Morphological Changes in the Lower Reach of Megech River, Lake Tana Basin, Ethiopia

Getachew Asmare[1(✉)] and Mengiste Abate[2]

[1] Amhara Design and Supervision Works Enterprise, P.O. Box-1921, Bahir Dar, Ethiopia
chadgallery@gmail.com

[2] Faculty of Civil and Water Resources Engineering, Bahir Dar Institute of Technology, Bahir Dar University, P.O. Box-26, Bahir Dar, Ethiopia
mengisteaba@gmail.com

Abstract. This study examined and identify, map the plan-form changes and to evaluate, investigate and explore the effect and impact or influence of drivers/catchment process induces for the plan-form changes along a 44.43-km stretch of Lower Reach of Megech River, Lake Tana Ethiopia, for the last 30 years by using secondary climate data, catchment characteristics, field observation, key informant interview and Satellite images of the year 1984, 1995, 2000, 2006, 2009 and 2014. For data preparation and analysis, Image analysis software (ERDAS 2014), Arc GIS and Terrain analysis tools were used. Lower reach of Megech River has undergone major plan-form changes for the past 30 years. At a distance about 19.3 km from the Lake, the river abounded the old channel course and shifted from west to east and developed new channel which directly drains to Lake Tana. The sinuosity of Megech River shows an overall increase of 8.2% for the 30-year study period. Generally, the plan form alteration of Megech River at different reach is due to natural and artificial influences. Hence, appropriate river engineering works should be practiced so as to minimize the negative aspects of channel bank retreats.

Keywords: Anthropogenic impacts · Megech River · Plan form · Sinuosity · Meandering

1 Introduction

Morphology of river is a field of science which deals with the change of river plan form and the shapes of river channels and how they change over time (Uddin et al. 2011). Rivers can degrade or aggrade, widen or narrow, become coarser or finer, meander or straighten, and braid. The response and the change can also change over the time and space of adjustment.

The continuous change of river channels over time has been a major focus study in geomorphology various techniques, such as sediment logical, historical sources, plan metric resurvey, repeated cross-profiling, erosion pins and terrestrial photogrammetric, have been used to measure riverbank erosion, bank collapse, deposition, channel direction change and channel change.

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Plan-form/pattern or adjustment of an alluvial river is organized through a feedback between channels, floodplain, bars and vegetation which in turn is controlled by the spatial sorting of aggradation and degraded bed load and wash load sediments. The migration of meandering rivers results from interactions among flow, sediment transport, channel, land use land cover, human interaction and environmental activities form that create complicated sedimentary structures and lead to the evolution of channel plan form over time (Singh 2014). The interference of anthropogenic activities on the natural river or environment influences the nature of the landscape processes and their activities also the increasing extent of the human disturbances or anthropogenic activities such as land feature changes, irrigation practice, urbanization, quarry mining or production for construction material, channelization, gravel and sand mining and hydraulic structures construction along or across the river have brought changes to a power of changing the river channel characteristics'.

The variables that affect channel or river system, such as climate, geology, vegetation, valley dimensions, hydrology, channel morphology and sediment load, have different causal relationships one with another, depending upon the time scale of analysis which means spatial and temporal analysis. However, channel form in particular is mainly a result of the interaction between river flows, sediment yields (driving variables), valley characteristics (boundary characteristics) and human activity (Taylor 2002). River form at all scales is controlled by a complex interaction of many environmental variables and the relative importance of any particular variable in shaping channel form depends on the time and geographic scale being considered (Taylor 2002) which those factors can be either natural or human-induced and can act at different spatial and temporal scales and river morphology investigates the evolution of fluvial environments through the analysis of qualitative and quantitative aspects to interpret valuable relationships.

The existence of infrastructural projects, urbanization, road construction, dam constructions, sand and gravel mining activities, quarry production for construction materials also lead to increase or decrease the stream transport capacity and thereby aggradation or degradation processes could occur which impacts the plan form and shape of the river (Abate et al. 2015).

Morphometric parameters, such as channel width, water surface area and sinuosity, were calculated in several studies to evaluate the migration of channel plan form morphology. Bank erosion and deposition, channel pattern identification, bank line and centerline shift and channel change caused by human intervention have been investigated on the basis of remotely sensed data (Yang et al. 2015).

The river Megech is one of the four main rivers of Lake Tana sub basin, which contributes flow for Lake Tana. The river is a major contributor to the building up of the delta which was evidenced of severe bank erosion and rapid rates of bank line retreat along the Dembia plain as we observed during site observation. The lateral migration (right and left bank shifting) of the river results in displacement of population and loss of fertile agricultural land as it is one of the most potential irrigation scheme of lake Tana (Getachew et al. 2013).

This study examined and identify, map the plan-form changes and to evaluate, investigate and explore the effect and impact or influence of drivers'/catchment process induces for the plan-form changes along a 44.43-km stretch of Lower Reach of Megech

River, Lake Tana Ethiopia, for the last 30 years by using secondary climate data, catchment characteristics, field observation, key informant interview and Satellite images.

The characteristics and dynamics of meandering rivers have been the subject of extensive research, Megech River channel plan form geometry has been changed over past years. Lateral migration of Megech River path specifically at the lower reach of Dembiya Woredas is enormous. Though, the mechanism involved, causes of shifting, migration, bank erosion, Valuable irrigated lands are lost because of riverbank erosion are not yet well investigated. In addition, Investigation of interaction of human activities and rivers has become an important problem because they have essential role on rivers morphology. This study is equally important as it will offer the option of using the capabilities of GIS and highly resolution Remote Sensing data or images (like Spot Images, rectified Google earth images, topo map and latest DEM) rather than using low resolution images like land sat image and 90 by 90 m DEM to solve problem associated with river course changing, channel pattern, channel shifting, bank erosion, bank line shifting, active and previous channel width and meandering at the study area, but land sat data will show only center line of the river, does not show bank line, width, delta, island and river spatial extents. This high resolution data's can help in understanding how river features are clearly identified and showed, how fast or slow is the river morphology is change. Previously studied shows researchers and other organizations use different catchment area and catchment stream length for their work still now a day they use the previous outlet for their watershed delineation. But now this research will provide and answer as to why and how changes of channel occur by using time series high resolution remote sensing data over decadal time scales are essential to study plan form change.

2 Materials and Methods

2.1 Descriptions of the Study Area

The Megech River is one of the four tributary of Lake Tana, Ethiopia (Fig. 1). It rises just from the nearest highlands of Gondar City, and has a catchment area of about 741.8 km^2 and the catchment elevation is ranging between 1784–2960.65 m above sea level. Approximately, the area where Megech River lays found between 12°45′25″N to 12°16′8″N latitudes and 37°33′19″E to 37°24′5″E longitudes. Megech River flows southward crossing the Denbia floodplain into Lake Tana for a total river stream length of about 92.6 km from the source to lake Tana but the studied reach of Megech River has length of about 44.43 km; it starts from Bahir Dar- Gondar bridge and ends at Lake Tana among the total stream length of 92.6 km of Megech River.

Major tributaries of Megech River are the Lesser Angereb, Keha Mezoriya and there are small intermittent and perennial rivers in the catchment, which flow into the main stem, Megech.

The farmers used the river for traditional irrigation agriculture for long years. Recently, the Federal Government of Ethiopia and regional government of Amhara plans a medium dam at the upper course of the river to irrigate the downstream of the

Dembia plain. Denbia is one of the most important potential areas for irrigation like that of Fogera floodplain in the above part of Lake Tana. Sand mining activity has also practiced in Megech River.

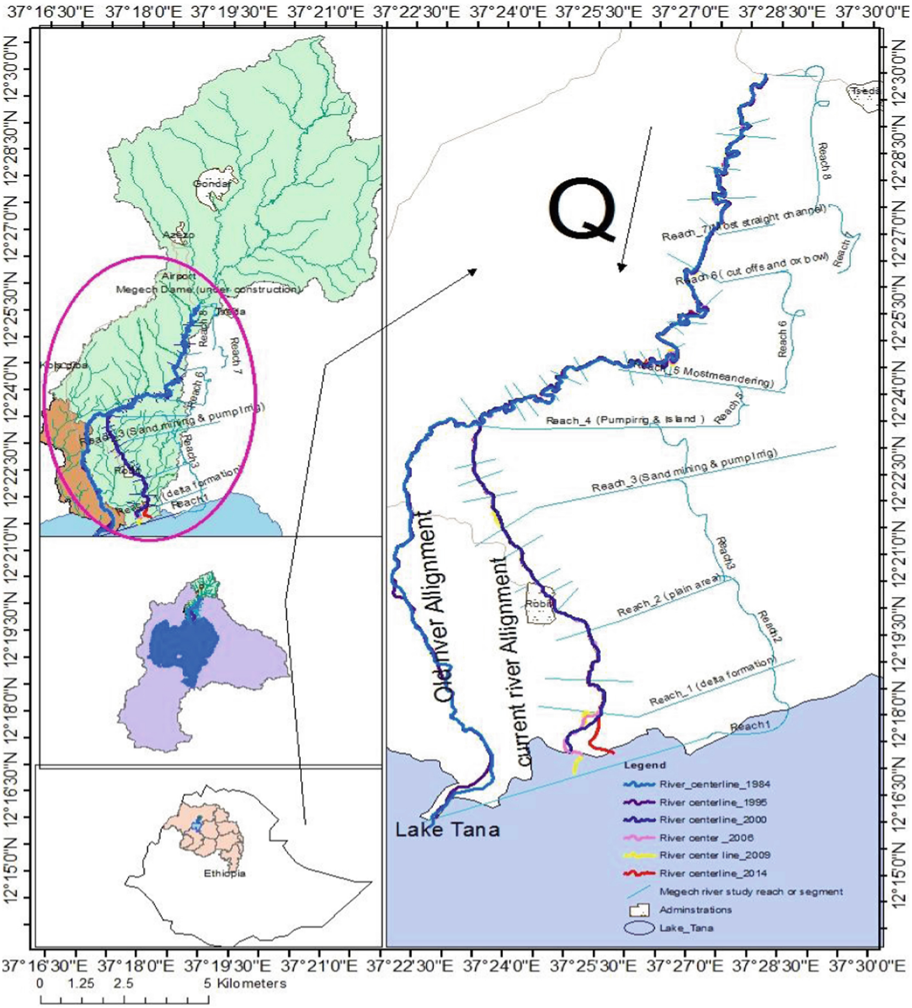

Fig. 1. Location map of study area (Megech catchment and Megech River)

2.2 Delineation and Characterization of the Study Reaches

The study of lower reach of Megech river is divided into 8 sub reaches of channel reaches and 34 cross sections (trans versed sections cross sections) based on channel characteristics the above criteria (Table 1) that reflect changes in channel pattern, dominant types of channel movement, channel bed morphology, and channel shifting, widening, erosion, observation of cut off and confinement.

The division of Megech study was made based on observations in channel pattern change, channel bed morphology, channel shifting, widening, erosion, observation of cut off and confinement. The methods described by Abate et al. (2015) were followed for reach demarcation. In addition to that for this study the subdivision of reaches was based up on the following criteria (Table 1).

Table 1. Characterization of the study reaches

Reach	Cross section	Length (m)	Demarcation characteristics
1	1 to 2	1850.6	Formation of delta and islands when the lake level fluctuates (spatially or plain extent) which means when the lake level decreases or drops there is delta and island when the lake level increases or rises the island or delta was submerged in the other hand back water effect affects the outlet point to other direction
2	2 to 4	3210.9	✓ Is located immediately u/s of Lake Tana, it is flat and plain area ✓ There is more irrigation during winter when the lake rerates (lake level drops and the water leaves the plain) ✓ There is over grazing land for cattle and facilitate for sediment input in to lake during site observation
3	4 to 9	4761.3	✓ Most sand mining activity area, pump irrigation in the right bank of the river, construction of dyke during flood mitigation area and artificial sand bag for ponding water for pump suction hose during pump irrigation
4	9 to 13	4128.7	✓ Pump irrigation and island formation
5	13 to 20	8946.5	✓ Most river meandering area
6	20 to 28	7932.7	✓ Formation of different river features area
7	28 to 29	1478.4	✓ Most stable river channel formation (straight plan form which is a more defined channel area
8	29 to 34	9612.8	✓ U/s of the study area up to bridge and most regular meandering area

2.3 Data Collection

Figure 2 shows general flow chart of the methodology starting from data collection. Satellite images (1984, 1995, 2000, 2006 (Spot 5), 2009 and 2014 (Spot 5)), 12.5 m by 12.5 m DEM, field observation and information obtained from local people were the main data for the analysis of Megech channel planform change. The Spot 5 imagery has a ground resolution of 2.5 m by 2.5 m and gives clear channel information.

"On 11 Jan 2016, field observation and measurements were made on channel width, available infrastructures around the river, sand mining activities, the extent of bank erosion, over bank deposition, breaching points and existing irrigation practice."

GPS points were also taken for accuracy assessment and for the interpretation of satellite images.

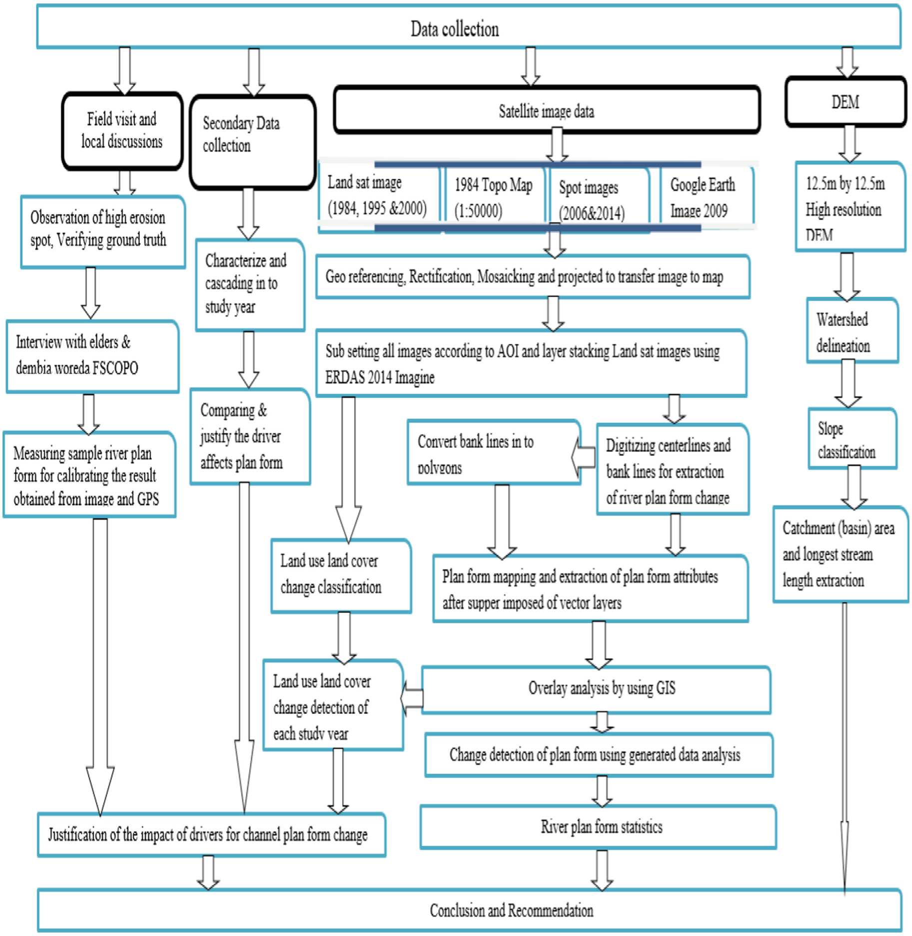

Fig. 2. Work flow chart of the Methodology

"River cross-sections was measured by role meter and staff roads for analyzing the existing river condition on existing gauge discharge site, reaches affected by bank erosion, and local bridge along the river site."

Information has also gathered from the local people and from the Dembia Woreda office on the recent and past channel conditions/alignments through unstructured interview. DEMs used as an input for Arc GIS for catchment delineation and for extraction of physical catchment characteristics.

Secondary data of rainfall, flow and sediment data were obtained from Ministry of Water, Irrigation and Electricity (MoWIE).

Trend analysis of rainfall and stream flow was done by using Spearman's rank correlation.

Both statistical analysis and a semi-distributed rainfall– runoff model was used to assess trends in the discharge in the Megech Catchment. The statistical analysis of trends in hydrologic variables uses the Mann–Kendall test (Lins and Slack 1999; Zhang et al. 2001; Huth and Pokorna 2004).

The Mann–Kendall (Mann 1945; Kendall 1975) test is a rank-based method that has been applied widely to identify trends in hydro climatic variables (Xu et al. 2003; Yue and Hashino 2003; Kahya and Kalayci 2004; Partal and Kalya 2006). Following Burn et al. (2004), we have corrected the data for serial correlation within the time series prior to applying the Mann–Kendall test using the modified version of the trend-free prewhitening (TFPW) approach developed and tested by Yue et al. (2003). According to Yue et al. (2003), the existence of a positive serial correlation in the unmodified TFPW approach results in an overestimation of the probability of trend, while a negative serial correlation causes an underestimation of the probability of trend.

2.4 Mapping of Channel Boundaries for Channel Planform Change Analysis

Starting from Lake Tana mouth of Megech River following the main course of the Megech river, the whole length of the Megech study reach, channel left & right bank lines and the river centerlines for the images of the year 1984, 1995, 2000, 2006, 2009 and 2014 were digitized using Arc GIS 10.1. For the interpretation of the local effects on the channel planform, the 44 km length (old alignment) and 41 km (new alignment) of the river were divided into 8 reaches and 34 cross sections. For Megech River the centerline and valley lengths were measured to calculate the sinuosity of the Megech considered reaches. By definition sinuosity is defined as the ratio of channel length to valley length (Schumm 1985) and (Van den Berg 1995). The sinuosity gives an idea of how much the river meanders. After digitizing all river features and existing condition in each year, comparisons were made so as to get insight about the locations where major bank instability had occurred.

Remote sensing software: ERDAS Imagine version 2014 and ArcGIS version 10.1 were used for the processing of the images and used for land use land cover classification. The raw satellite image was converted from Tag Image file format (Tiff) to image format using EDRAS in order to be compatible with other ERDAS Imagine file.

The advantage of ERDAS Imagine version 2014 direct linked with Google earth during classification. So it avoids accuracy assessment checking from other methods.

All acquired Landsat images and spot images are rectified, 2009 google earth is downloaded as rectified image but it should be mosaicked and sub setting by ERDAS imagine 2014. After rectified identifying the areas of the catchment which by using Megech catchment to fix area of interest by clipping (sub setting) it. The clipping process is done using ERDAS Imagine 2014 subset tool.

For Land use cover classification supervised classification scheme with maximum likelihood classifier decision rule was used. Supervised classification is the most common type of classification technique in which all pixels with similar spectral value are categorized in to land cover classes or themes. Supervised classification relies on the prior knowledge of pattern recognition of the study area. It requires the manual identification of point of interest areas as reference within the images, to determine the spectral signature of identified features.

3 Results and Discussion

3.1 Change in Watershed

The channel course of Megech River has been shifted from west to east since 1996. As a result of this shift, two watershed areas were found; before and after 1996. About 741.8 km^2 and 693.1 Km^2 watershed areas were calculated by delineating the

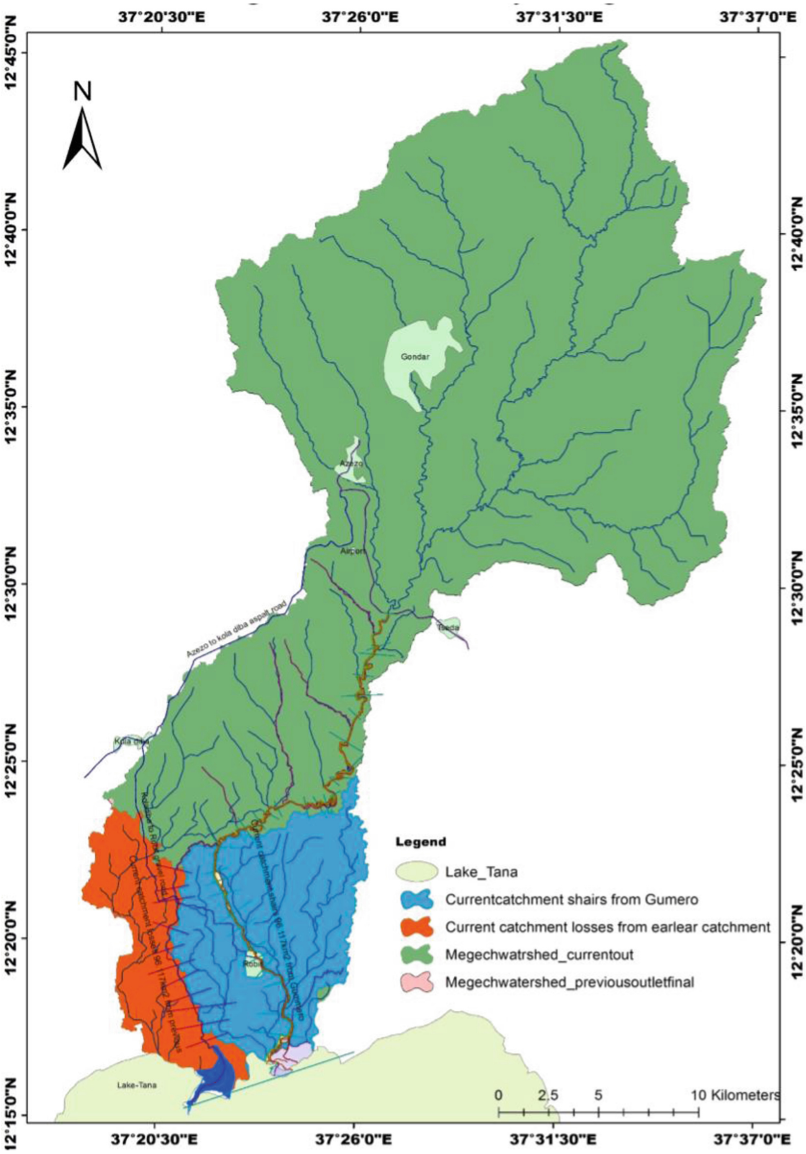

Fig. 3. Megech watershed variation due to different outlet point

catchment areas using the current outlet and the old outlet of Megech River to the Lake respectively (Fig. 3). The overlying analysis of the current and the old watershed boundaries clearly demonstrated that the Megech watershed boundary is shifted to eastward and lost about 48.1 km^2 area from the old watershed and gained 96.1 km^2 area from Gumero watershed, east of Megech Watershed. The overall result showed that the Megech River and its catchment boundary shifted to the east ward and now the left side of the old catchment boundary line has become the divide line for the current drainage flow. The increased watershed area contributes much flow and sediment to the Dembia floodplain and to the Lake Tana. This result or increasing could facilitate aggradation of the lower reach of Megech River and its outlet point. This may be one of the reason why the lower course of Megech River is shifted to east.

By using the same DEM but different outlet point for delineation of watershed we get different catchment size. From site observation and as shown from Fig. 3 when we use the previous outlet the river was followed ridge which the drainage and the stream flows from right to the left. In case of the current catchment gains additional catchment from Gummero. Since the amount of flood for Megech is greater than Gummero while flood comes from upstream and the Megech flood overflows over the plain and moves the Gumero flood back and dumps its sediment as a check structures and trap boulders and debris to the Gumero plain and formation of boundary of divide line.

The result indicates plan form or river morphological alignment change affects the watershed and watershed parameters and vice versa.

3.2 Slope of Megech Watershed

According to Shields 1982, channel slope is one of the important factors that influence the flow velocity in the channel and the profile of most river systems is steep in the headwaters, gradually becoming less steep on the downstream part of the river toward the mouth. From the result Megech Catchment has slope classes ranging from 0 to 25% (Fig. 4) and slope class and land form description is based on Shields (1982). The catchment is classified into six slope classes and the dominant slope classes are flat and gently slope 303.6 km^2 (40.9%) and 1.97 km^2 (26.5%) respectively.

Megech at downstream of the study is low gradient streams with the slope class of 0–3% (flat slope) and channel bank lines tend to shift sideways by meandering. The flow velocity is greatest on the concave side of the meander bend. This is where erosion tends to occur. In contrast, the flow velocity of lower reach of Megech on the convex side of the bend. This is where sediment is deposited.

According to (Ward 1957), Slope of the stream channel is one of the most significant parameters studied to understand the river behavior and the river will have a tendency to develop straight channels, when the slope is more. When the slope increases, the velocity of the river also increases. In the lower reach of Megech river overlaying analysis shown that more sinuosity exists at the flat slope areas (0–3%), where they tend to erode their sides and move back and forth across the megech floodplain. A major change in the morphology of the Megech river was observed in the lower or flat slope class regions.

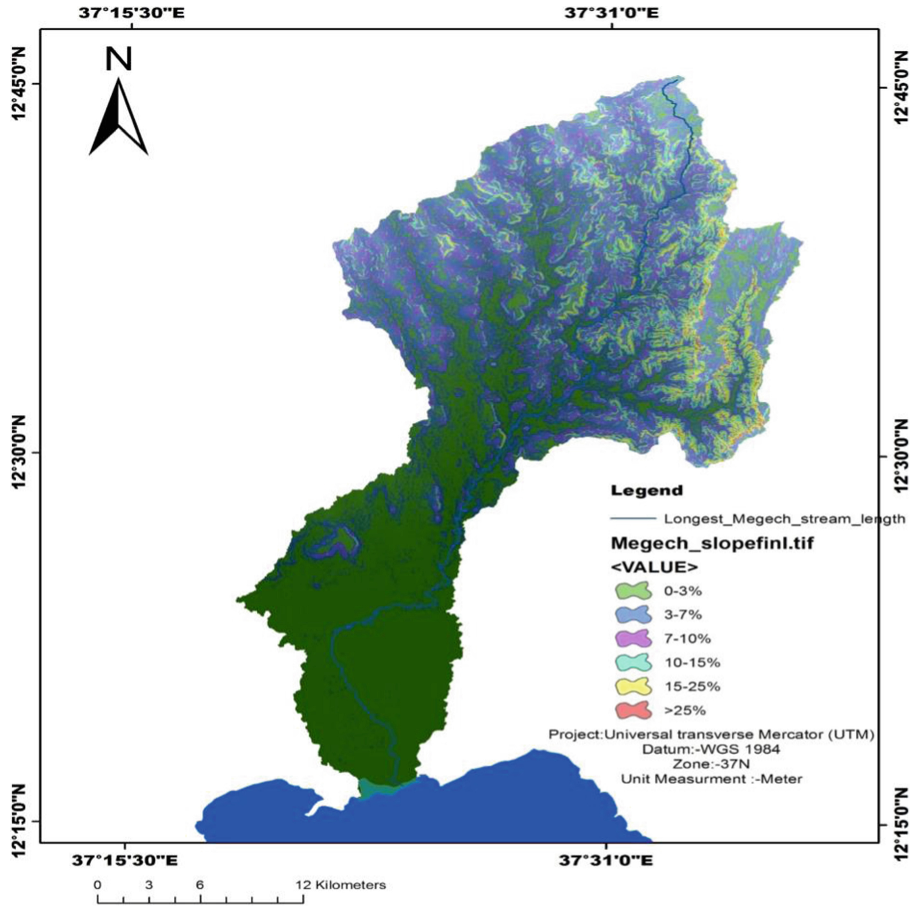

Fig. 4. Megech river watershed slope classes.

3.3 Trend Analysis of Rainfall, Stream Flow and Sediment Concentration

From the graph shown the trend analysis of annual rainfall in the Megech catchment does not show significant changes for the years 1952 to 2014 (Fig. 5), The Megech river precipitation at Gondar station has no clear trend for precipitation, both increasing and decreasing trend observed in the catchment but there is a minor change in precipitation for the precedent record slightly decreasing reduction in precipitation in major rainy season (Kiremit) and an increment of precipitation in Bega season. This indicates that although the river exhibit plan form alteration the rainfall pattern in the area is almost homogeneous. But, the trend analysis of Megech catchment reported annual stream flows starting from 2006 to 2012 has shown an increased trend on flow magnitude (Fig. 6). It is uncertain however whether higher levels of water on the staff gauge have been correctly interpreted and/or the upstream catchment is highly

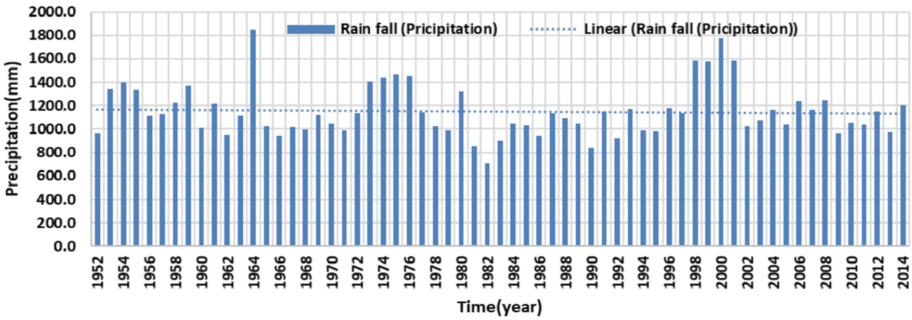

Fig. 5. Annual average precipitation

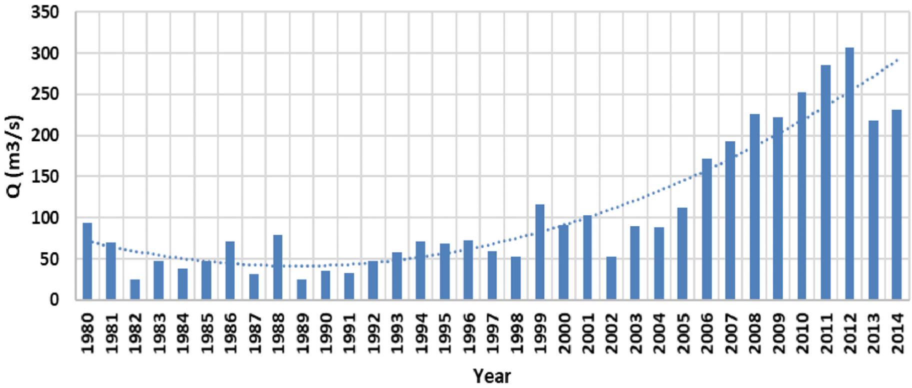

Fig. 6. Annual average flow

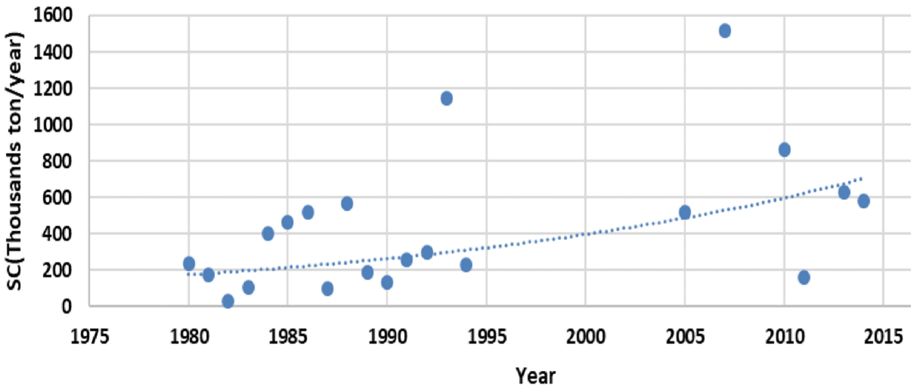

Fig. 7. Annual average Sediment concentration trends

impervious which leads to high runoff generation. The sediment concentration trend has also showed an increasing trend (Fig. 7). These all factors lead to Megech River channel modification in its planform and bed level raise at its outlet.

Therefore, any factor affecting the hydrological response and sediment delivery of a catchment and discharge and sediment yields will influence the channel geomorphological conditions. Finally, these factors are also modified by human activity either directly. Human activities, including land use changes, irrigation practice, quarry production, urbanization, construction of road and infra structures, affect discharge and sediment supply indirectly, typically by increasing peak flows and increasing the quantities of sediment and direct impact on river systems, particularly channelization and in stream mining.

3.4 Land Use Land Cover Changes

The land use, land cove change dynamics of the Megech catchment has been analyzed for the years 1984, 2000, 2006, 2009 and 2014. Field observations that we made in the catchment, information obtained from satellite images and Google maps showed that the major portions of the forest land and bush and shrubs including grass land have decreased continuously in these years. The results show that there was a significant agricultural development from 1984 (57.4%) to 2009 (90.6%) (Fig. 8 and Table 2). Based on the land use map, about 63.2% of the vegetation (forest) covers and 34.0% of bush and shrubs were lost or converted to other land use.

Table 2. Megech catchment land use land cover classification

Land use type code (ha)	Change assessment year and area coverage in ha from the total watershed area									
	1984	%	2000	%	2006	%	2009	%	2014	%
Bush and shrub land	27712.6	35.1	26398.9	33.5	19156.7	24.3	4142.4	5.3	4058.100	5.15
Wetland	541.5	0.7	620.7	0.8	20.5	0.0	104.5	0.1	282.100	0.36
Built-up area	541.5	0.7	334.9	0.4	552.3	0.7	646.6	0.8	722.340	0.92
Water body	358.4	0.5	446.2	0.6	488.7	0.6	470.9	0.6	534.980	0.68
Cultivated land	45277.0	57.4	48108.0	61.0	55783.8	70.8	71400.1	90.6	71621.180	90.84
Forest land	4413.1	5.6	2935.7	3.7	2842.4	3.6	2079.9	2.6	1625.660	2.06
Total	78844.4	100.0	78844.4	100.0	78844.4	100.0	78844.4	100.0	78844.4	100.0

An error matrix that is established using 56 ground control points and Google earth image in the Megech Catchment. From the error matrix four measures of accuracy are estimated that are the overall accuracy, user’s accuracy, producer’s accuracy, and the kappa statistic. The kappa coefficient (k) of 0.79 and 0.86 of the maximum likelihood classification in the periods 2006 and 2009 represents it is better accuracy. According to Monserud (1990) suggested a kappa value, the classification in this study has very good agreement with the validation data set.

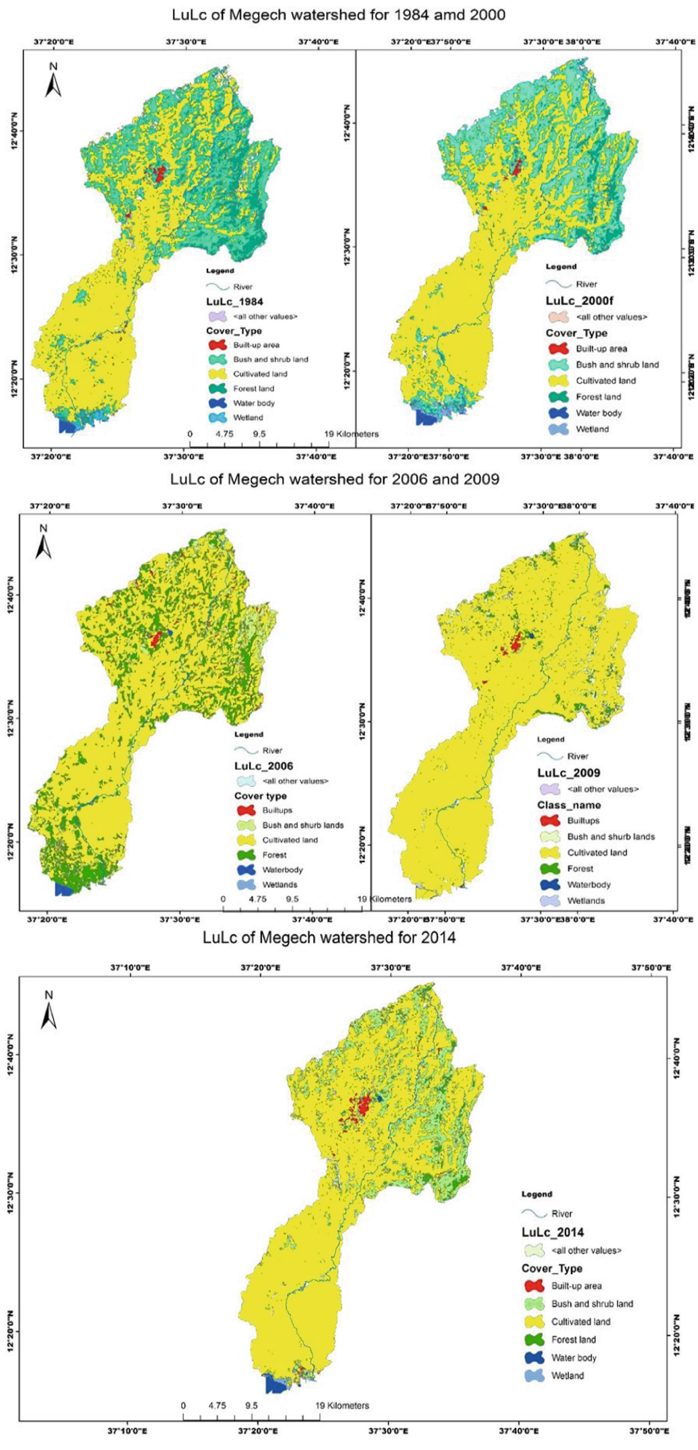

Fig. 8. LuLc change detection of Megech catchment from 1984 to 2014

From land use land cove change (Fig. 8 a to c) most of the vegetation covers showed a decrease in the last 30 years. Forest land and bush and shrubs including grass land have decreased continuously in these years. As expected, water body and wetlands showed small variation as compared to the other cover types. Another well expectation was the increase of cultivated lands. It progressed from 57.4 to 90.6 in the year 2009 and decrease to 77.7 in present instead build up area increases because there is high expansion of urbanization.

Based on the land use map, about (table) 63.2% of the vegetation (forest) covers and 34.0% of bush and shrubs were lost or converted to other land use. In case of the Megech River, it is observed that the highly affected areas by erosion throughout the years are agricultural land followed by river channel and forest land followed by agricultural land and building area. Erosion and deposition by both the rivers affected settlement areas in the floodplains. Naturally bush and shrubs are very use full for soil stability and infiltration purpose but from the local people interviews bushes and shrubs are used for fire wood.

Replacement of forest land by agriculture and use for bush and shrubs for their domestic fire wood usage are a common trend within the study area and is seen to be one of the major causes of erratic river bank erosion and channel breaching or shifting of channel. It has been observed that bank erosion has increased by instability of the river behavior due to deforestation and inadequate land use in the upper reach of land use land cover from u/s makes the catchments of Lay Armachiho, Wogera and including urbanization and drainage network from Gondar and Azezo towns which ultimately led to excessive sediment load into the rivers.

Land use\Land cover is one of the most important factors that affect surface erosion, runoff, and evapo-transpiration in a watershed. As shown in the result soil bank erosion is high in the lower reach of Mgeche River; this is because of soil degradation, deforestation, over grazing, plowing steeply slope areas for the purpose of expanding agricultural land and sedimentation is high around the Lake; this creates competition of settlement near the Lake.

From observation, qualitative analysis or interview of elder people, Dembia Woreda Food Security Coordination and Disaster Prevention Office, the river breaches the previous alignment in 1996 and the stable channel bank collapse, tree and other types of sediment traps was pushed and closed the river alignment as a check dam due to an expected flood because of u/s deforestation and replace to agriculture and settlement (urbanization). This indicates there is highly fluctuation of land use land cover fluctuation and followed by high run off.

All land uses and practices in the drainage catchment (e.g., deforestation, agriculture, mining, urbanization and fires) affect runoff and sediment yield. Human activities, including land use changes, affect discharge and sediment supply indirectly, typically by increasing peak flows and increasing the quantities of sediment and direct impact on river systems, particularly channelization and in stream mining.

The high runoff response and sediment load of Megech River are reported to occur due to strong degradation of the catchment.

The agricultural intensification by land clearing and deforestation has resulted in increasing the area of degraded soil. This suggests high runoff response and sediment load of Megech River to the delta and the floodplain. The increasing population pressure and the continuous cultivation caused a loss of organic matter of the soil that has a binding effect (Tebebu et al. 2015). This leds to more bare and plowed soil and decrease the aggregate stability of soil. This, in turn, resulted in higher sediment concentrations in Megech river. All that has led to greater sediment transport by Megech River towards the lake and this changes the Megech River characteristics.

3.5 Plan Form Changes

Sinuosity

The general trend shows that; the sinuosity of Megech River is increasing from 1984 to 2014 (Fig. 9). The sinuosity of Megech River shows an overall increase of 8.187% for the 30-year study period. The valley length and channel length of Megech river decreases from 1984 to present 2014. Overall net channel area ranged from a minimum of 1.635 km^2 during 1984–2006 to 3.103 km^2 in period 2009 to 2014. The Megech River registered an overall net percentage change increase or gain of 74.14% in channel area over 30 years.

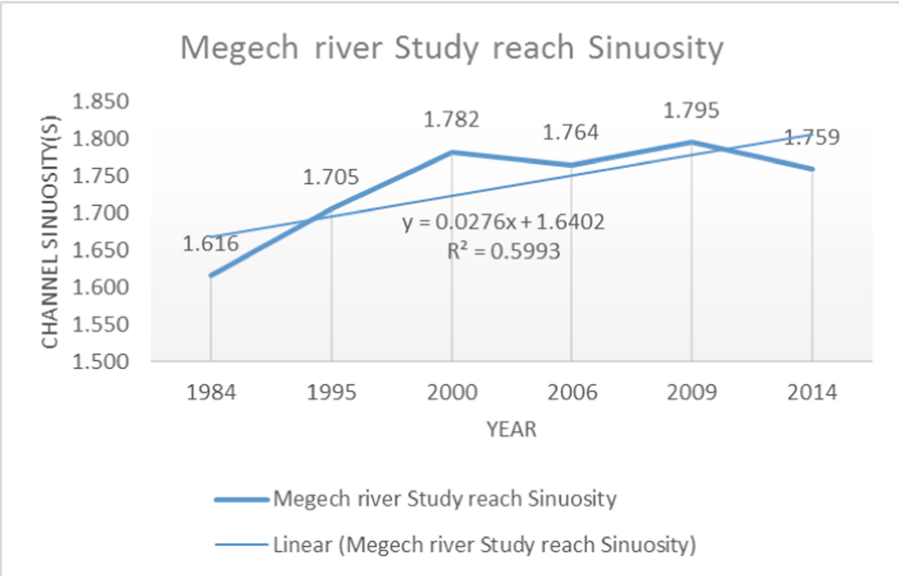

Fig. 9. Megech river sinuosity for different years

Channel Width and Cross Section

The channel width of the study reach increased by 25.42 m on average. The change in width was highest in the middle part of the river along Reach 6. In the present study, the width of the Megech River has increased and eroded a large part of land along the both banks of the river. Considering the cross-section of 2000 as a base for comparison, there was high erosion in the right side even there was island in 2000 and it was removed by flood and deposition in the left side by the year 2007, there was high erosion in the left side (1.5 m) and deposition in the right (0.5 m) side by deposition in 2014. There was 12.4 m extent bank erosion and widening in 2014 in the left bank of the river. There is bank narrowing in the left side of the river by 2010. It is clear that the bed level fluctuation in 2000 was relatively the maximum. The variation in 2007 was the minimum which can be attributed to some factors.

River Bank Erosion and Lateral Migration

The total area of bank erosion from 1984 to 2014 were about 437 ha, of which 293 ha were on the left bank and 144 ha on the right bank. The total area of bank accretion (deposition) from 1984 to 2014 equaled 221 ha, of which 120 ha were on the left bank and 101 ha on the right bank. It has been found that the total area lost as a result of erosion were 437 ha and the total area gained as a result of sediment deposition along its bank were about 221 ha. These totals translate into annual bank erosion rates of 2.9 ha/year from 1984 to 2006, 31 ha/year from 2006 to 2009, 56 ha/year from 2009 to 2014 and total of 89.87 ha/year from 1984 to 2014 and became part of channel and the trend shows increase.

The gain could be attributed to widening of the channel due to starting of neck cut-off, bank erosion & deposition, bend migration, extreme irrigation practice. The lateral erosion on the river banks led to a decrease in agricultural lands bordering the river banks and decrease in the areas of the river islands, which in turn led to a decrease in agricultural production. Both the erosion and deposition rates are increased during the period 1984 to 2014. High rates of erosion are observed, the increase in erosion and deposition rates resulted in formation of new islands, change in island areas, erosion, and deposition of river banks which resulted in disturbance of cultivated lands. An effect of the plan form change is the loss of agricultural land is estimated about 172.903 ha in the left bank and 43.206 ha in the right side total area loosed from 1984 to 2014 was 216.109 ha. Annually total net area lose is 7.203 ha per year from the bank.

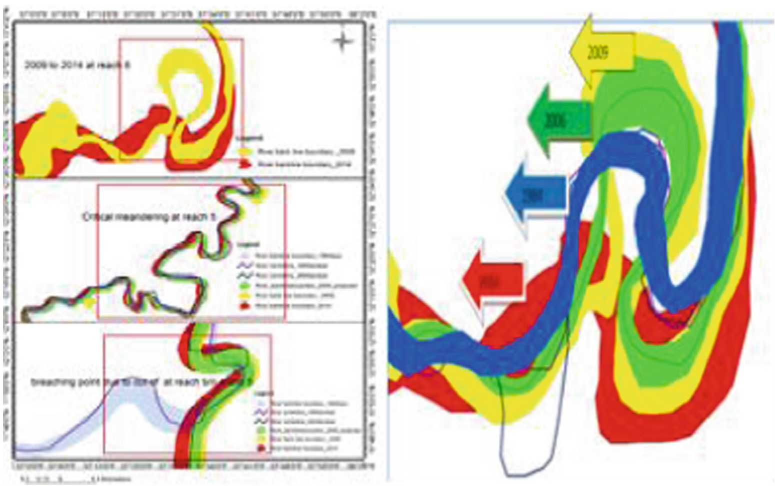

Fig. 10. Typical bend migration, formation of neck cut off and ox-bow lakes at reach 6 in different years

In general erosion is more dominant in the Megech river because of which the width of the river has increased significantly.

Bends migrated followed by expansion, extension, rotation, and translation and all are combination process and exist through the process. The bend migration was determined by comparing the images of different years given from the study year. Active meandering occurs when the channel banks were eroded, which also drives channel widening. The meander oscillation has been observed in all study reaches. In reach 6 cut-off has been created and an oxbow Lake was formed (Fig. 10).

4 Conclusion and Recommendations

4.1 Conclusion

The River had undergone a significant plan form changes over the past and last 30 years (1984 to 2014). Significant channel widening, channel course change, loss of land due to bank erosion, formation of different river features like cut off and oxbow lakes were found. Stream bank failures were very common along the study reaches. The collapsed banks contributed huge sediment to the channel bed, facilitates bar and the collapsed materials contributes delta development. The sinuosity of Megech River shows an overall increase of 8.2% for the 30-year study period. The Megech River is a meandering with sinuosity index values varying in between 1.6 to 1.8 in terms of general sinuosity and 1.01 to 2.39 for reach based sinuosity. The channel width of Megech River is increasing year after year, eroding a large part of land along both banks of the river and the overall shifting of the river towards east. It was found that erosion is more pronounced in both banks than the deposition while calculating river bank migration. The principal causes of the observed dynamics in Megech River were deforestation and intensive agriculture in the upper and lower catchments, gravel and quarry mining and irrigation activities in upper part of the catchment, the left and right banks of the river and these have worsened stream bank erosion. The present conditions of channel erosion and deposition have been aggravated by Anthropogenic effects which changes the morphology of Megech River.

4.2 Recommendations

While managing and studying rivers, it is important to identify potential causes and impacts of channel change. River training works along the River should be in place where river bank erosion occurs.

Effective catchment treatment should be done so as to minimize the flashy nature and the sediment concentration of the river.

There should be sediment and flow gauging station near Lake Tana to model the river system.

Infra structures especially Bridges or foot bridges should be provided across Megech River for peoples to access from one kebele/gote to another, to market or other to satisfice people around dembia. The regional government should consider this assignment.

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