Original Article *Journal of Sustainability and Environmental Management (JOSEM), Vol. 3, No. 4 (2024), 203 – 208*
p-ISSN 2822-1729, e-ISSN 2822-1737 Available online at https://www.nepjol.info/index.php/josem

Riverbed Materials Crusher Plant Site Evaluation along Daraudi River in Gorkha District using Geographical Information System

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Abstract: Selecting optimal locations for crusher plants is essential for promoting sustainable development and reducing environmental impact. This study applies Geographical Information Systems (GIS) to identify the restricted area for the location of a crusher plant along the Daraudi River in Nepal's Gorkha District. This analysis aligns with national regulations and environmental guidelines, as outlined in the Stone Aggregate Crusher Guidelines Revised 2079, by integrating multiple criteria such as transportation access, proximity to settlements, historical and cultural sites, educational institutions, and environmental factors. A final map incorporating all the factors was developed, showing that almost 56% of the study area is not eligible for the establishment and operation of the crusher plant. In addition to this, it is also found that all the existing six Stone Aggregate Crusher plants do not comply with the national rules and regulations that must be monitored. The results demonstrate that GIS supports sustainable decision-making and compliance with local regulatory frameworks, thereby contributing to the development of responsible infrastructure.

Keywords: *Buffer zones, GIS, Multi criteria, Maps, Spatial analysis*

Conflicts of interest: None
Supporting agencies: None

Received 15.10.2024; Revised 18.12.2024; Accepted 27.12.2024

Cite This Article: Kumal, P., Malla, P. & Rakhal, S. (2024). Riverbed Materials Crusher Plant Site Evaluation along Daraudi River in Gorkha District using Geographical Information System. *Journal of Sustainability and Environmental Management, 3*(4), 203-208.

1. Introduction

Mining has increasingly become integral to human development, with river mining standing out for its ease of extraction, processing, and transportation. In mountainous rivers, these extraction activities are expanding rapidly, fueled by the growth of engineering infrastructures, urbanisation, and industrialisation (Sharma et al., 2012). The extraction of riverbed materials, including sand, gravel, and boulders, has profound environmental and socioeconomic consequences. Environmentally, excessive mining from the river has led to significant riverbank erosion, altering the river's natural flow patterns and increasing the risk of flooding during monsoons (Kondolf, 2006). Moreover, continuous extraction reduces groundwater recharge, thereby lowering the water table and exacerbating water scarcity issues (Khanal, 2015). This depletion has already affected local farmers, who rely on the river for irrigation (Upreti, 2021). Habitat destruction is another pressing concern, as excessive mining disrupts aquatic ecosystems and threatens biodiversity.

On a socio-economic level, unsustainable mining practices have led to disputes between local communities and crusher plant operators, particularly where extraction sites encroach upon agricultural lands. Infrastructure, such as bridges and roads, faces increased vulnerability due to unstable riverbanks caused by unregulated extraction. Additionally, the unregulated operation of crusher plants raises health concerns due to dust pollution and noise, negatively impacting nearby settlements (Manzoor & Khan, 2020). A similar case is happening in different parts of Nepal. Following the 2015 earthquake, the Gorkha District in Gandaki Province, Nepal, has seen rapid urbanisation and infrastructure development. With the increasing demand for construction materials such as sand, gravel, and boulders, riverbed extraction from water bodies like the Daraudi and Marsyangdi is rising at an alarming rate.

The Crusher plants in Gorkha are typically located near riverbanks to extract, process, and crush riverbed materials

for construction purposes. These plants are strategically located close to major rivers, such as the Daraudi and Marsyangdi, to minimise transportation costs and facilitate easy access to raw materials. A typical crusher plant processes material like sand, gravel, and crushed stone, which are used for building roads, bridges, and other civil engineering projects. Crusher plants are essential for producing these materials; however, their location has a significant impact on the environment, economy, and local communities. Improper site selection can lead to environmental degradation, increased transportation costs, and regulatory violations. Thus, selecting an optimal location for a crusher plant is vital.

Geographic Information Systems (GIS) play an essential role in monitoring and managing the extraction of riverbed materials. GIS technology is used to map the rivers, their changing flow patterns, and the impact of human activities, including material extraction and crusher plant operations. GIS tools facilitate mapping the locations of crusher plants and monitoring their proximity to sensitive areas, such as protected forests and residential zones. Planning sustainable extraction zones that balance development needs with environmental conservation can be done using GIS. Incorporating GIS in the management of riverbed material extraction ensures a data-driven approach, promoting both economic growth and environmental sustainability (Pokhrel et al., 2025).

In the context of Nepal, this is especially relevant as the Environmental Protection Act (2019) mandates that industrial developments meet stringent environmental standards. Additionally, the Local Government Operation Act 2017 (Government of Nepal, 2017) empowers local governments to regulate land use and industrial siting, reinforcing the need for systematic decision-making in siting crusher plants. Similarly, the newspaper has also highlighted the environmental impacts and issues resulting from the excessive and haphazard extraction of the river bed in this River. Farmers in Gorkha Municipality are facing challenges in irrigating their farmlands because the water level in the Daraudi River has been declining over the years, primarily due to the over-extraction of riverbed materials (Upreti, 2021).

This paper examines how GIS can facilitate the optimal placement of crusher plants along the Daraudi River in Gorkha District by incorporating national regulations and environmental guidelines into the site selection process.

2. Literature Review

Geographic Information Systems (GIS) have been widely used in industrial facility site selection, including for crusher plants, due to their ability to integrate various spatial datasets for informed decision-making. According to (Malczewski, 2006), GIS-based Multi-Criteria Decision Analysis (MCDA) is a popular approach for selecting optimal locations by evaluating environmental, social, and economic criteria simultaneously. Similar methodologies have been employed in other contexts, such as the selection of solid waste disposal sites (Şener et al., 2011). In Nepal, the Environmental Protection Act 2019 mandates environmental sustainability in industrial development, ensuring that facilities are located away from sensitive environmental areas.

The Local Government Operation Act 2017 also plays a vital role by delegating authority to local municipalities to oversee industrial zoning and land use regulations. More specifically, Nepal's Stone Aggregate Crusher Guidelines 2077 and 2079 (Government of Nepal, n.d.) outline specific criteria for crusher plant locations near riverbeds to minimise adverse environmental impacts. Similarly, Kondolf (2006) emphasised the importance of regulations, noting that poorly placed plants contribute to habitat destruction, water quality degradation, and increased flood risk in river systems.

(Khanal, 2015) states that river mining, particularly for construction aggregates like sand, gravel, cobbles, and boulders, has been extensively practised due to its ease of extraction and transportation. However, indiscriminate mining in river systems, such as in Malekhu Khola, Central Nepal, has led to significant environmental degradation. Malekhu Khola, rich in gravelly sediments, has been heavily mined for several years, particularly upstream from Malekhu Bazar. The mining activities, combined with disorganized extraction practices, have severely impacted the river's physical health and morphology.

The study reveals that the stone crushing and quarrying operations in the area have a significant adverse impact on natural vegetation, soil, agriculture, water bodies, aquatic life, workers, and nearby local residents. The management of these units must take measures to reduce pollution or mitigate its impact on the environment and public health (Manzoor & Khan, 2020).

Nepal has several legal provisions governing crusher plant operations and riverbed material extraction:

1. Environmental Protection Act 2019: This Act mandates that industrial activities, including stone crushing, undergo environmental assessments to minimise ecological damage (Government of Nepal, 2019).
2. Local Government Operation Act 2017: Grants local governments authority over land use and industrial zoning, reinforcing the need for systematic decision-making in site selection (Government of Nepal, 2017).
3. Stone Aggregate Crusher Guidelines Revised 2079: Specifies buffer zones for crusher plant placement, such as a minimum 500m distance from settlements and schools and 200m from riverbanks (Government of Nepal, 2079). However, the scientific basis for these distances remains unclear, warranting further investigation.

Despite these regulations, weak monitoring and corruption have led to widespread non-compliance, resulting in environmental degradation.

Significance of the Study

The study addresses problems, including ecological damage and socioeconomic difficulties brought on by uncontrolled riverbed material exploitation, by integrating environmental, economic, and regulatory factors.

Furthermore, the study emphasises the importance of strict adherence to environmental standards by following key national regulations and acts, such as the Environmental Protection Act (2019) and the Stone Aggregate Crusher Guidelines (Revised 2079). It emphasises how important it is to manage the growing demand for building materials while minimising adverse effects on ecosystems, communities, and natural resources. Applying multi-criteria decision analysis based on GIS provides an organised, data-driven approach to well-informed site selection. This strategy strikes a compromise between environmental preservation and development objectives, providing a scalable framework for comparable issues in Nepal and other areas. The research promotes responsible industrial growth, long-term sustainability, and regulatory compliance by offering practical insights for engineers, legislators, stakeholders and environmental safeguard manager.

Objectives of the Study

- To identify a restricted area for the crusher plant location in Gorkha District along the Daraudi River using GIS, in accordance with Nepal's environmental regulations.
- To evaluate existing crusher plant sites for compliance with the Stone Aggregates Crusher Guidelines Revised 2079 to support sustainable development.

3. Methodology

3.1 Study Area

The study area is along the Daraudi River in Gorkha District, with the river's coordinates from Abukhaireni (27°54'18.35"N, 84°32'22"E) to Rangrung (28°11'22.78"N, 84°43'2.19"E). The Daraudi River flows through different municipalities and rural municipalities (Gorkha, Palungtar, Siranchowk, Ajirkot and Barpark Sulkot). The River is rich in riverbed materials, and every year, these materials are extracted for various purposes. Not only this, but different infrastructures, such as hydropower, Drinking Water Supply, and Irrigation Canal Intake, are constructed along this river. Additionally, several existing crusher plants have been established in the study area for road construction and others for commercial purposes.

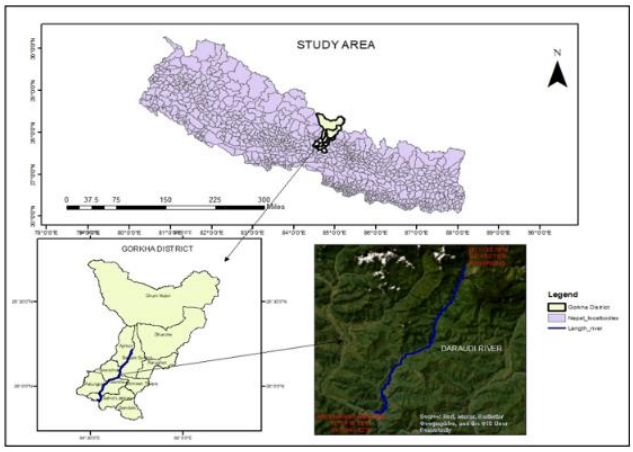

Figure 1: Map showing the study area

3.2 Data collection

This study depends on both primary and secondary data. The primary data include the field survey, while the secondary data comprise satellite images, information from the respective authorities, and a literature review. Field surveys identified six crusher plants along the Daraudi River, from Abukhaireni to Rangrung. Additional data were gathered from Google Earth to confirm that no international airports, conservation areas, historical ponds, or wetlands lie within the district's vicinity. The Chure belt does not pass through the study area. The different sources of the data collection are shown in the table below:

Table 1: Data Collection

S.N.	Description	Data Size	Source
1	Digital Elevation Model (DEM)	12.5m x 12.5m	Alos Paslar
2	Land Use Land Cover (LULC)	10m x 10m	Esri Sentinel-2
3	Nepal/ Districts Shape	N/A	National Geoportals
4	Highway	National Highway	DOR: SSRN (Strategic Road Network)
5	Different Infrastructures Along Daraudi River	N/A	Google Earth, Field Visits
6	Chure Belt	N/A	DOI: 10.1155/2018/1383482
7	Existing Crusher Plants Location	N/A	Field Visits

Altogether, it is found that there are more than 20 bridges (Reinforced Cement Concrete (RCC) and Suspended bridges) along the river. Similarly, certain sections of two National Highways: Gorkha Abhukhaireni Highway (NH44) and Mid Hill Highway (NH03) falls in the study

area. It is found out that the Initial Environmental Examination (IEE) has been done and the extraction sites have been identified every year through the municipality.

The X & Y co-ordinates of the existing crusher plants are:

	Location of Crusher Plants	
Crusher	X-Co-ordinates	Y-Co-ordinates
C-1	84.7103	28.1884
C-2	84.6963	28.122
C-3	84.57	27.9986
C-4	84.56	28.006
C-5	84.577	28.01
C-6	84.64	28.064

3.3 GIS Mapping:

GIS spatial analysis was performed to integrate various layers and create buffer zones. The Stone Aggregate Crusher Guidelines Revised 2079 specify distance criteria for establishing crusher plants in hilly regions, as shown below.

Table 2: Stone Aggregate Crusher Guidelines Revised 2079 Distance Criteria for Crusher Plant Site Selection

S.N.	Description/Criteria	Distance
1	Highway Right of Way	200 m
2	Khola or River Bank	200 m
3	School or Educational Institution, Hospital & Health Post, Cultural & Historical Places, Police Posts	500 m
4	Permanent Bridge	500 m
5	International Airports	1 Km
6	National Park and Conservation Area	2 Kms
7	Forest	500 m
8	Dense Settlement	500 m
9	High Tension Transmission Line	100 m
10	Historical Ponds,	500 m
11	Wetlands	1 Kms
12	Chure Belt	1000 m

The research area is located along the Daraudi River, extending 2 km on either side as a buffer zone. The Research area is about 187 km². Buffer zones were created on GIS maps based on the aforementioned distance criteria, identifying areas that comply with environmental guidelines. These buffer zones are created as the restriction area for the stone aggregate crusher plant location, as per the guidelines.

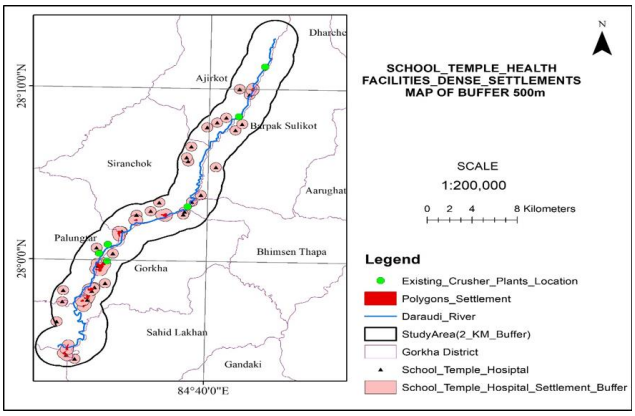

Figure 2: Location of the school, temple, hospitals and dense settlements in the study area. The 500m buffer zone, as per the guidelines, is indicated on the map. This buffer zone is the restriction zone for the Stone Aggregate Crusher plant establishment.

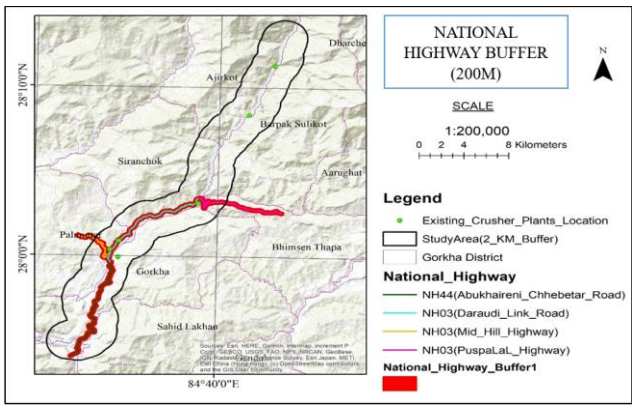

Figure 3: National Highway in the Study area and its buffer zone of 200m.

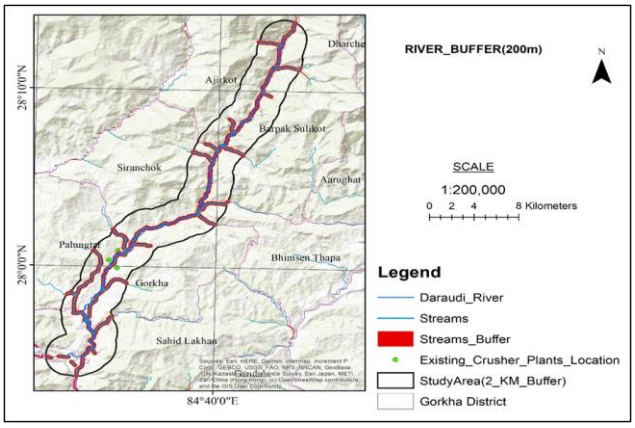

Figure 4: Stream Features in the study area was obtained

using the DEM. The buffer zone of 200m is shown in the map.

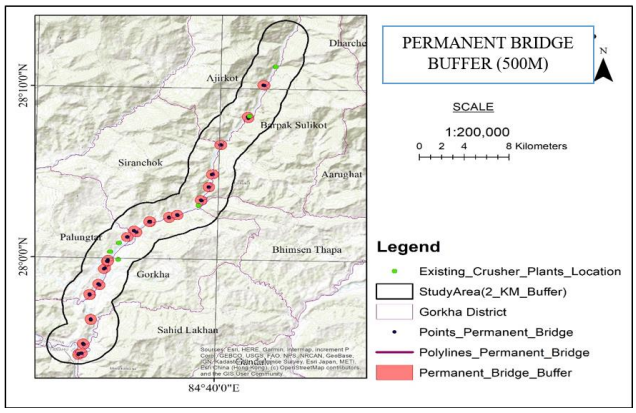

Figure 5: In total 22 number of permanent bridges was located from the field survey and google earth observations. The buffer zone of 500m around the permanent bridges are created.

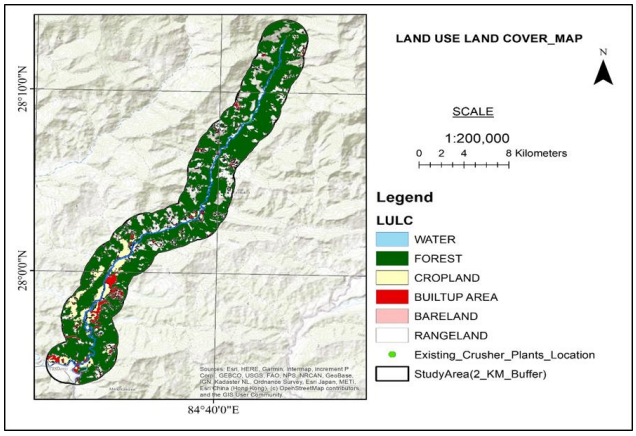

Figure 6: Around 70% of the land in the study area is covered with the forest.

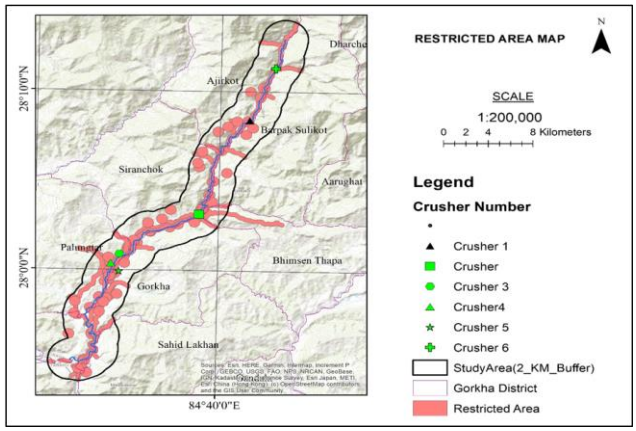

Figure 7: A final map showing the restriction area to establish the Stone Aggregate Crusher Plants in the study area incorporating all the factors mentioned above. Almost 56% of the study area is not eligible for locating the crushing plants. A total 6 number of the existing crusher plants does not comply with the guidelines.

4. Results and discussion

The Buffer line is shown in Figure 7, and these buffer zones are the restricted areas for the establishment of stone aggregate crusher plants. GIS analysis revealed that the current locations of the crusher plants do not fully comply with regulations. Plants should be sited to meet Nepal's Environmental Protection Act (2019), which restricts industrial sites in environmentally sensitive areas, and the Local Government Operation Act (2017), which empowers municipalities to enforce zoning laws. By considering these laws alongside the Stone Aggregate Crusher Guidelines Revised 2079, GIS offers a spatial approach that promotes economic efficiency and environmental sustainability. The final site selection prioritises access to materials and transportation routes, reducing operational costs and minimising environmental impact. One hundred per cent of crusher plants in the study area do not comply with regulatory buffer zones. The total restricted area identified through GIS analysis encompasses 56% (105 km²) of the potential mining zone, thereby limiting the sustainable extraction sites. In Malekhu Khola, Central Nepal, excessive mining led to severe erosion and altered sediment transport (Khanal, 2015). Unlike Malekhu, Gorkha's crusher plants are less clustered but still impact local hydrology.

5. Conclusion

This study highlights the effectiveness of GIS in optimising crusher plant locations by incorporating environmental, economic, and regulatory factors. The GIS-based site selection approach offers a data-driven and compliant framework that promotes sustainable industrial development while minimising environmental and social disruptions. Moreover, this methodology is flexible and scalable, making it applicable to other regions and supporting a more sustainable approach to resource extraction in Nepal.

Although GIS is a powerful preliminary tool for site selection, comprehensive environmental impact assessments should be conducted before finalising crusher plant locations. Engaging local communities in the selection process can enhance social acceptance and promote harmony. Once established, crusher plants should be subjected to ongoing environmental and social impact monitoring to ensure long-term sustainability. To improve regulatory enforcement, real-time GIS monitoring of crusher plants should be implemented to enable swift detection of non-compliance. The determination of buffer zones should be guided by scientific research to support evidence-based policy modifications. Active community participation in the decision-making process can further enhance compliance and acceptance. Additionally, regular environmental impact assessments (EIAs) should be mandated to evaluate the long-term effects of crusher plants on both the environment and local communities. Integrating GIS into regulatory frameworks will also enhance automated detection of non-compliant sites, strengthening oversight and enforcement mechanisms.

This study highlights the significance of GIS-based decision-making in selecting crusher plant sites, ensuring regulatory compliance while minimising environmental and socio-economic impacts. Future research should focus on hydrological modelling and ecological assessments to develop more sustainable extraction strategies in Nepal.

Acknowledgements

The authors express their sincere gratitude to the Campus, friends and family for their invaluable support and provision of essential resources throughout the study.

Conflict of Interest

The authors declare that there are no conflicts of interest associated with this research. Additionally, this project did not receive any funding from any organisation, and no external entity was involved in the study's design, data collection, analysis, or preparation of the manuscript.

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