectively, moderate value was observed around Potiskum while low value was observed around southwest of the study area. Therefore, SWAT has the capacity to simulate the level of groundwater in areas with deficiency in groundwater recharge and low precipitation.

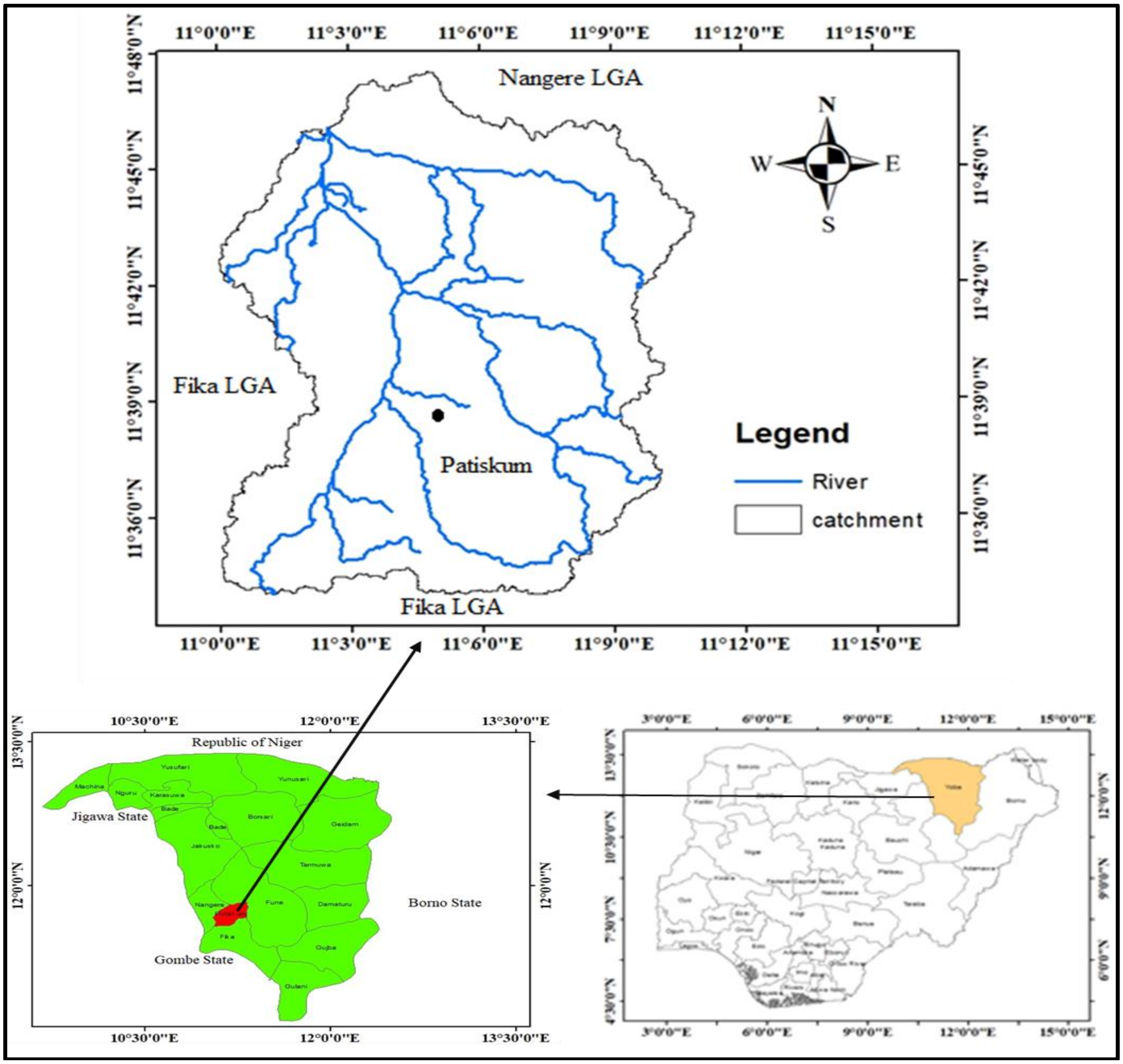
Keywords: Resistivity, groundwater, simulation, climate change.

INTRODUCTION

Climate change influences the entire system of groundwater directly and indirectly. Directly through recharge replenishment and indirectly through changes in groundwater use (Maggirwar and Umrikar, 2011). For direct impacts, replenishment of groundwater occurs either from rainfall recharge and via leakage from surface water, the leakage can come from streams, wetlands or lakes. Therefore, both rainfall recharge and recharge via leakage are highly dependent on the prevailing climate as well as on land cover and underlying geology. Geographical variability in modeled recharge is relay on the distribution of global precipitation (Maggirwar, 2011). Climate is the major factor that determined precipitation and evapotranspiration, whereas soil and geology of a location will dictate if water surplus (precipitation minus evapotranspiration) can be transferred and stored in the subsurface. (Zhou et al, 2017). The combined impact of these effects will definitely affect groundwater recharge.

The semi-arid region of northeastern Nigeria where the study area fall is characterized by low rainfall (500-700 mm/annum), and high evaporation (> 2000 mm/annum) the recharge for groundwater will defiantly be low (Yusuf, 2015) as such the tendency of groundwater to be low is high. Despite the challenges the demand for water in the study area has increased over the last few decades, due to increase in population, social and economic development in the region, a lot of pressure is on the groundwater through frequent pumping of the water from the aquifer (Edmunds et al., 2002). Various factors such as climatic, hydrologic, geologic, topographic, and soil-forming factors limits the capacity of groundwater system to meet these demands, including potential reduction of stream flow by groundwater withdrawals and large seasonal and long-term declines in water levels in wells. Available information and tools have remains a major challenge to quantify the level of groundwater in the study area. Numerical model such as SWAT now has the capacity to simulate the level of groundwater in areas with deficiency in groundwater recharge and low precipitation. Simulation of groundwater level will have proposed groundwater development and also support water-resources management decisions.

MATERIAL AND METHOD



The study area is located along Kano- Maiduguri federal highway. It is located between latitudes 11°03' and 11°30' North of the Equator and between longitudes 10°50' and 11°51' East of the Greenwich Meridian. Its distance by road from the State capital is about 98 kilometers west. The study area is a nodal town is which is bounded on the North by Nangere Local Government, South by Fika Local Government Area, East by Fune Local Government Area, and in the West by Fika and Nangere Local Government Areas respectively. The study area is located in the tropic which has two sessions which are; wet and dry seasons. Wet season is distinguished with the moist maritime South- westerly monsoon which emanated from the Atlantic Ocean and dry season is distinguished with the dry continental Northeast trade wind which emanated from Sahara Desert. Rainy season commences in the month of June and end in the month of September with the annual rainfall ranges from 500mm – 700mm (Audu, 2012). There are no precipitations from January to March in the study area. The study area lies within the wet and dry Sudano-Sahelian Savanna belt of Nigeria (Audu, 2012). The Vegetal cover is sparse as the grass grows nearly at the base leaving bare surfaces in between. The grasses in the Sudano-Sahelian Savanna belt are short in height (0.5m to 1.0m). The study area lies within the Nigerian sector of the Chad Basin. The area is a part of the sediments of the Chad Basin comprising such rock types as sand and sandstone, clay/shale intercalations that formed the Chad Formation which dips concentrically at about 1.5m/Km (Dawoud & Raouf, 2009). The soil of the study area is originated from drift materials which are mainly silt clay. The soil has poor capacity to retain water, the soil in the study area is mainly brown and reddish-brown soils (Oladimeji, et al., 2019). Calcium carbonate concentration is present at about a meter depth. The soil has low organic content but the organic matter is highly humified and well allocated in the profile.

Data required
The data used for this study included the following
The coordinates of the sampling points of each borehole was obtained using Global positioning system (GPS). Resistivity of boreholes to show variation of groundwater level. Climatic data from 1980 to 2019 was obtained from Nigerian Meteorological Agency, it served as an input used to build the ArcSwat model while Landsat Imagery was used to obtained Land use and land cover change data

Data preprocessing
The data obtained were preprocessed prior to analysis to account for any type of effect. Coordinate was imported in to Microsoft excel, it was arranged accordingly and converted to decimal degrees then saved as Command Delimited and then imported in to the GIS environment for further use.
Resistivity data was imported in to Microsoft excel, saved as Command Delimited and then imported in to GIS environment. Join and relate tool were used to link the resistivity data with the coordinates.
Climate data was subjected to clipping, missing value, outlaying and normalization. The missing values were test in order to ascertain the completeness of the data for further analysis. According to World Meteorological Organization (WMO) standard, it is not recommended to fill more than 10% of missing data. Due to the scarcity of data, a threshold of 15% was used. Therefore, the Missing data in climate variable will be filled using the ordinary least squares (OLS) methods (Schneider, 2001).
Landsat imagery was subjected to co-registration, conversion to radiance, solar correction, and atmospheric correction. Radiometric and geometric restoration processes were applied to restore image from errors. Landsat imagery has limitations, it has thirty meters resolution which does not give accurate results especially when conducting land use, land cover analysis. Within a pixel, any class with a dominant spectral reflectance will cover the entire pixel.
The SRTM DEM data was projected to UTM using ArcGIS 10.4 software package. Subsequently, it was used to provide the catchment characteristics such as delineate watershed into a number of sub-watersheds or sub-basins, drainage pattern, slope, channel width and stream length within the watershed, which were required for hydrological modelling.

METHOD OF DATA ANALYSIS
Soil Water Assessment Tool (SWAT) was used in the study, because it has been successfully used to model the water availability and variability in basin scale especially in the watershed where there is no stream gauge (Abbaspour et al., 2015). River Mallam Sule Catchment boundary was delineated using SRTM DEM (90m resolution), while be AsterDEM (30m resolution) was used for drainage network in Arc SWAT 2012. Sub basin and their topographic characteristic was generated. The defined groundwater head and flow at the catchment scale required a high number of marshes. Thus, a grid of 1m x 1m cells was used to cover the area of 280.11km^2. The DEM of the defined catchment was used as the top of the grid, and the coverage of the model top was extended to all cells in order to differentiate the active cells from the inactive cells. Whereby grid within the catchment refers to as active cells and the inactive cells are the grid outside the catchment boundary.

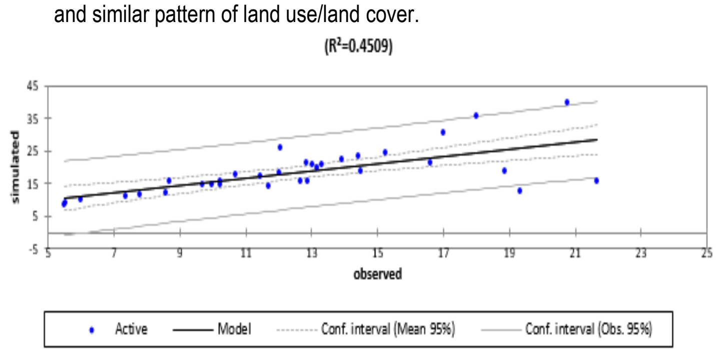
Due to unreliability of the pumping tests and unavailability of the hydraulic conductivities material, the aquifer was assumed to be a single layer aquifer having a vertical recharge with top soil, lower weathered and fractured rocks. The bottom of the aquifer was assumed impermeable bedrock. The numerical model therefore was used to simulate the groundwater flow under the current stress conditions. The land-use map, soil and stream flow data, were used as input, and hydrological response unit definition was determined in the model based on these data. Meteorological data was loaded as an input with the help of the weather input interface. 30-years climate data (1980-2019) was used to build initial model. The model setup for the simulation period of 1980 and 2015 (35 years). Finally, the model was set for run for the simulation, calibration, and validation analysis respectively.

Table 1: Seventeen Sensitivity value from the Kamadugu Watershed

Parameter Code	Definition	Relative Sensitivity	Rank
CN2	Moisture condition II curve number	1.250	1
GWQMN	Threshold depth of water in the shallow aquifer for base flow to occur (mm H_2O)	0.935	2
RCHRG_DP	Aquifer percolation coefficient	0.534	3
SOL_Z	Depth from soil surface to bottom layer (mm)	0.354	4
ESCO	Soil evaporation compensation coefficient	0.201	5
SOL_AWC	Soil available water capacity (mm/ mm)	0.054	6
CH_K2	Effective hydraulic conductivity of channel (mm/ hr.)	0.027	7
BLAI	Maximum potential leaf area index	0.016	8
CANMX	Maximum canopy storage (mm H2O)	0.011	9
SURLAG	Surface runoff lag coefficient	0.006	10
GW_DELAY	Delay time for aquifer recharge (days)	0.006	11
ALPHA_BF	Base flow recession constant	0.004	12
SLSUBBSN	Average slope length (m)	0.004	13
EPCO	Plant uptake compensation factor	0.004	14
SOL_K	Saturated soil hydraulic conductivity (mm/ hr.)	0.002	15
SLOPE	Average slope of the sub-basin	0.002	16
CH_N2	Manning's "n" for the main channel	0.002	17

Source: Ejiejeh et al., 2016

The sensitivity value obtained from the Kamadugu watershed (Table 1) was used for SWAT model calibration and validation. After the SWAT model was developed and was run for the first time, the sensitivity value was imputed in to the SWAT model and then run, this is where the calibrated and observed value was compared using R^2, the sensitivity was considered due to lack of observed data in the study area. The seventeen-sensitivity value is adopted by the researcher due to the fact that the area is same, they have same characteristics of geological formation, same soil formation and similar pattern of land use/land cover.



Source: Author's analysis, 2021
Figure 2: Comparison between Observed and Calibrated Data

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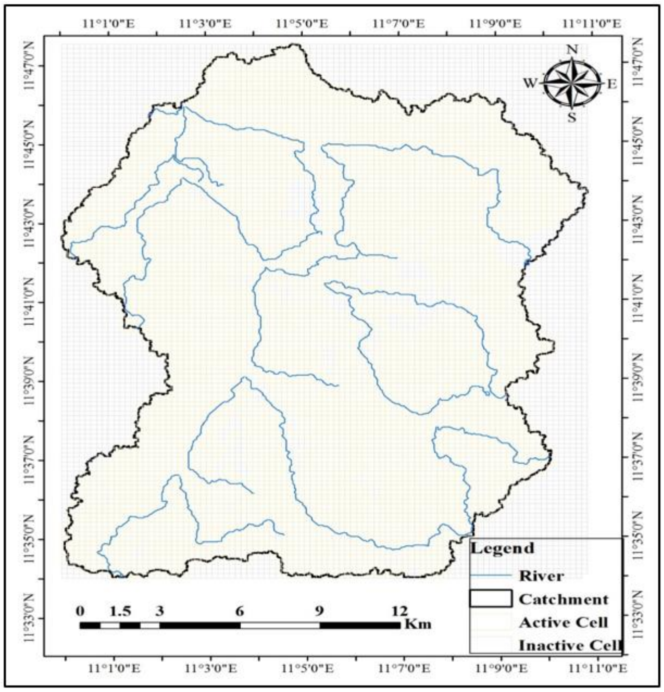
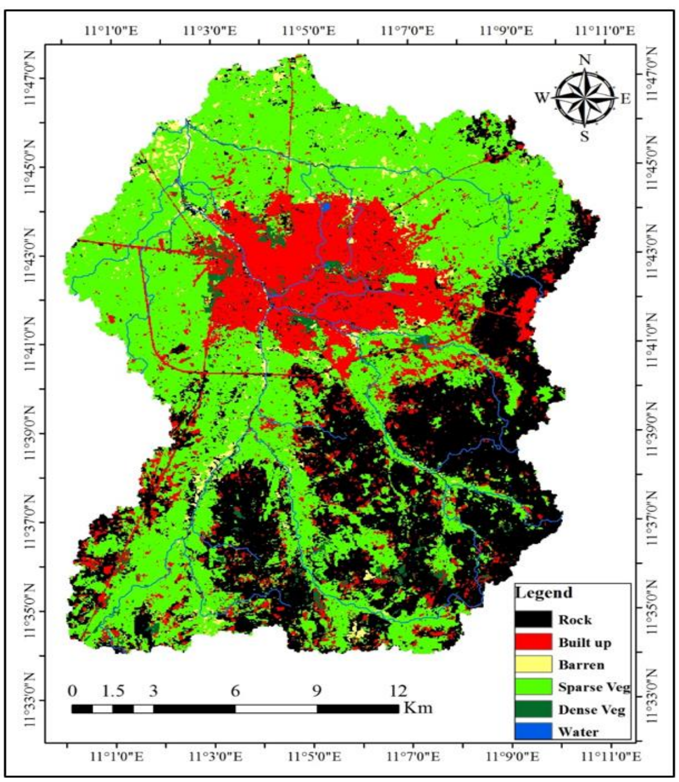
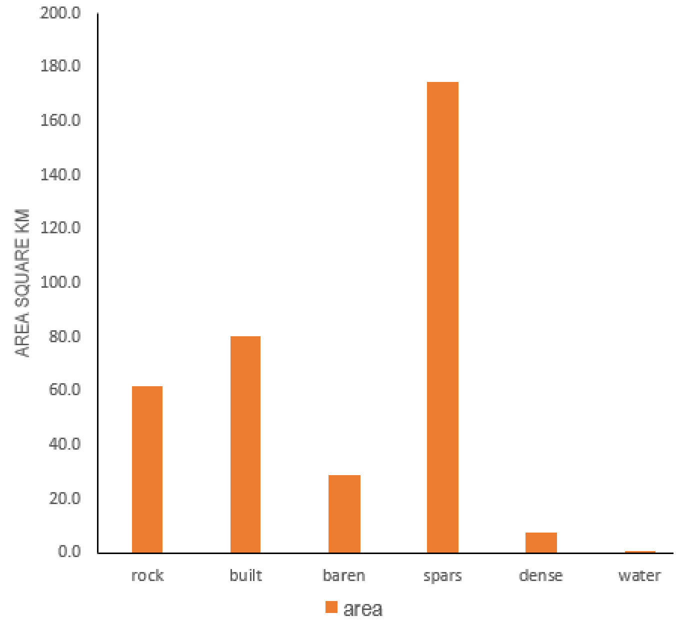
RESULTS AND DISCUSSION



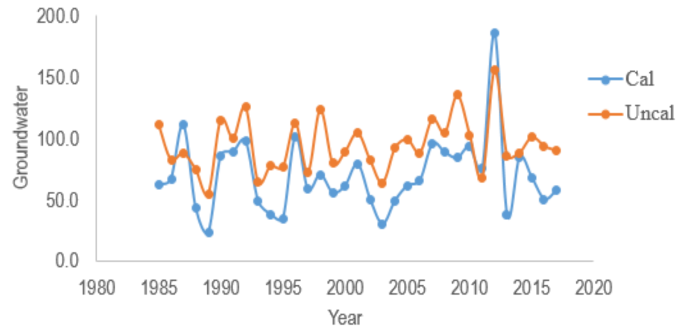
Source: Author's analysis, 2021
Figure 3: shows the boundary definition of the catchment for groundwater simulation



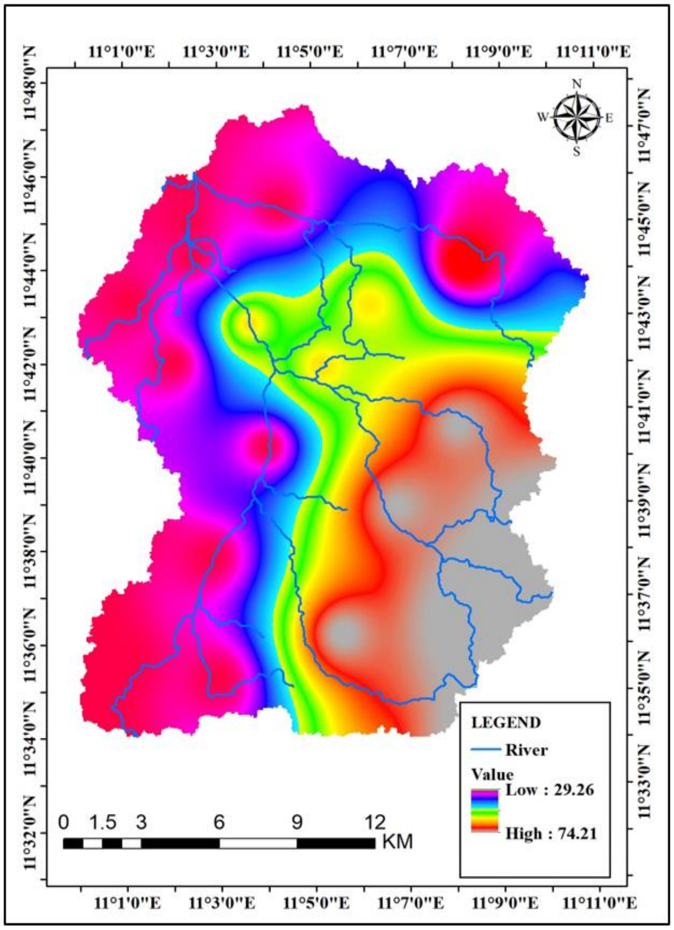
Source: Author's analysis, 2021
Figure 4: Land use, Land Cover



Source: Author's analysis, 2021
Figure 5: Graphical representation of LULC



Source: Author's analysis, 2021
Figure 6: Calibration of groundwater simulation models



Source: Author's analysis, 2021
Figure 7: Simulation of Groundwater of the Study Area

The boundary consists of active cell, and inactive cell. The active cell is the cell within the catchment while the inactive cell is the cell outside the catchment. Active cells define the area where the groundwater simulation took place while inactive cell is the boundary that prevent groundwater from the boundary. The findings is in line with the work of Edmunds et al., (2012) which shows active and inactive cell in their work. The result of the land use land cover of the study area, which comprises of rock, built up area, barren, sparse vegetation, dense vegetation, and water. The area is majorly dominated by sparse vegetation, followed by buildup area and rocks while water is the least spatial distribution in the study area. The LULC indicate the sparse vegetation has the highest area. Built-up area with the total area covered of about 80 square KM. also, rocks have a total area of about 70 square KM, bare land has a total area of about 30 square KM, dense vegetation has a total area of about 10 square KM and water has the lowest area covered in the study area.

The groundwater level variation between the calibrated and uncalibrated data shows that the uncalibrated was overestimated the groundwater before the calibration. After the calibration, the bias of the data was reduced to the minimal level. The findings has so much similarity with that of Dawoud & Raouf, (2009), this may be as a result of closeness of both study areas. There is a very close relation between the Grace data and the simulated groundwater in the period of study except in 2004, 2006, 2008, 2012, 2013, and 2015. The finding of the simulation revels that the eastern and southeastern part of the study area has the highest level of groundwater respectively, which may be because of low extraction. The area is covered with rocks, and therefore resulted in low groundwater extraction due to the absence of settlements and human activities. Moderate value of groundwater was observed around Potiskum which may also be as a result of regular extraction because of the high demand of groundwater by individuals and low value was observed around southwest of the study area which may also be as a result of the sparse vegetation cover and few overlaying settlements located across the area. This result is in line with the findings of Mohammed et al., (2014), which shows the groundwater level in part of the study area.

Conclusion

Attempt was made in this study to simulate the level of groundwater in River Mallam Sule Catchment Area, Yobe State using SWAT as a model. The land-use map, soil and stream flow data, hydrological response unit and Meteorological data were used as input to the model. The finding shows high, moderate and low level of groundwater in the study area respectively. It can be concluded that there is groundwater stress in the study area.

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