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Environmental impact and Management of Sand Mining: a case study of Kangsabati River Water shed, West Bengal, Using Remote Sensing and GIS Technique

B. Mandal[1], D. Bej[2], N. K. Baghmar[3]
Research scholar, S.o.S in Geography, Pt. Ravishankar Shukla University[1, 2]
Professor, S.o.S in Geography, Pt. Ravishankar Shukla University[3]
baburamiirs2012@gmail.com[1]

Abstract: *Rivers are the most important life supporting system of nature. River sand is used just as much as river water for human subsistence. The uses of sands in various fields are likely, concrete work in building sites, construction of roads, making of various sizes of bricks, glasses industries, even fill in deep space, reclamations to replace eroded coastline etc. Sands of river streams have no substitute for use as building material in reinforced concrete cement. Indiscriminate sand extraction from river is changing the course of the river bed and leading to environmental degradation. This kind of environment that is being degraded as a result of excess sand mining can be seen not only in India but all over the world. The study conducted in the Kangsabati lower catchment shows that indiscriminate and illegal sand mining has created many problems in the environmental setting and water quality of the river basin. In the basin area, it has created certain negative impacts on land use, landscape and land stability. Mostly the rapid growth of urbanization is the major cause for sand demand and is responsible for unsustainable extraction of sand from dried river beds. As per the state government norms the sand extraction is permitted up to three feet's, but it is being dug up even up to 10-20 ft. These are an excessive demand which in turn has a very negative impact on the irrigation system of agriculture. The main objective of the study is to investigate, analysis of the sand mining areas through Visual Image Interpretation using remote sensing and modern GIS techniques. The final results highlight the impacts of environment and its management in Kangsabati watershed of PaschimMedinipur and Bankura Districts, West Bengal, which is a suitable model in similar geological conditions.*

Keywords: *River sand mining, Kangsabati River beds, Remote Sensing and GIS.*

1. INTRODUCTION

Sand is a loose, fragmented, naturally-occurring granular material consisting of very small particles of decomposed rocks, corals, or shells. Sand is used to provide bulk, strength, and other properties to construction materials like asphalt and concrete. Sand accumulation as layers in river courses is a dynamic phenomenon. Sand is vital for the existence of the rivers. Riverbeds, streams, channels, beaches are excellent sources of sand. As a resource, sand by definition is 'a loose, incoherent mass of mineral materials and is a product of natural processes. River sand is one of the world's most plentiful resources (perhaps as much as 20% of the Earth's crust is sand). When sand is freshly formed; the particles are usually angular and sharply pointed but they form gradually smaller and more rounded as they become constantly worn down by the wind or water (Basavarajappa and Manjunatha, 2014).

The demand for sand is increasing because its importance and role in construction is indispensable. Extraction of sand

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is more likely to have ramifications around the environments of their occurrence. Extraction of sand from rivers, streams, flood plains, and channels conflict with the functionality of river in e ecosystems and some of the disturbances are from the mining methods and machines used (Kori and Mthanda, 2012).

Sand is used for all kinds of projects such as land reclamation, the construction of artificial islands and coastline stabilization, and these projects have economic and social value, but sand mining can also bring environmental problems (Ashraf et al., 2011).

Sand mining activities have impacted, in one way or another, on the economic, social and environmental aspects of man in mining areas. However, many people resort to the trade of sand so as to earn a living. Since sand mining has economic gains, most community and traditional leaders sell community lands within their domains to miners. This is done because people derive their livelihoods from sand mining to ensure their survival from the natural resources available and accessible to them (Onwuka Et al., 2013).

Sand is a very important construction material. UN Environmental Program of Global Environmental Alert Service noted that in concrete processing of infrastructure industry, sand is six to seven times much more consumed than other materials including cement (UNEP Global Environment Alert Service, 2018).

Sand mining is the process of removal of sand and gravel where this practice is becoming an environmental issue as the demand for sand increases in industry and construction. In almost every mineral bearing region, soil mining and land degradation have been inseparably connected. Unscientific mining has caused degradation of land, accompanied by subsidence and consequential mine fires and disturbance of the water table leading to topographic disorder, severe ecological imbalance and damage to land use patterns in and around mining regions (Ghose, 1989).

Sources formed from eroding mountain rocks carried by a river. The mining of sand and gravel is one of the activities that positively impact the local economy. Sand and gravel are also important sources for the economic development activities of developed and developing countries (Kori and Mathada, 2012).

To cater for the rapid urbanization, several sites are now been explored for the mining of sand and other building materials. Traditionally, site for sand mining are rivers and beaches, however, sand is mined from river mouths, banks and even at inland sand deposits. Many inland sand deposits, which are lateritic in nature, are under immense pressure due to various kinds of human activities among which indiscriminate extraction of sand is the most disastrous (Kondolf, 1994; Sayami and Tamraker, 2007).

Therefore, the study assessed and evaluated environmental impact of sand mining within Kangsabati watershed of PaschimMedinipur and Bankura Districts, West Bengal. The main aim of the research paper is to establishing the trend and the current state of sand mining and its impact on environment of study area.

2. STUDY AREA

The Kangsabati River watershed is a lowermost tributary of the lower Ganga basin. The study area is covered by 5796 km^2 and its lies in PaschimMedinipur and Bankura Districts of West Bengal state, India. The extension of mentioned area is 87°32´E to 85°57´E longitude and 22°18´N to 23°28´N latitude. The Kangsabati reservoir project situated at the border of Purulia and Bankura districts and of provides water supply for purpose agriculture in Bankura and Midnapore districts. The Midnapore district has been divided into two separate districts: East and West Midnapore in 2001 and most recently west Midnapore further divided in PaschimMedinipur and Jhargram districts. However, socio-economic data are not available separately but available in the combined Midnapore district (East and West Midnapore and Jhargram districts). Due to this reason, the combined Midnapore district has been considered for this study. The study area has been shown in Fig.1.

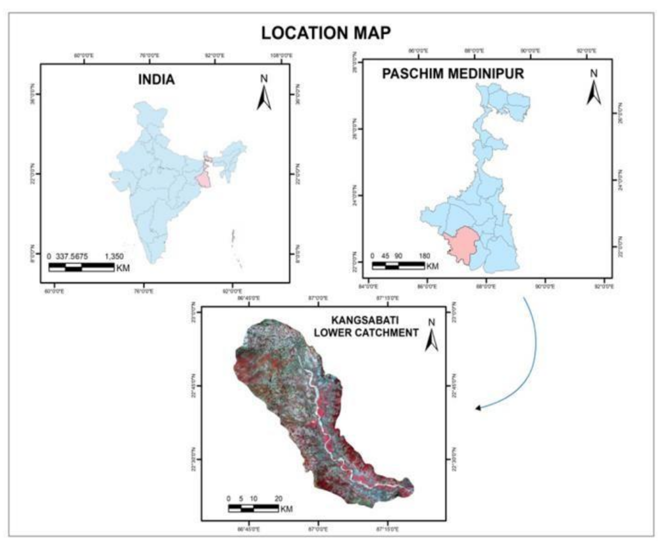


Figure 1: Location map of the Study Area

3. METHODS & MATERIALS

The topographical map (48P/15, of scale-1:50,000) were used for watershed delineation. The different kind satellite imagery has been used for analysis of sand mining IRS-1D, PAN (5.8 m Resolution), LISS-III (23.5m Resolution) of the year 2019 and quick bird imagery (0.5 m. in 2019) has been used for better understanding. GPS (Garmin) has been conducted for ground verification in the particular locations during sample collection. Field photography has been conducted at the same. Erdas imagine software has been used for image enhancement and Arc GIS 10.3 has been used for image interpretation and detail analysis.

4. CLIMATE AND RAINFALL

The area is experienced by a great variation in climatic characteristics. The climate is very much tropical and exercising monsoonal characteristics with variations in micro regions. The climate of the northern and western part of the area is being characterized by semi-arid climate having a vicious dry heat in summer, a short winter season. Moderately rainfall has been found in monsoonal rainy season. The climate of eastern and southern part is different in nature; characterized by hot and humid climatic condition. Season wise temperature and rainfall have shown in table 1 and 2. The seasons are follows:

- Summer season – (March to May)
- South west Monsoon season – (June to September)
- Post-Monsoon season – (October to November)
- Winter season – (December to February

Table 1: Season wise distribution of temp.^{0}C

Year	**Season wise distribution of temp. ^{0}C**		
	Pre-monsoon	Monsoon	Post-monsoon
2005	27.5	29.13	22.75
2006	27.88	28.75	22.88
2007	27.88	29.25	22.63
2008	28.50	29.12	22.12
2009	29.75	31.25	22.50
2010	28.5	29.88	22.50
2011	28.63	29.25	23.13
2012	27.75	29.25	19.00
2013	27.37	28.87	23.12
2014	27.39	28.33	23.22
2015	29.88	32.50	22.75
2016	28.5	31.13	22.75
2017	27.56	30.25	22.70
2018	28.7	29.55	21.85
2019	28.45	31.25	22.65

Table 2: Season wise distribution of rainfall in cm.

Year	**Season wise distribution of rainfall in cm.**		
	Pre-monsoon	Monsoon	Post-monsoon
2005	75.75	279.50	11.25
2006	90.75	281.50	44.75
2007	55.75	328.00	32.00
2008	50.75	207.25	130.50
2009	22.75	275.00	43.50
2010	56	254.50	91.50
2011	48.5	297.75	12.75
2012	54.5	476.75	115.25
2013	51.00	398.25	24.50
2014	76.50	200.50	20.75
2015	41.50	192.75	29.50
2016	41.50	192.75	29.50
2017	55.54	214.55	24.95
2018	48.25	196.78	18.54
2019	46.75	245.52	25.40

5. GEOMORPHOLOGY

Geo-morphologically, the study area mostly represents flat topography with regional slope. The study area came under lower Ganga plain area. The entire watershed has been broadly divided into two natural divisions–the Western upland including undulating lateritic Rarhplain and the Eastern Gangetic alluvial plain along with southern maritime tract. It is assumed that a metal road passing from Raniganj to Cuttack through undivided Midnapore district that cut across the district north to south is the approximate boundary line of these two natural divisions. Physiographically, the region has been sub-divided into three macro-regions and five micro-regions. Macro- regions are: a. The Western Upland, b. The Rarh, c. The Plain (Deltaic and Coastal) and the micro-regions are: a. Medinipur upland, b. Silaiplain, c. Lower Kasai plain, d. Contai plain, e. Digha coastalplain.

The geomorphological units has been digitized by the help of IRS-1D, PAN (5.8 m Resolution), LISS-III (23.5m Resolution) of the year 2019 and quick bird imagery (0.5 m. in 2019) and to posheets as the base map through Arc GIS 10.3. The thematic map of geomorphology helps in identification and mapping of various landforms such as highly dissected hills, moderately dissected hills, dissected hills & pediment-pediplain complex, piedmont zone, alluvial plains, older flood plain, reservoir, and river/stream and etc. Geomorphological map of the Kangsabati river catchment has been shown in Fig.2.

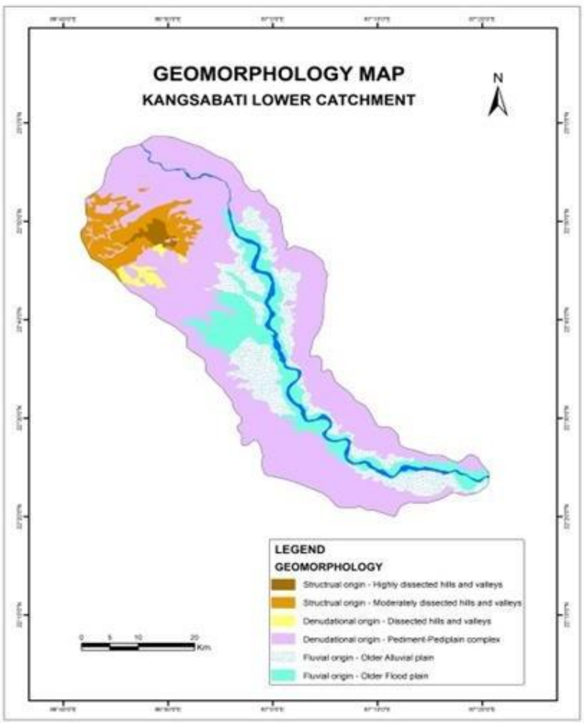


Figure 2: Geomorphological map of KangsabatiRiver

5.1. REGIONAL LITHOLOGY

The terrain characteristic has been found in study area. The lateritic rock is available in the western and north-western part of study while in southern and south- eastern parts is gradually changed with alluvium deposit of Gangetic delta. Due to north-west and western portion is covered by hilly upland and the several ridges are formed where micaceous schist carved out from the beneath of lateritic outcrop. Grey and bluish-grey micaceousschists are found in the ridges. The hills are separated by valley in an irregular manner. The hills are composed of hard grey and grayish-white gritty quartzite whereas blue slater and traps are found in the valleys.

Most of the area is covered by ordinary river sand deposited decade back. The other rock formation in area is alluvial rocky upland and undulating lateritic upland these formations undergo series of metamorphic cycles, like weathering, erosion, transportation and deposition of sand material. The geological parameters / features of the ore body as obtained from the field mapping and exploration studies reveal the following (Singh. A.). Geological map of Kangsabati river has been shown in Fig. 3. And the Sedimentary deposit shown in table 3.

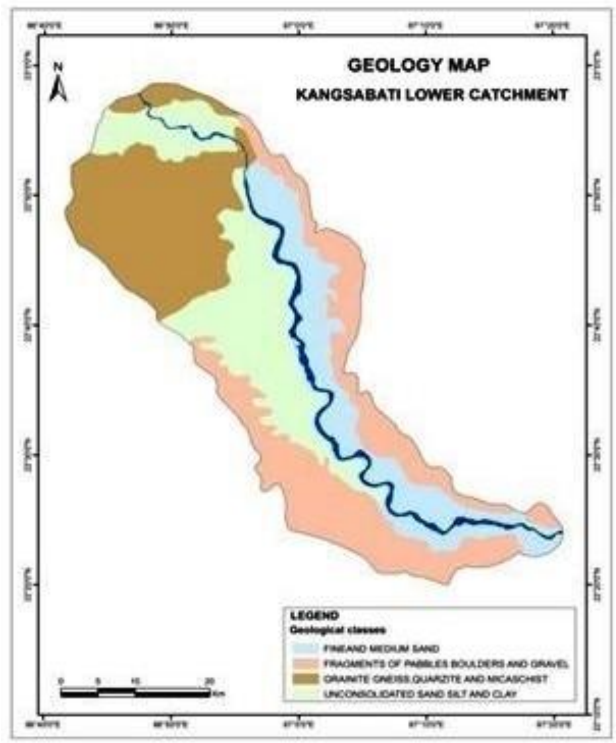


Figure 3: Geological map of Kangsabati

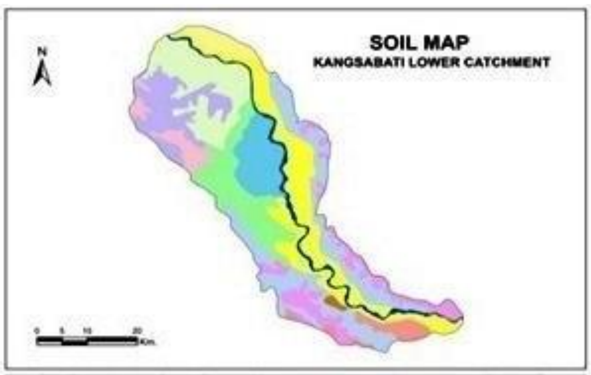
Table 3: Sedimentary deposit

Length of the Deposit (Lease Area.)	450-500 m
Width of the Deposit (Lease Area.)	160-170m
Depth of the ore body	Depth of the ore body

The lands Surface of the Geological Map & Section of the different lithological units are mapped and the cross-sections have been showed the disposition of the different lithological units.

5.2. SOIL

The soil structure of the watershed is found light and medium, some places have heavy types. North and North-Western part of this study is a part of Chotanagpur Plateau and covered with hard laterite soil. In the western and eastern part, laterite alluvial soil persists. The SYI method is highly useful for prioritization of micro-watersheds according to erosion impact (Bej & Baghmar, 2019) Soil map of Kangsabati River shown in Fig. 4.



Sl. No.	Major unit	Minor unit	symbol	Description	Soil Taxonomy	Area (Sq. Km.)
1	Sub Recent Alluvial Soil	W1		Very deep, poorly drained, fine cracking soil	Fine Vertic Ochraqualfs	132.66
		W2		Very deep, moderately well drained, fine loamy soil	Fine Loamy Typic Ustifluvents	339.77
2	Red Lateritic and old Alluvial Soil	W3		Very deep imperfectly drained coarse loamy soil	Coarse Loamy Typic Haplustalfs	146.48
		W4		Very deep imperfectly drained fine loamy soil	Fine Loamy Ultic Paleustalfs	331.30
		W5		Very deep, poorly drained, fine loamy soil	Fine Loamy Aeric Ochraqualfs	58.89
		W6		Very deep, poorly drained, fine soil	Fine Aeric Ochraqualfs	199.47
3	Costal sub recent and Marshy Soil	W7		Very deep, poorly drained, fine loamy soil, strong salinity	Fine Aeric Haplustalfs	7.70
4	Old Red- Yellow & Catenary Soil	W8		Shallow well drained gravelly loamy soil.	Loamy Lithic Haplustalfs	67.52
5	Laterite Soil	W9		Very shallow somewhat excessively drained gravelly loamy soil.	Loamy Skeletal Lithic Ustorthents	169.06
		W10		Deep, moderately well drained fine loamy soil.	Fine Loamy Typic Haplustalfs	214.79
		W11		Very deep, moderately well drained fine loamy soil.	Fine Loamy Typic Paleustalfs	62.88

Figure 4: Soil map of Kangsabati River

5.3. SLOPE

General slope is noticed in this area is from NW- SE a sloppy undulating terrain. The flow of the water is west and north-western to South east direction. Most of the River bed area covered fine grain to coarse grain sand with rocky pebbles at places & there is no vegetation except grass at places.

Drainage map and Slope map of Kangsabati river shown in Fig. 5 and Fig. 6.

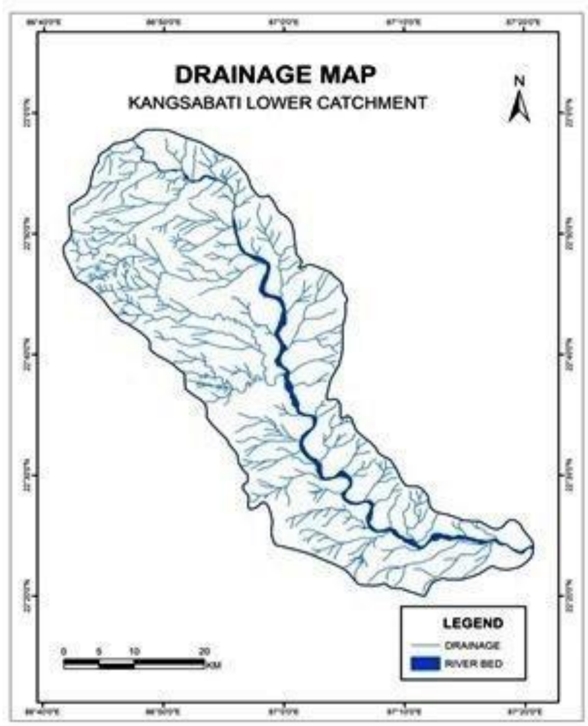


Figure 5: Drainage map of Kangsabati River

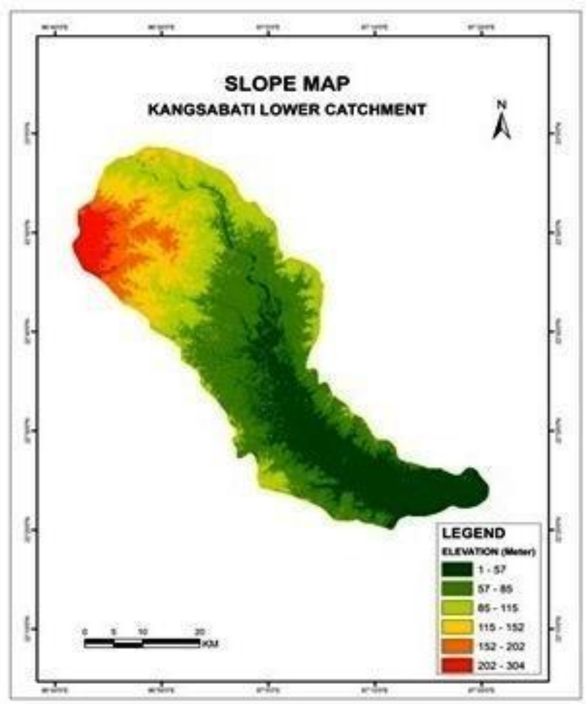


Figure 6: Slope map of Kangsabati River

6. RESULT AND DISCUSSION

River bed sand mining locations were identified on Google earth imagery based on the image elements like tone, texture, shape, size, pattern and association, etc. Generally, River sand appears in tones of bright white to dull white (yellow) with medium to fine texture due to the presence of silicate minerals. The total sand mining area of Kangsabati lower catchment is 73600 m2 whereas the sand mined areas easily identifiable with their irregular shape, uneven tone, and rugged surface. Sand Mining area marked in Quick bird satellite imagery shown in Fig. 7.

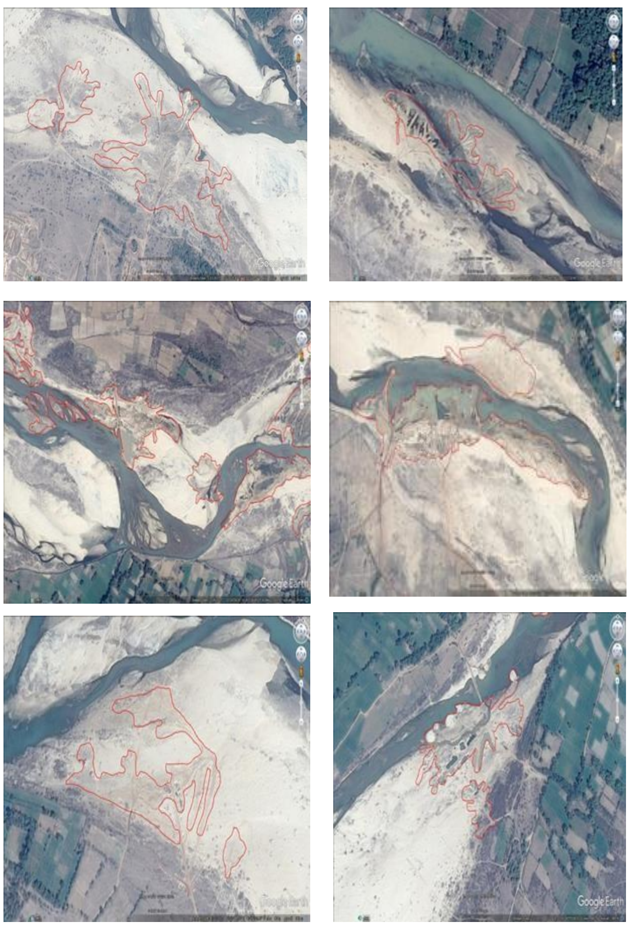


Figure 7: Sand Mining area marked in Quick bird satellite imagery.

The geological reserves of river sand are 73600 m^2. Every year silt will be removed and allow excavated pit for sedimentation of Kangsabati river. The sedimentation study reveals that every day 0.8cm. of silt will be filling in the proposed area, hence mining activity only for four months rest 8 months allowed for sedimentation of silts. The depth of send mining allowed is 2 meter from the ground level and the total volume (73600 m^2 * 2) m^2 = 147200 m^3. The total extractable sand available is 147200 m3 * 2.5 (bulk density) = 368000 MT/ Annam. But all total extractable sand is being made several times more than the government guideline has and the land degradation is having a huge impact. Some ground photograph of sand Mining has been shown in Fig. 8.

Figure 8: Ground photograph of Sand Mining

7. REPLENISHMENT OF THE SAND

Replenishment of the sand in river bed is calculated according to the Dandy - Bolton Equation. It should be found out that how much sand is replaced in the river bed in per year. The equation has been calculated through the mean annual rainfall, mean annual run off and also net drainage area.

7.1. DANDY BOLTON EQUATION

Dandy Bolton equation is an important formula is broadly used to calculate the sedimentary yield in river bed. However the use of these equations to predict silt yields for specific area but wide variety of local factors is highly influence on the development of equation. Its help to quick and mostly accurate measurement of sediment yields in particular local area for purpose of watershed planning. Dandy Bolton equation is an important formula is broadly used to calculate the sedimentary yield in river bed. However the use of these equations to predict silt yields for specific area but wide variety of local factors is highly influence on the development of equation. Its help to quick and mostly accurate measurement of sediment yields in particular local area for purpose of watershed planning. The lithological structure, physiographical division, topographical variety, climatic condition, drainage pattern, soil properties, local plants, Anthropogenic activities are mainly influence on equation. This is normally found that the highly erosive area computed to low sediment yield and low erosive watershed where established with plants are shown high sediment yield. Lithological structure and geological setup mostly control the formation of soil and erosion. Highly hill region with steep slope surface area mostly found high to severe erosion land and gentle slope are vice versa. Densely vegetation areas are protects soilerosion.

Dandy Bolton equation analyzed the combined influence of surface runoff and watershed area on sediment yield to predict the sediment yield.

(Q < 2 inches)S = 1280*(Q) 0.46*{1.43-0.26 Log (A)} F…1

For runoff more than 2 inches (Q > 2 inches) S = 1958*(e- 0.055*Q)*{1.43-0.26 Log (A)} F…2

Where: S = Sediment yield (tons/sq. km/yr.)

Q = Mean Annual runoff (inches) A = Net drainage area in sq. km

Kangsabati catchment falling in (2) equations due to high annual run off.

Replenishment of sand around = Sediment yield = 22.98 M. tons/km^2/yr.

The area 5796 Km^2 is representing the Kangsabati river basin. Thus, about 368000 MT^3 area/ year sediment has been extracted in every year in the basin area as replenishment against the deposit quantities. The maximum annual production is more than deposition. The different type satellite data with ground sample has been analyzed to calculate the sediment deposit and extraction.

7.2. IMPACT ON ENVIRONMENT

Impact on River Morphology: One of the principal causes of environmental impacts from in-stream mining is the removal of more sediment than the system can replenish. Coarse material transported by a river (bed load) commonly is moved by rolling, sliding, or bouncing along the channel bed. Some ground photographs of sand mining shown in Fig.9.

Figure 9: Ground photograph of Sand mining which impact on River morphology

Water table depletion: Sand aquifer helps in recharging the water table and sand mining causes sinking of water tables in the nearby areas. Apart from threatening bridges, sand mining transforms the riverbeds into large and deep pits; as a result, the groundwater table drops leaving the drinking water wells on the embankments of these rivers dry.

Water Quality: Turbidity increase at the mining site due to resuspension of sediment, sedimentation due to stockpiling, organic particulate matter, oil spills or leakage from excavation machinery and transportation vehicles.

Destruction of riparian vegetation: Caused by heavy equipment, processing plants and gravel stockpiles at or near the extraction site. Heavy equipment also causes soil compaction, thereby increasing erosion by reducing soil infiltration and causing overland flow (NMFS, 1998). Disturbing the natural hydraulics of the riparian zone during infrequent elevated flow levels.

Riparian habitat, flora and fauna: In stream mining can have other costly effects beyond the immediate mine sites. Many hectares of fertile land are lost, as well as valuable timber resources and wildlife habitats in the riparian areas. Degraded stream habitats result in loss of fisheries productivity, biodiversity, and recreational potential. Severely degraded channels may lower land and aesthetic values. All species require specific habitat conditions to ensure long-term survival. Factors that increase or decrease sediment supply often destabilizes bed and banks and result in dramatic channel readjustments

8. MANAGEMENT OF RIVER SAND MINING

There is some management plan according to the environment of Kangsabati catchment these are:

1. Permit the mining volume based on measured annual replacement.
2. Establish an absolute elevation below which no extraction may occur.
3. Limit in stream extraction method to bar skimming.
4. Extract sand and gravel in the downstream portion.
5. Concentrate activities to mining disturbance.
6. Maintain flood capacity.
7. Limit in stream operation to the period of May to September.

8.1. RIVER SAND SUBSTITUTES

Sand Researchers world over are in continuous search for the alternatives to sand. Fine aggregate is one of the important constituents of concrete and mortar in construction industry. River sand is becoming a scarce material. Sand mining from our rivers has become objectionably excessive. It has now reached a stage where it is killing all our rivers day by day. As a solution for this, various alternatives are explored and used in many parts of the world. Sustainable Sand Mining method has been shown in Fig. 10.

Some of them are:

1. Processed QuarryDust
2. Processed Crushed Rock Fines(CRF)
3. OffshoreSand
4. DuneSand
5. Washed Soil (Filtered Sand)
6. Fly Ash/ Bottom Ash/Pond Ash
7. Slag Sand
8. Copper Slag Sand
9. Construction Demolition Waste
10. Powdered Glass
11. Aluminum saw mill waste
12. Granite Fines/Slurry and Many More.

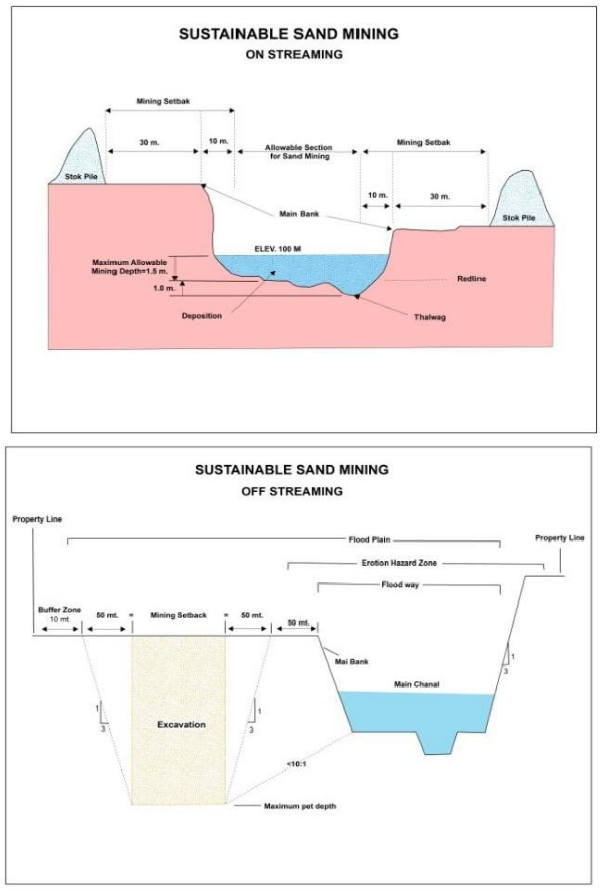


Figure 10: Sustainable Sand Mining

9. CONCLUSION

Geomatics is the advent high-tech tool that provides synoptic view of a larger area, accurate & effective results in environmental quality, planning and decision making processes. River sand mining has many negative impacts on the environment as well as in the society. The study conducted in the Kangsabati River has established that rivers are dying due to human activities. Approximately 100 kilometer of the river length there is so many sand mining pits are here. Some of the portions like Sijua, Brambhandia, Dherua, Baita are highly affected by sand mining activities. Ground water level is lying from its previous level. And also the river path is highly affected; some where the width of the channel is larger than its previous width like Baita and Brambhandia villages etc. And one of the most things is observed that currently sand extraction is permitted up to 1.5 – 2 mt. but is being dug up even up to 3mt.

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