

Effect of Land Use/Cover and Dam on River Morphological Change in Este District, Gomit River, Amhara, Ethiopia

Abiyu Wubalem*, Dawit Yihunie

Department of Water, Irrigation and Energy, South Gondar Administration Zone, Amhara, Ethiopia

Email address:

abiyuwub@gmail.com (A. Wubalem), dawityihunie19@gmail.com (D. Yihunie)

*Corresponding author

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Abstract: Recently, the construction of dams has affected the morphological process of the downstream river reach by storing water and sediment, changing the water discharge regime of the river and releasing relatively clear water to the downstream. Due to this, GIS and RS software have been used to identify land use and land cover changes, as well as the dam impact of the downstream of the river. The objective of this research is to determine the effect of land use, land cover change, and dams on river morphological change in the Gomit River. The methodology of the study was used four significant parameters (land sat imaginary, slope, soil, and river cross-section) to determine the river morphological change of the study area. Land use/cover changes have been recognized as percent (%), which are forest and grass land, have been decreased by 3 and 27% respectively. Whereas the cultivation land and settlement area were become increasing 26 and 3.4% respectively. While the degrading and aggradation values have been obtained 0.612m, 0.566 and 0.345m from the respective years of 2002, 2016 and 2020 respectively. The sinuosity index values of the years were obtained (2002, 2016 and 2020) is 1.374, 1.30 and 1.294 respectively. As the result the narrowed and widened values are 79.99 and 20.01% respectively.

Keywords: Dam, Gomit River, GIS & RS, Land Use/Cover Change, Vertical Change

1. Introduction

Recently, the construction of dams affects the morphological process of the downstream river reach by storing water and sediment, changing the water discharge regime of the river and releasing relatively clear water to the downstream [1-4]. For this connection, the river channel becomes degraded and narrows [1-4]. Therefore, geomorphologic affects that change the pattern of erosion and deposition of the main channel of the river, banks, and floodplains. For this reason alluvial rivers were adjacent to their slopes, platform and bed topography in response to sediment, or water input changes due to either anthropogenic influences, natural events, (landslides), or climate change [5]. Furthermore, river channel morphology is influenced by dependent land escape variables (sediment, discharge and vegetation) whereas the independent variables were climate, human and geology [6]. As a result, land use/cover change influence the hydrological cycle and availability of water

resources by changing canopy interception, surface roughness, soil properties, and evapotranspiration [7-9]. Thus, it significantly contributes to the earth's atmosphere interactions, forest fragmentation, and biodiversity loss.

The purpose of this study is to determine the impact of dams and land use land cover change on river morphology in the Estie district, Gomit River, Amhara regional state of Ethiopia. This study would seek to determine the impact of land use/cover and dams on river morphology at the global, national, and regional levels [7-9].

Today's new technology innovation is needed to determine the effect of dam and land use/ cover on river morphology. Therefore, geographic information system (GIS) tools and remote sensing (RS) data are the most applicable software in this research [10-13]. Due to this, change analysis has become an important tool to generate evidence for decision-makers, spatial planners, and local communications to develop detailed land use plans as well as understand the agents of changes.

2. Data Used and Methodology

2.1. Location of Study Area

Co-SAERAR (Commotion of Sustainable Agriculture and Environmental Rehabilitation in Amhara Region) established the Gomit micro earthen dam irrigation project in Este district, Amhara Region Ethiopia, in 2002. The study area has been covered (2848.739) ha and the main stream length from the dam outlet to the Wanka River joint is about 3390 meters, which is located on the Gomit River in the upper Blue Nile Basin. The geographical location of the area is about 396105 E and

1277654 N, with an average elevation of 2316 masl. The Gomit micro earthen dam irrigation project is zoned for embankment earthen dam, which has a crest length of 324.00 m, a top width of 4.00 m, bank top level of 2370.36, dam height of 20.00 m, river bed level of 2350.36 m, and an ogee weir spillway at the left end of the dam (source: design document of Gomit dam). According to the Ethiopian Meteorological Agency, the mean annual precipitation in this area is about 1218mm, and the climate in this area is sub-tropical, with a mean annual temperature of 20.5°.

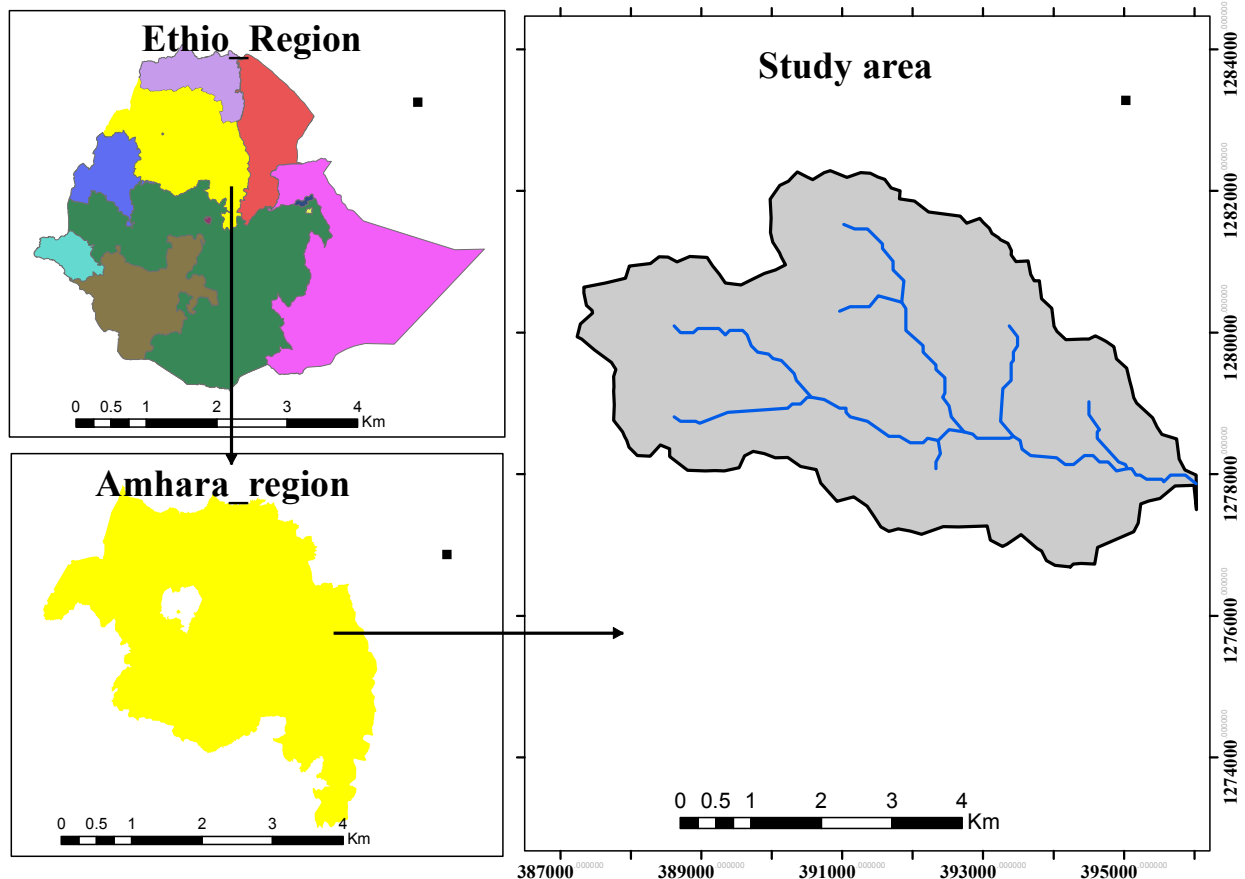


Figure 1. Location map.

In this study four thematic parameters (land sat image, soil type, slope, and river cross section) were used. Slope was derived from STR DEM of 30m resolution and soil type data of the study area was collected from Ethiopian international Geological survey (EIGS). The land sat satellite images have been taken by the United States Geological Survey (USGS) in three different years (1989, 2002, and 2020). Imaginary data was down loaded from United Stat geological survey (USGS) in the years of 1989, 2002 and 2020. Methodology is crucial for the effectiveness of this study. Study methodological approaches have been feasible to analyze the river morphological behavior in the Gomit River by identification of the channel platform and pattern of rivers from satellite images of different years using GIS and remote sensing (RS) technology and conventional ground surveys

such as geomorphology that have been conducted by the river morphology. This method is described in terms of cross section data collection using total station instrument measurement point by point.

2.2. Slope Study Area

The precipitous terrain causes rapid runoff and does not store water easily. The slope of any terrain is one of the factors that allow infiltration [14-16]. The major landforms in this study include those ranging from flat to very steep. The Gomit micro embankment dam is elevated from 2307msl to 2707msl in the upper ridge, so this dam is located in the highland part of the country (Ethiopia). The slope of this study area is determined from the topographic map with a dominantly gentle slope followed by flat, rolling, moderately

steep, steep and very steep plains sloped mountain ranges. platform.
The slope categories' have been calculated on the arc GIS

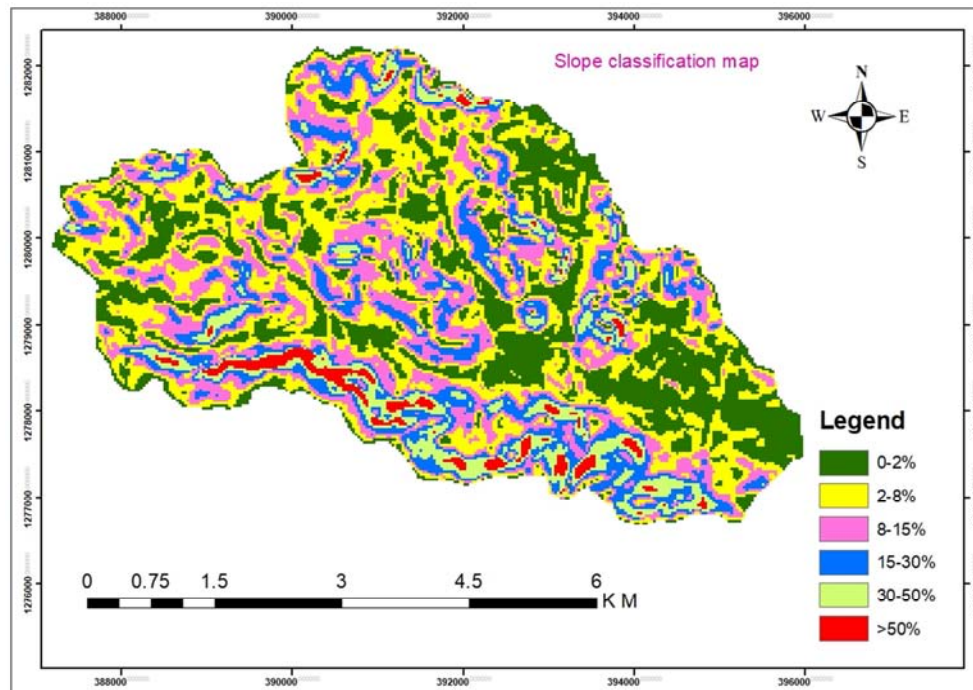


Figure 2. Slope map.

2.3. Land Sat Imaginary Data and Soil Types of Study Area

Land sat image data (1989, 20002, and 2020) years were downloaded from the official website (GLOVIS), to detect the change in land use/cover change between 1989 and 2020 years. The whole 32-year period was grouped into three

periods (1989-2002, 2002-2020, and 1989-2020). The images were purposely extracted during the dry seasons (in the months of January and February) to acquire a quality image and low cloud cover).

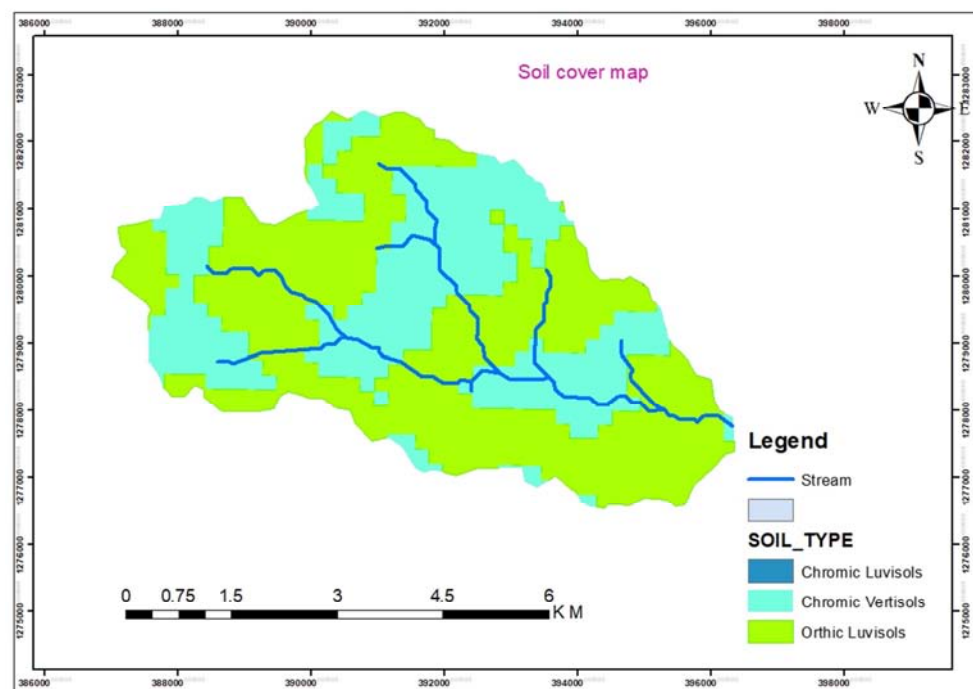


Figure 3. Soil map.

The soil type of the study area contains chromic Luvisols, chromic Vertisols, and Orthic Luvisols, which affect the great shift of the river center line and the runoff in the channel, eroding the weak and cracked bank of the river channel [17]. But orthic Luvisols are dominant in the watershed and comprise 60% of the total area, followed by chromic

Vertisols, which comprise 40% of the total area. Finally, chromic Luvisols have the least coverage, with 0.00032% and covering 0.009ha in the area. The Ethiopian International Geological Survey (EIGS) collected the soil type map in all vector formats and extracted it to the study area using the arc GIS platform.

Table 1. Accuracy assessment of land use/cover at land sat (1989) image (where WB=Water body GL=Grass land F=Forest CL=Cultivation land SL=Settlement).

user classified	Ground control point					Row total	User accuracy (%)
	WB	GL	F	CL	SL		
WB	5	0	1	1	0	7	71.43
GL	0	45	2	3	1	51	88.24
F	0	2	40	0	2	44	90.91
CL	1	2	0	45	2	50	90
SL	0	2	2	3	13	20	65
Column total	6	51	45	52	18	172	
Producer accuracy (%)	83.3	88.2	88.9	86.5	72.2	Overall accuracy (%)=86; Kappa statistics=0.84	

Table 2. Accuracy assessment of land use/cover at land sat (2002) image.

user classified	Ground control point					Row total	User accuracy (%)
	WB	GL	F	CL	SL		
WB	6	1		1	0	8	75.00
GL	0	49	2	1	1	53	92.45
forest	0	2	48	0	2	52	92.31
CL	1	3	1	48	2	55	87.27
SL	0	1	0	3	14	19	73.68
Column total	7	56	51	52	20	187	
Producer accuracy (%)	85.7	87.5	94.1	90.6	73.7	Overall accuracy=88; Kappa statistics=0.85	

3. Results and Discussion

3.1. Land Use/Cover Analysis

To explain land use and cover change patterns and overall land use changes over time, assessments of the accuracy of land use and cover classification mapping and classifying land use and cover analyses were carried out in the previous work [18-20]. Furthermore, the accuracy assessment of the study area was used to determine the correctness of the

classified image, which was performed using a confusion matrix [21, 18]. To assess the accuracy of the classified image, a confusion matrix was constructed by using collected ground control points for 2020, Google Earth historical images were also used for accuracy assessment in 1989 and 2002. The 1989, 2002, and 2020 land use/cover classification accuracy assessments showed, kappa statistics were above 0.84 in all the results. Therefore, the interpretation of the images was all but perfect. The confusion matrix has been shown in tables 3, 4 and 5 below.

Table 3. Accuracy assessment of land use/cover at land sat (2020) mage.

user classified	Ground control point					Row total	User accuracy (%)
	WB	GL	F	CL	SL		
WB	7	2	1	0	0	10	70.00
GL	0	46	2	2	1	51	90.2
F	0	2	47	1	0	50	94.0
CL	1	3	1	50	1	55	90.91
SL	0	1	1	2	13	17	76.47
Column total	8	54	51	54	16	182	
Producer accuracy (%)	87.5	85.2	90.4	90.9	86.7	Overall accuracy%=89.6; Kappa statistics=0.87	

The overall result of the producer's accuracy ranges from 72% to 94%. The lowest values were misclassified due to similar spectral value of different land cover classes. For instance, cultivation areas with forest cover during wet season, crop lands during dry season with grass land (which is classified as grass land) affects the level of classification. In this study, the user's accuracy ranges from 65% to 94%.

The lowest value of settlement was to some extent, misclassified because of the similarity spectral properties of settlement as grass land in dry season.

3.2. The Land Use/Cover Maps for 1989, 2002 and 2020 Years

The land cover map of 1989 (Figure 4) and the land class

coverage (Table 3) shows that about 0.59% of the Gomit River catchment was covered by built up/urban land, 40.7% by grazing/bar land, 14.7% by forest land, and 43.8% by

cultivation/crop land. The spatial land grazing/bar land, 14.7% by forest land and 43.8% by cultivation/crape land.

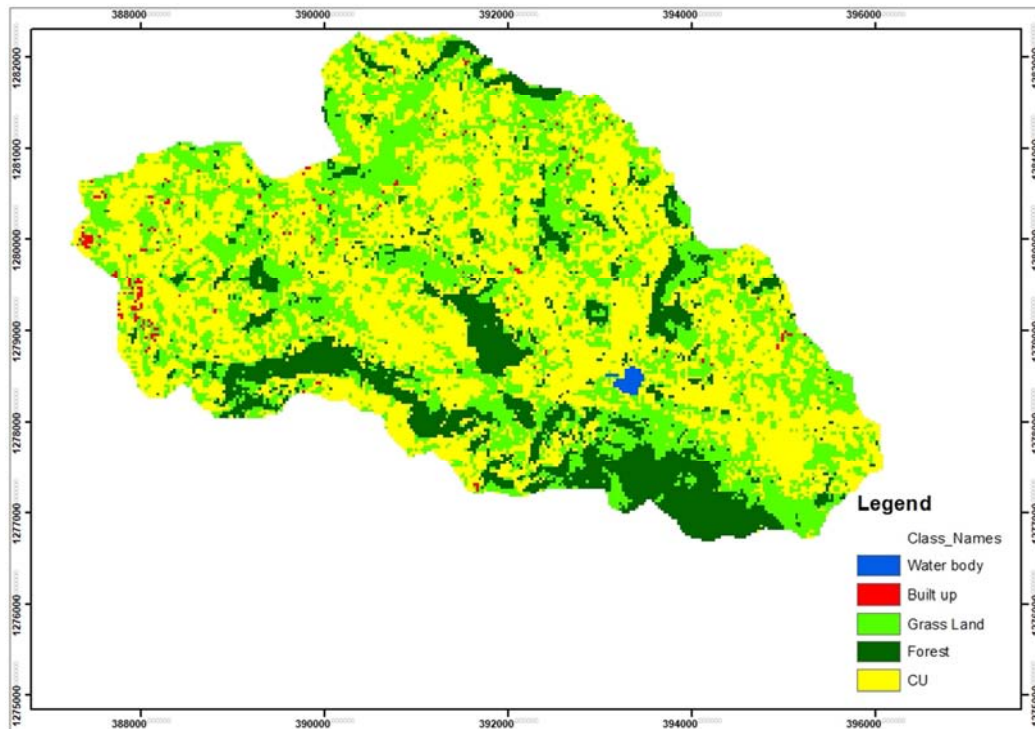


Figure 4. Land use map 1989.

The land cover map of 2002 (Figure 5) and the land class coverage (Table 2) shows that about 0.9% of the Gomit River catchment was covered by built up, 33.87% grazing/bar land, 13.22% by forest land, 51.7% by cultivation land.

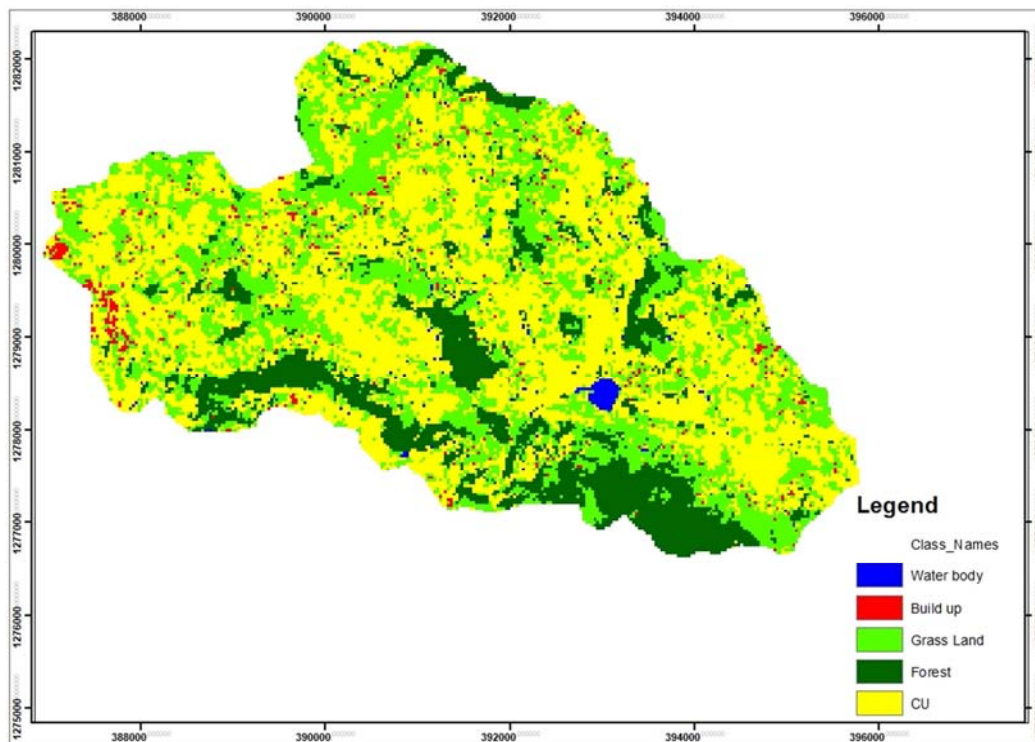


Figure 5. Land use map 2002.

The land cover map of 2020 (Figure 6) and the land class coverage (Table 3) shows that about 3.95% of the Gomit River catchment was covered by built up/urban, 13.87% grazing/bare land, 11.6% by forest land, 69.95% cultivation/crop land.

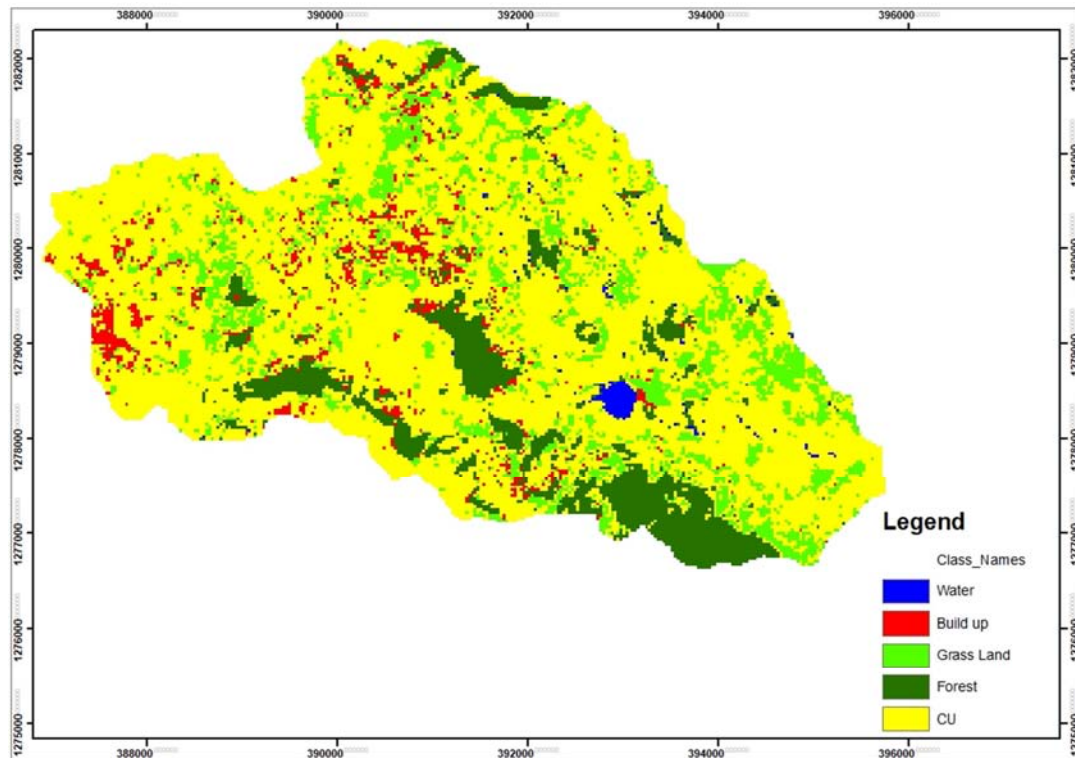


Figure 6. Land use map 2020.

3.3. The Land Use/Cover Change Analysis

The spatial analysis was conducted to describe the land use and cover changes that could be seen from the classification. The study area's land use and cover include five major classes: settlement, grassland, forest, water body, and cultivation. It has been evident that the Gomit catchment has undergone significant land use and cover change from the years of 1989 to 2020.

Table 4. Land use/cover classes in three different years.

No	LULC	1989		2002		2020	
		ha	%	ha	%	ha	%
1	Water	5.11	0.2	7.53	0.26	18.6	0.65
2	Settlement	16.76	0.6	26.8	1	112.5	4
3	Cultivation	1248.9	44	1473	52	1992.7	70
4	Grass	1160.1	41	964.8	34	395	14
5	Forest	418	15	376.6	13	330.6	12
Sum		2848.739	100	2848.739	100	2848.739	100

In general, clear expansion of settlement and cultivated area has been observed from 1989 to 2020. As the result grass land and forest have been decreased from 1989 to 2020 of the years.

Table 5. The land use/cover Change detection between 1989 and 2020 years.

Land class (1989) year	Land class (2020) year	Area (ha)	Area (%)
Forest	Forest	0.3106	0.003

Land class (1989) year	Land class (2020) year	Area (ha)	Area (%)
Grass	Cultivation	4.8501	0.05
Settlement	Settlement	0.3136	0.003
Settlement	Settlement	0.2721	0.003
Settlement	Settlement	7.7941	0.08
Cultivation	Settlement	32.4394	1.14
Settlement	Forest	0.6037	0.02
Settlement	Grass	5.6484	0.2
Cultivation	cultivation	1.6889	0.06
Cultivation	Settlement	35.5189	1.25
Cultivation	Cultivation	1030.9	36.19
Cultivation	Forest	8.05	0.28
Cultivation	Grass	174.5738	6.13
Water	Water	1.1876	0.04
Forest	Grass	1.1175	0.04
Forest	Grass	0.9015	0.03
Forest	Settlement	6.3791	0.22
Forest	Cultivation	104.0048	3.65
Forest	Forest	240.8793	8.46
Forest	Grass	11.8017	0.41
Forest	Water	0.9331	0.03
Grass	cultivation	3.0397	0.11
Grass	Settlement	62.4833	2.19
Cultivation	Cultivation	821.3161	28.83
Grass	Forest	83.141	2.92
Grass	Grass	200.8137	7.05
Grass	Water	2.2623	0.08
Water	Cultivation	1.6358	0.06
Water	Forest	0.64	0.02
Water	Grass	0.0891	0.003
Water	Water	3.2932	0.12
Un changed		2308	

3.4. Change in Channel Width Analysis

The recent study shows the river's shifting channel was measured at numerous river cross sections throughout the river stretch [22]. As a result, the highest erosion values were found in the river's middle and upper reaches, while the lowest erosion values were found in the lower reaches.

Therefore this research was used to identifying the right and the left bank of the channel were digitized on all sets of data in GIS (2002 and 2020) at each study reach. The channel width is commonly defined as the length of the line from bank to bank to the channel centerline. Those channel center line, i.e. the line whose points are equidistant from the two limits of the channel.

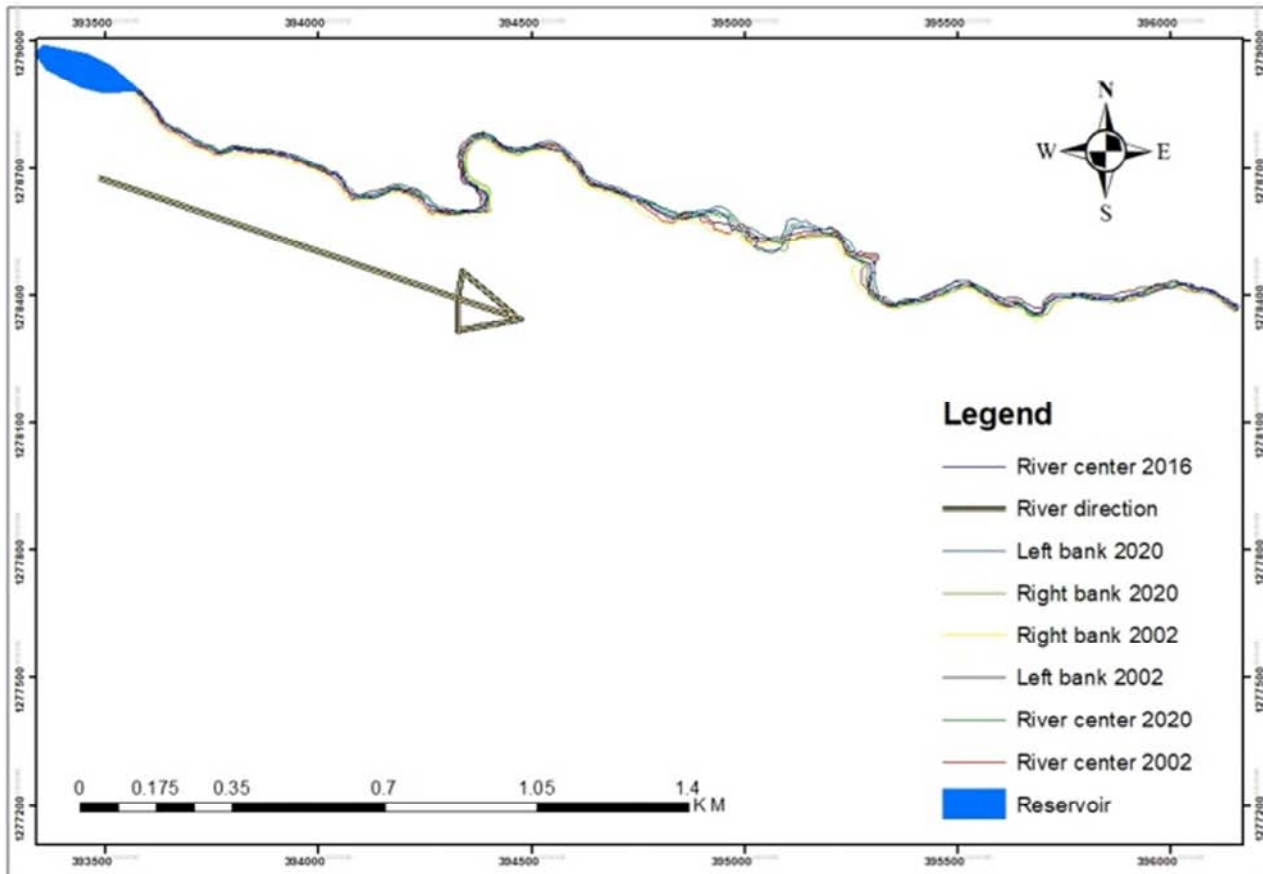


Figure 7. River width measurements.

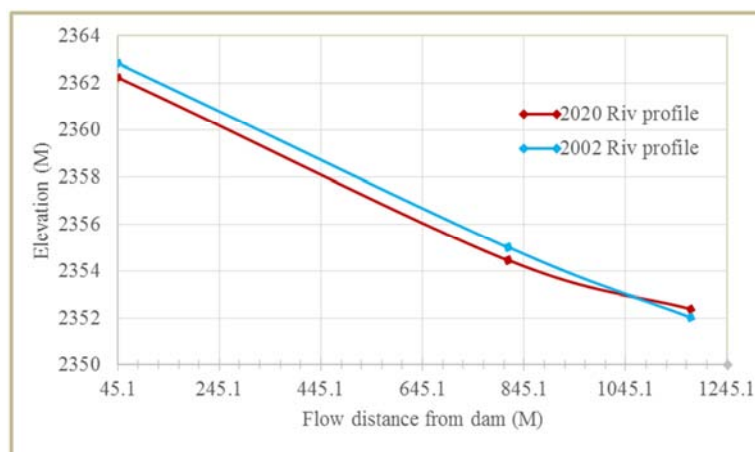


Figure 8. River width change measurement.

The changes in width were determined from Google Earth compiled before the dam was built in 2002, with an altitude of 2.2 km eye sight with reference ground data, and error

quantification with 6.092 meters after the dam was constructed, with measured width current data from 2020. From 26 cross-sections analyzed, 79.99% have narrowed and 20.01% have

widened. Figure 8 shows the overall pattern of width change of the channel in different sections from 2002 to 2020. The width of the Gomit River has narrowed from the previous to the current, creating additional land along the river banks. The river becomes narrow due to growing grass and vegetation in the river channel that resists bank erosion. The sediment that comes from the catchment is entrained in grass roots and vegetation, establishing a channel, and then, far downstream, aggradation

occurs. But in the middle part, the width of a river increases due to lateral erosion along the left bank at a distance of 1171 m from the dam to downstream, and it is relatively lowest in the upper part of the section at a distance of 25.1 m. Basically, the width of a river increases due to lateral erosion along both sides of the banks due to erosion that comes from catchment and decreases due to sedimentation.

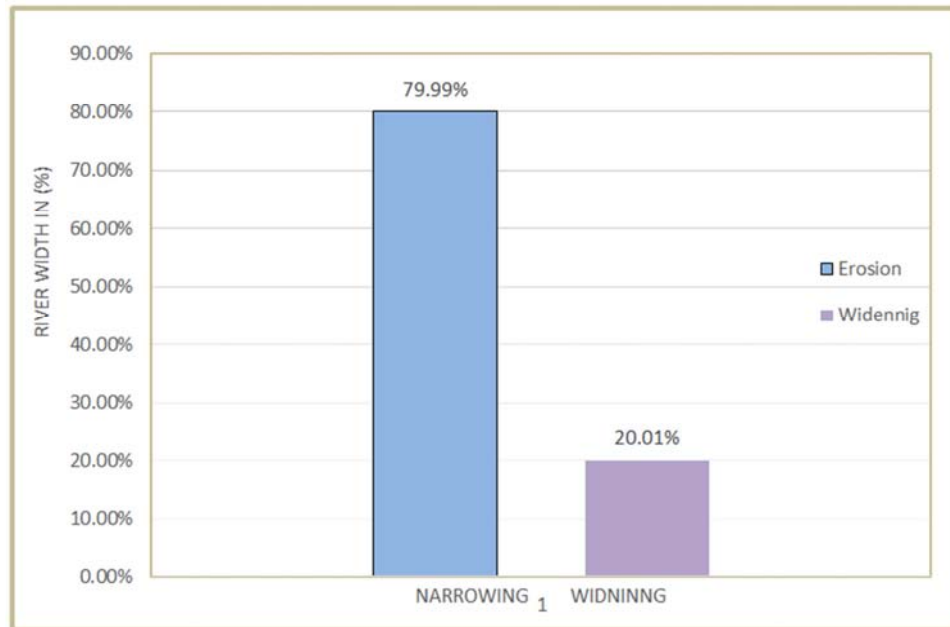


Figure 9. Total erosion/deposition along the river banks.

3.5. River Plan Form Analysis

The river plan form shows an overview of the river channel in order to evaluate the plan form. The channel through Gomit was blocked by hydraulic structures (dams). This channel usually disappears during the dry season, meaning a flow controlled by hydraulic structure for irrigation purposes only during the summer season [22].

The River reaches to be studied are identified and subdivided into three study reaches such that a precise profile of the energy line may be established for the study. The reach selected reach A at the end of spillway stilling basin to assess dam impact, reach B select at middle which is clay soil soils that crack and slide and farming up to river banks, reach C selected almost far from dam impact instead land use/cover change impact aggravate that input sediment to River. In meandering reaches, the study reaches are so demarcated as to identify the curved and straight portions. In each study reach, cross-sections are laid out normal to the direction of flow at the distance of about 45.1, 812, 1171m distance being measured along the center line of the main channel. Considerable planform changes were observed and identified at the beginning of the outlet of Gomit dam and the mouth of the River. The analyzed sections labled up to 26 cross-sections and explanations of each detail results were explained below.

Table 6. River channel center change from 2002 River center to 2020.

Cross section	2002 River center shift	2020 River center shift
2	3.1	-1.25
3	3.21	-2.23
4	3.56	-3.72
5	3.26	-3.48
6	2.52	-3.61
7	3.23	-4.32
8	2.8	-2.43
9	3.02	-4.13
10	1.07	-2.81
11	-2.54	-4.4
12	-4.25	-1.87
13	-3.32	-1.56
13	-4.51	-3.76
15	-3.63	-4.3
16	-1.65	1.22
17	-2.05	2.03
18	-2.76	2.61
19	-3.01	2.33
20	-1.35	2.77
21	-2.13	2.63
22	2.51	2.24
23	-1.27	2.35
24	-2.7	3.13
25	-1.56	2.71
26	-2.66	2.43

The (-ve) sign show left and (+ve) sign show right from reference year.

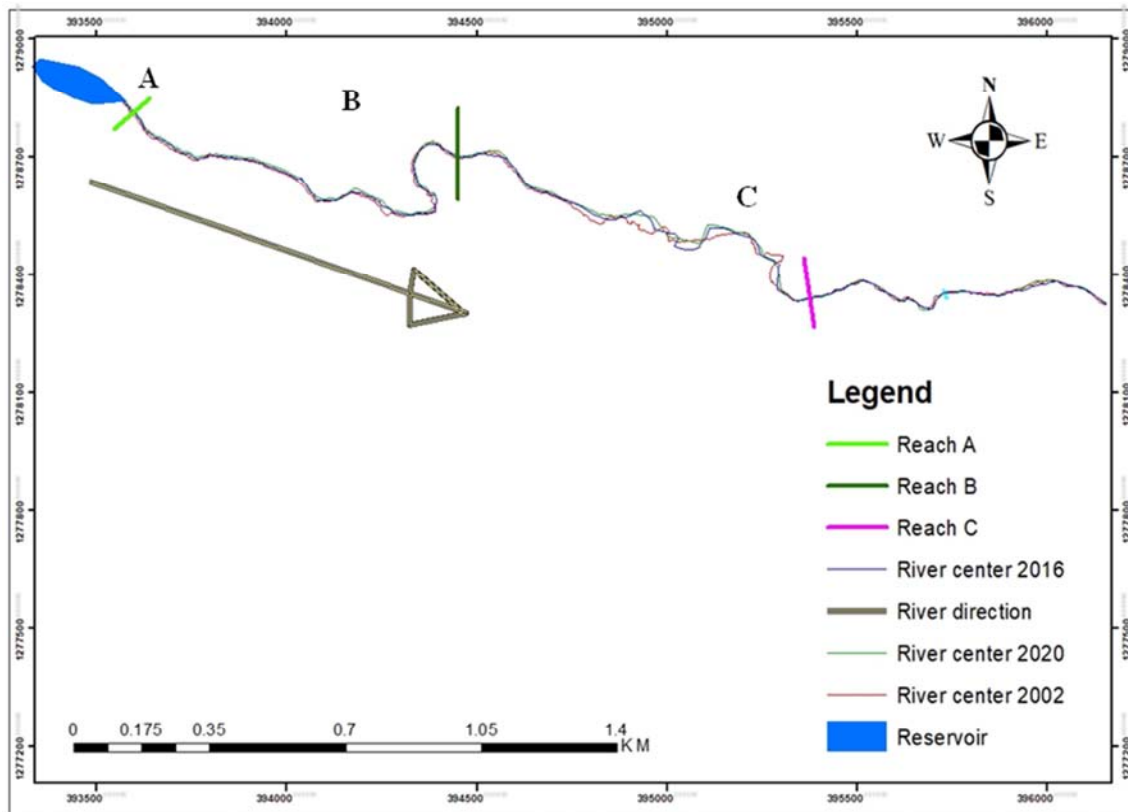


Figure 10. River center in different years along the cross- sections.

3.6. River Cross Section Analysis

Reaches-A between cross sections 1 and 9: The river center at reach-A from cross sections 1 to 9 shifted to the right, and the river center 2020 shifted to the left banks from

the reference year 2016 river center downstream of the dam. In these sub reaches, the changes come from the dam that diverts water with its spillway and relatively releases sediment-free water, which affects river characteristics [22].

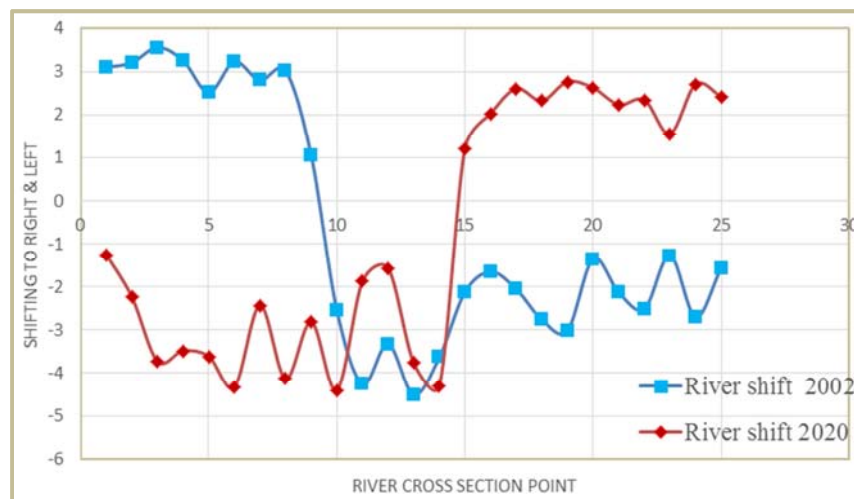


Figure 11. Overlapped River centers at cross-section from reference year.

3.7. Sinuosity Index Analysis and Assessment of Meandering Characteristics

From the digitized map of different plotline and polygons

are representing the river, each other exactly, so the plotline represents a change in plan form and different courses of the river for use by GIS software. The stream length and valley length are also measured for calculating sinuosity ratio. Another alternative, the channel length was measured by

estimating the location of the river thalweg profile based on the GIS survey of the reach. According to [23, 10], the

sinuosity index of a River reach is defined as the ratio of the channel length to the valley length.

Table 7. Total sinuosity index of Gomit River (where CL: Channel length, VL: Valley length, AL: Air length, VI: Valley index, HSI: hydraulic sinuosity index, TSI: Topographic sinuosity index, SSI: standard sinuosity index).

RC	CL (M)	VL (M)	AL (M)	CI	VI	HSI	TSI	SSI	Plan form
2002	3390	2467	2212	1.533	1.115	0.784	0.216	1.374	Moderate meander
2016	3184	2449	2209	1.441	1.108	0.755	0.245	1.300	Sinuuous
2020	3155	2439	2205	1.430	1.106	0.753	0.247	1.294	Sinuuous

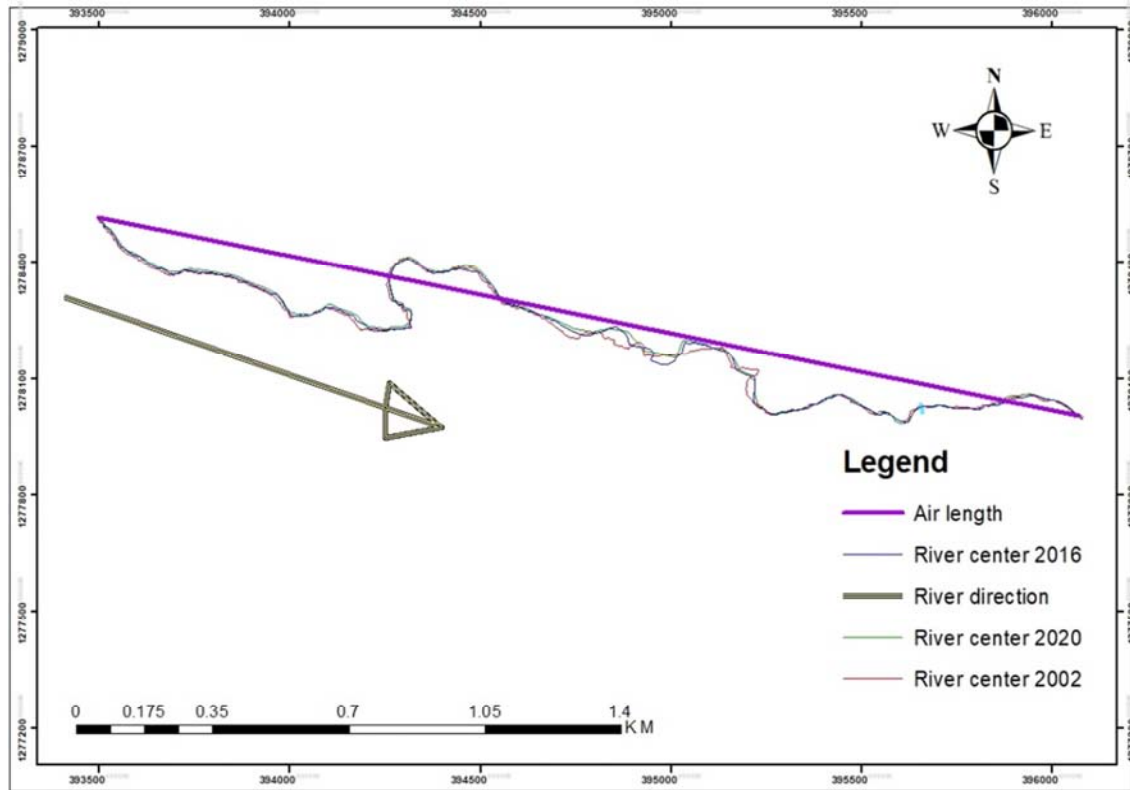


Figure 12. General Gomit River longitudinal profile.

3.8. Vertical Change Analysis

The River center line was used to analyze river profile changes that show the difference between 2002 and 2020 river center depth. Figure 13 shows a line diagram that depicts the elevation difference between two years and the vertical changes in the river center line over a period of 19 years.

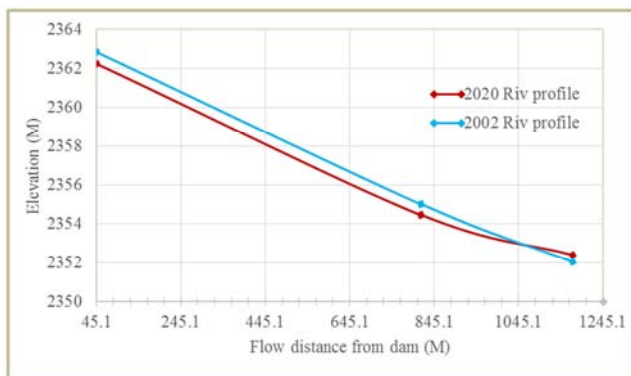


Figure 13. Vertical River bed profiles of Gomit River.

From the profile analysis, the average change in river depth was found to have been degraded by 0.612m, 0.566m, and aggraded by 0.346m at a distance of 45.1m, 812m, and 1171m downstream of the dam. This indicates that there is degradation below the dam due to relatively releasing sediment-free water from the reservoir and the slopping chute spillway stilling basin starting to scour the river at its end. At the second reach, the degradation was due to soil type, which was clay soil that cracks in the dry season, which caused the slide and farming practices up to the river banks.

Finally, at the third reach, aggradation occurred due to sediment input from the catchment that was trapped by grass in the bank channel and vegetation encroachment at the bank that narrowed and aggraded the channels because of the obstruction of the dam from which sediment free water was released to the downstream and further downstream sedimentation from the catchment.

4. Conclusion

From the result of land use/cover classification, there is a

decrease in forest land, the Bushes and shrubs and accompanied by increase in agriculture land and settlement area. The anthropogenic impacts such as farming, deforestation, resettlement and animal free grazing have also aggravated the change of the plan form in the downstream part of the River.

The Gomit River shape was lay between moderate meander to sinuous River, sinuosity index values varying in between 1.374 and 1.294 in the year 2020 and 2002 respectively, it indicates that meandering activity of the River decreases. The overlaying analysis showed that for the considered reach starting from the dam for a length of about 3.9km the general trend of the River banks were shifted to right and after that the river banks shifts left (at reach A RC 2002 was shift to right and 2020 to left, at reach B, both shift to left, at reach C, 2002 shift to right 2020 to left). From 2002 to 2020 the bank line of the River was changes significantly 79.99% narrowed and 20.01% wide and creating additional lands along the River banks. Comparisons of cross-sections average change of River depth was found to have been degraded by 0.612m, 0.566m, and 0.346m respectively at a distance of junction point between the spillway out let and the River, 45.1m, 812m, and 1171m respectively downstream of the Dam.

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