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Potential River Sediment Extraction Zone Analysis of Bagmati River for Flood Mitigation and Economic Value using GIS

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***Abstract*—The Kathmandu Valley, located in central Nepal, is highly prone to flooding due to its unique terrain and hydro logical conditions. Rapid urban expansion, increased impervious surfaces, and altered river dynamics have intensified sediment deposition, particularly in the Bagmati River, exacerbating flood risks. Recognizing river sediment as one of the key contributors to flooding, this study used GIS-based spatial analysis to identify potential sediment extraction zones along the Bagmati River. While government regulations limited the feasible extraction only to four sites totaling 50,332 m² in area, these zones present significant economic potential, from where processed river sediments could generate over NPR 1 crore in revenue, with even higher returns possible under more supportive policies. Systematic sediment extraction not only offers a practical strategy for flood mitigation but also supports sustainable regional development by turning a hazard into a valuable resource.**

***Keywords*—Sediment, Flood, Dredging, Policy, Resource**

I. Introduction

Flood is a major global disaster that every year causes enormous damage and affects human life and also economic and sustainable development all over the world [1, 2]. Over the past three decades, there were about 6000 global flood events every year which resulted nearly $1.15 trillion total loss, while in 2022 alone the loss was about $44 billion—25% above the 30 years average [3]. Similarly, there were 1680 total flood events in Asia from year 2000 to 2025 which affected about 1.68 billion people, along with 92,899 total deaths and about $450 billion economic loss, which is equal to 31.31% of total economic loss caused by disasters in Asia [4]. Furthermore, in Nepal, flood is a major disaster especially during monsoon, have caused significant loss of life and economic damage with an average of 300 deaths per year and economic losses surpassing more than $10.6 billion from 1954 to 2018 with Bagmati and Madesh province being the most affected ones [5].

Nepal have recently experienced a devastating flood in 2024 which resulted in the total loss of NPR 46.68 billion with 249 casualties [6]. The same flood led to 34 deaths alone in Kathmandu valley [7], and during that flood the precipitation data also shows the record-breaking rainfall in every rainfall measuring stations [8, 7].

Flooding in Kathmandu valley is due to various factors including slope, elevation, distance from rivers, drainage density, changes in land use and land cover (LULC), and rainfall [9, 10]. Being the capital city of the country, Kathmandu valley has seen significant rise in its urban area [11], at the rate of 6.65% per year, which have led to the increase in concrete structures and impervious surface in the valley [12, 13]. Urbanization increases impervious surface which directly increases the surface run-off to stream-flow and this change in LULC results more sediment yield in the river [14, 12]. The increase in sediment in the river influences its natural flow dynamics [15] and it is necessary to include the effects of sediment transport while studying about the flood [15, 16]. High sediment flow also compromises the strength and stability of river structures that includes bridges, embankments, and so on [14, 16]. According to [8], the aftermath of flood 2024 showed the debris pile up and failed river structures all around the Kathmandu valley. Moreover, although embankments constructed along the rivers in the valley may increase sediment transport by 32%, they also worsen flood risk by causing sediment to accumulate within the river channel, leading to a rise in the riverbed [16].

The major river of the Kathmandu valley, that is Bagmati river, flows at a gradient of 126.8m/km in Shivapuri area (north of Kathmandu valley) and 2.7m/km in Kathmandu valley [17, 18]. The difference in gradient between Shivapuri area and Kathmandu valley suggests that the Bagmati river flows rapidly in Shivapuri area and when the river reaches the valley basin it flows comparatively slower. Similarly, a study reports that, upon entering a valley basin, any river experiences a decrease in channel gradient, which in turn causes a decline in flow velocity [19]. Also, the Exner equation clarifies that reduced sediment flux resulting from decelerating water contributes to sediment deposition and bed aggradation [20].

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Empirical studies support that in lower-slope reaches, diminished transport capacity results in coarse bed-load deposition [21]. So, the difference in flow velocity suggests, valley can be a major area for the river to deposit sediments. Similarly, the flood of Kathmandu 2024 was majorly caused by extreme rainfall events and landslide that occurred around Kathmandu valley; the river swept the sediment of landslide into the river, altering the natural sedimentation process and increasing the amount of sediment in the river [8]. Moreover, flooding occurred without an increase in peak discharge because increased sediment deposition decreased river channel capacity [22].

Recent studies on flood of Kathmandu valley have also highlighted sediment in river channel as one of the causes [8, 23, 16]. To mitigate flood risk caused by sediment, river dredging must be done from the major rivers in the valley, which helps to lower the bed level of the river and increase the flow area within the river [24]. But we can see the sediment deposition and floodplain along the river channel in the Kathmandu valley. Why has the river not been dredged? Is there any policy restriction? Similarly, the sediment found in river in Kathmandu valley has high mica contents (10-32%) [25]. If so, what can be done to the river sediment? To answer these questions, we conducted this study.

II. METHODOLOGY

This study was mostly carried out through a desk-study approach. We examined the river section for visual evidence of sediment deposition (fig 1); however, our primary focus was on gathering information from a wide range of existing sources such as, peer-reviewed research papers, government reports, technical documents, and relevant articles. Our goal was to build a clear understanding of the topic using the best available published knowledge.

Fig. 1(a): Field photograph of the Bagmati River channel showing sediment deposition (outlined in red)

Fig. 1(b): Google Earth Pro image of the same location, with coordinates 27◦42′39.80′′N, 85◦22′1.61′′E, indicating the site of sediment deposition

In order to create the map, we must account for the regulation established by the Government of Nepal that declares the standard buffer distance along the river within which river-bed mining activities are prohibited. Since, there is no clear law established by the Government of Nepal regarding the river dredging process, we have adopted this regulation as our working standard for this study. The regulation governing this process is detailed below.

TABLE I
STANDARDS RELATED TO THE EXTRACTION, SALE AND MANAGEMENT OF STONE, GRAVEL AND SAND 2077 B.S. [26]

S.N.	Description	Standard Buffer Distance	
		Terai	Hill
1	From the right of way of Highway	500m	200m
2	From the river or stream bank	500m	200m
3	Educational institute, health institute and places of religious, cultural and archaeological importance and security body	1 km	500m
4	From concrete bridge	500m	500m
5	From international border	1 km	1 km
6	From parks and reserves	2 km	2 km
7	From the forest area	500m	500m
8	From densely populated areas	1 km	500m
9	From the pole of the high-tension line	100m	100m
10	From the historical lake, pond and reservoir	500m	500m
11	From wetlands	1 km	1 km
12	From the foot of the Chure hills	1500m	1500m

Among the above criteria we only considered criteria number 3 and 4 because those are the major criteria that may get affected by the river dredging process in densely populated region like Kathmandu valley. Also, we only mapped Bagmati river as it is the trunk river in the valley and all the other river of the valley eventually drains into it [27]. Similarly, other criteria mentioned in the standard were left out of this study because they make the work more cumbersome for desk study analysis.

To create the suitability map, we generated KML (Keyhole Markup Language) file of Bagmati river, from upstream near Sundarijal (27◦46′2″N, 85◦25′26″E) to downstream near Chovar Dry Port (27◦39′5″N, 85◦17′16″E), where both river banks were mapped. Similarly, we mapped concrete bridges over the river using the polyline feature in Google Earth Pro [28]. Likewise, we used polygon feature to outline the boundary of educational and health institutes, religious, cultural and archaeologically important places, and security bodies, that directly shares boundary with the river or with the river corridor road. Thereafter, we used ArcMap 10.8 software to convert it into layers and performed the analysis. We chose ArcMap 10.8 software due to its robust geoprocessing capabilities, structured geodatabase output, and compatibility with existing workflows [29]. We then downloaded Nepal's district map from NTNC geoportal [30] and exported Kathmandu valley districts map from it and plotted all the vector data in it. After the map was created with all data components, we created the buffer zone using the parameter addressed in the above table. We gave the color red to bridges buffer zone, yellow to religious place buffer zone and brown to the remaining institutes and places buffer zone. Some temples and institutes were not mapped because they lie in close proximity to the others and would have resulted in redundant overlapping of their buffer zone. Afterwards, we calculated the area of river channel that falls outside the buffer zone.

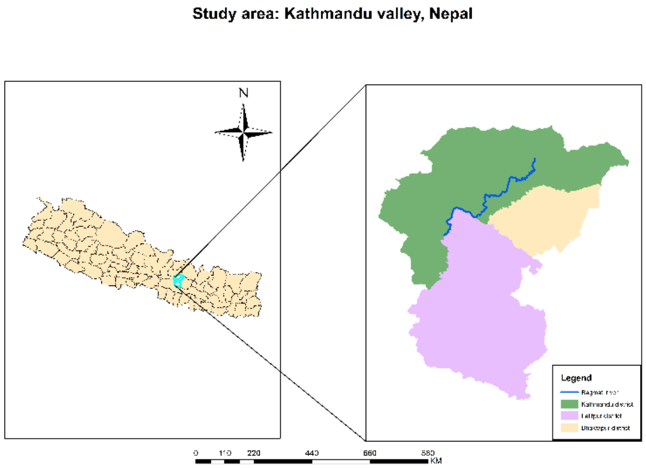

Fig. 2: Map of study area

III. RESULTS

A total of 30 concrete bridges over Bagmati river and 1 concrete bridge over Dhobikhola which is very close to the confluence of Bagmati river and Dhobikhola, were mapped. 9 river sections were identified, with cumulative area of 173,938m² located outside of restricted zone.

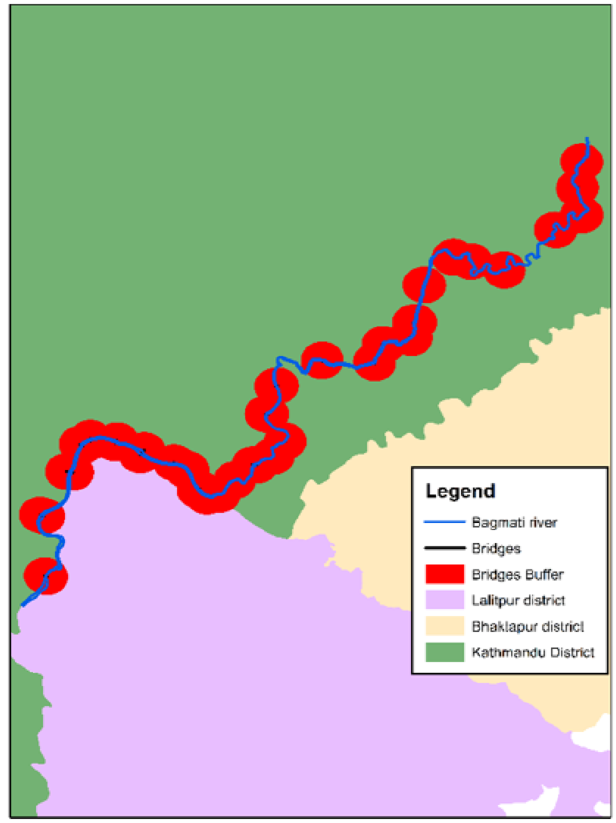

Fig. 3: Buffer zones of bridges over Bagmati river within Kathmandu valley

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Similarly, we found 11 religious places along the close proximity of Bagmati river. The map analysis of religious places revealed 8 river sections occurring outside of prohibited zone with the combined area of 498,459m².

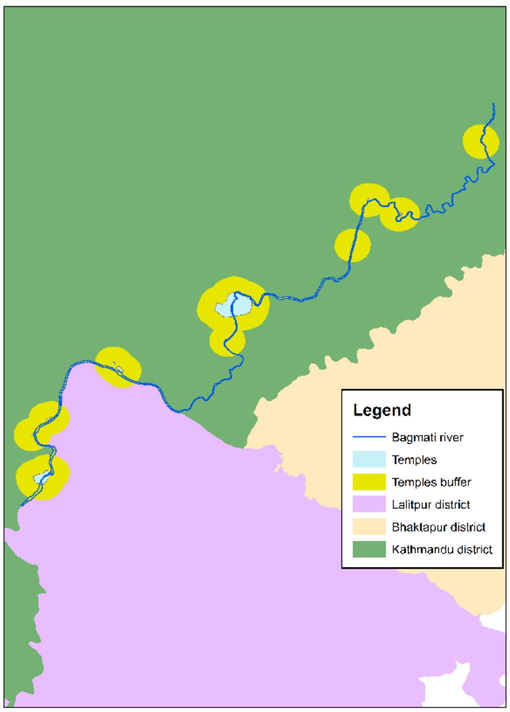

Fig. 4: Buffer zones of religious places along Bagmati river within Kathmandu valley

Also, we found 25 institutes (educational, health and security bodies) along the close proximity of Bagmati river. In the map of institutes buffer zone, 7 river sections were identified that are situated outside of restricted zone with joint area of 427,676m^2.

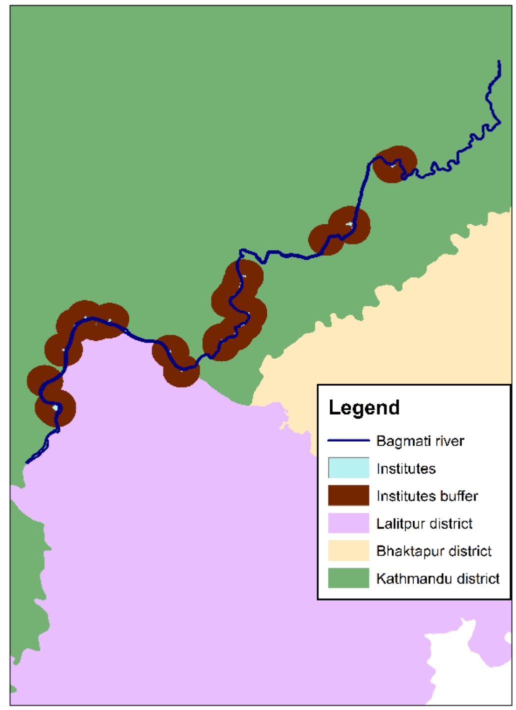

Fig. 5: Buffer zones of institutes along Bagmati river within Kathmandu valley

Hence, when all these maps are combined to form one in-order to visualize the river channel along with all buffer zones. It revealed 4 river sections outside of buffer zone with the total area of 50,332m^2.

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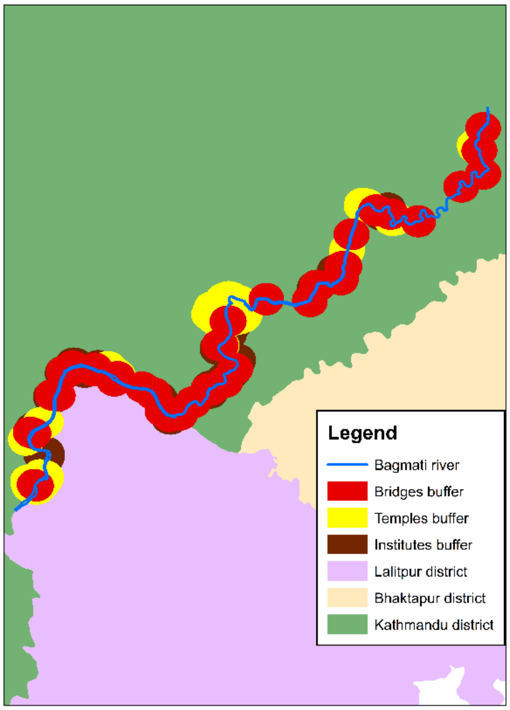

Fig. 6: Combined buffer zones

IV. Discussions And Conclusions

Therefore, the findings clearly highlight why sediment within the river channels of the Kathmandu Valley is often overlooked. Only four river sections, with a combined area of approximately 50,332m², were identified as suitable for extraction, but this much area is insufficient to control flooding and also support large-scale sand and gravel mining. Assuming an extraction depth of 1 m, the total recoverable sediment volume is estimated at approximately 50,332 m³. At the prevailing market rate of Rs. 318 per cubic meter, this corresponds to a potential economic value of NPR. 16,005,576. In the absence of effective utilization strategies, this value represents a significant capital that is effectively being wasted. This limitation exposes a significant gap in current policy. The application of uniform extraction regulations across Nepal does not adequately address the Valley's distinct terrain and hydrological conditions.

Furthermore, while the Standards Related to the Extraction, Sale, and Management of Stone, Gravel, and Sand (2077 B.S.) include a provision that permits dredging in cases of potential infrastructure failure or flooding, this clause is restricted to emergency situations, implying that action is only taken reactively, after damage has occurred. Consequently, there is a urgent need for a policy framework specifically designed for the Kathmandu Valley.

In addition to policy limitations, sediment quality presents another challenge. The high mica content in it [25] makes much of the material unsuitable for construction purposes [31, 32]. However, these sediments need not be disregarded entirely. They can be repurposed as fill material or processed with appropriate chemical treatments to produce usable aggregates [33, 34]. By processing mica-rich sediment into a usable form, the material can contribute to meeting the growing demand for construction aggregates while simultaneously providing local communities with an additional source of income. Moreover, systematic dredging of such sediment from river channels would also serve a dual purpose by reducing flood intensity, thereby enhancing regional flood management efforts.

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