Delineation of Potential Sites for Gemstone Mining in Kuru Ganga Catchment, Ratnapura: A GIS Approach

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Abstract: Sri Lanka has been known as 'Ratnadeepa', which translates to 'Island of gems' because of the precious natural gemstones found in its gravelly soil. Even though the gem industry in Sri Lanka extends back to ancient times, studies on patterns of gemstone occurrences were rare. However, identification of potential gem bearing lands can provide guidelines in mining and land valuation. This study was carried out to identify the potential lands for gemstone mining in Kuru Ganga catchment, Ratnapura, based on patterns of gemstone occurrences and mining cost using integrated geo-spatial technologies. Fieldwork was conducted to collect gravel samples from riverbanks and gem mines. The samples were subjected to microscopic analysis to trace potential gemstones. The results obtained were combined with the data gathered from gem mines and mapped on a GIS platform to identify the occurrence patterns. Mining cost at each sampling location was estimated based on depth to the gem bearing gravel layer, *"illama"*. Subsequently, potential lands for feasible gemstone mining were delineated through a knowledge-driven weighted analysis. The results depict that the South Western region of the Kuru Ganga catchment encompasses the highest feasibility of gem mining while North Eastern region of the catchment has the least feasibility of gemstone mining based on mining cost and values of potential gem varieties in the area.

Key words:GIS, gemstones, patterns of gem occurrences, gem mining, binary land use

1. Introduction

Sri Lanka is well known for precious gemstones, and gemstone mining has been practiced over centuries.However, studies on gemstone mining and occurrence patterns are limited.

Most of the Sri Lankan gem mines today adhere to conventional gem mining practices rather than a proper or systematic procedure. For instance, a possible location for a gem mine is generally chosen based on experience.

The primary objective of this research is to delineate the potential sites for gemstone mining, based on occurrence patterns and mining cost. The main objective is supported with the following secondary objectives:developing a GIS database of gem

mines in Kuru Ganga catchment area of Ratnapuradistrict and identifying the factors affecting feasibility of gemstone mining in Kuru Ganga catchment.

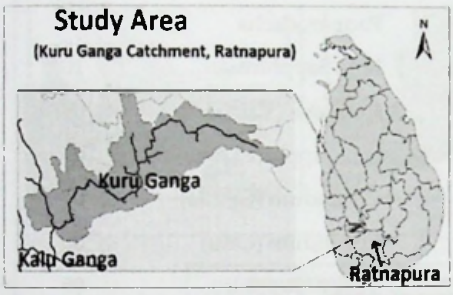

Figure 1: Study area, Kuru Ganga catchment, Ratnapura.

2.Study Area

Sri Lanka has been traditionally divided into three major geological zones namely, Highland Complex, Vijayan Complex and Wanni Complex (Kroner et al., 1991).The potential gemstone deposits in the island are mainly confined to a narrow zone within the Highland Complex. Common rock types found in this zone are charnokite and charnokitic gneisses, marble, quartzite and khondalite (Dharmaratne, 2005).The Southern part of Highland complex, the region where most of gemstones are found, encompasses of three main rock types, namely; metasedimentary rocks, charnokitic gneisses and magmatic rocks (Dharmaratne, 2005).

The main gemstone mining area in the country, Ratnapura, is located in the Southern part of the Highland Complex(Herath, 1984).Ratnapura belongs to Sabaragamuwa Province of Sri Lanka and covers approximately 3289 km^2 of land area. Ratnapura district extends from Northern latitudes 80^{0}13'02'' to 80^{0}58'27'' and Southern longitudes 6^{0}55'04'' to 6^{0}13'12''. Kalu Ganga is the major river which traverses over this region.

One of the sub catchments of Kalu Ganga, Kuru Ganga catchment was selected as the study area for this research (Fig. 1).

3.Methodology

The Kuru Ganga catchment was delineated by using tributaries and contour data obtained from the available 1:50,000 topographic maps prepared by the Survey Department of Sri Lanka. GIS techniques were employed for catchment delineation.

Throughout the field survey, primary data on gem mining activities in the study area such as, depth to the gem bearing gravel layer (*illama*) and data on gem varieties found in the past from gem pits were collected through interviews with local villagers, gem-miners, and government officials. Gravel samples were collected through systematic test pits in the catchment area of Kuru Ganga and at available gemstone pits in the study area. Approximately, 1 kg gravel sample was collected at each location.

Samples were washed and subsequently oven dried at 150^{0}C for 24 hours. The dried samples were washed again with diluted HCl to remove mud stains adhered to gravel particles. Thereafter, samples were washed with clean water and oven dried at 150 ^{0}C for 24 hours to remove the moisture. Subsequently, sample weight was reduced down to 5g for the microscopic observation using a sample splitter. Different ranges of particle sizes were observed under microscope (Axio Scope.A1) using reflected light, and it was found that 75-250µm is the best particle size range for observations using microscope. Gemstones were identified based on colour and the crystal shape under microscope.

Information gathered through microscopic analysis and the field data collected were considered as raw data in this study and tabulated on a GIS platform. Appropriate ranks were assigned for these gem varieties found in the study area based on their market values (Table1). Average market values of gem varieties were obtained from the National Gem and Jewellery Authority, Ratnapura Division, Sri Lanka. The weight fraction of potential gem varieties at each sampling location was computed using equation 1.

$$\left(\frac{V_i}{R}\right) x\ 60 = W_{GV} \quad \ldots\ldots\ldots (1)$$

where,

W_{GV}= Weighted value of potential gemstones found at ith location.

R= Total of the rank values of potential gemstones found in the study area

V_i = Total of the rank values of gemstones found in ithlocation

Table 6: Rank values assigned for the gem varieties found in Kuru Ganga catchment, Ratnapura based on their market values.

Gemstone Varity	Rank
Ruby	11
Padparadscha	11
Blue Sapphire	10
Cat's eye (Vairodi)	09
Star Sapphire (Arunul)	08
Corundum (Geuda)	07
Corundum (Ottu)	06
Yellow Sapphire (Pushparaga)	05
Corundum (Malukkam)	04
Aquamarine (PachchaPadiyan)	03
Spinel (Kirinchi)	02
Garnet	01

Subsequently, a map depicting the weighted values of the potential gemstones in Kuru Ganga catchmentwasinterpolated using GIS techniques (Fig. 2a).

In estimating the mining cost, following assumptions were made in this study. The land value was considered as constant within the Kuru Ganga catchment. The project duration for a particular gem mine was assumed as 30 days with six mine workers each. The cost

calculation was made for simple surface placer mining and pit-head and tunnel mining methods without cross-cuts. Cost of mining at each location was estimated based on depth to "*illama*", land value, type ofthemine and the duration of the project by considering the costs involved in gem mining such as, dewatering, labour cost and cost for timber supports. Afterwards, lower weights were assigned to the locations with high mining costs (i.e. low feasibility of mining) and vice versa. Accordingly, a map depicting the estimated mining cost in Kuru Ganga catchment wasdeveloped by interpolating the weighted values on a GIS platform (Fig. 2b).

After evaluating the Kuru Ganga catchment area based on the market value of potential gem varieties and gemstone mining cost, the restricted land use/land cover classes for gem mining were demarcated based on the circulars of Gem and Jewellery Authority of Sri Lanka. Accordingly, a binary land use map was developed where zero pixel values '0' represent the restricted areas and pixels with value '1' represent the minable areas (Figure. 2c).

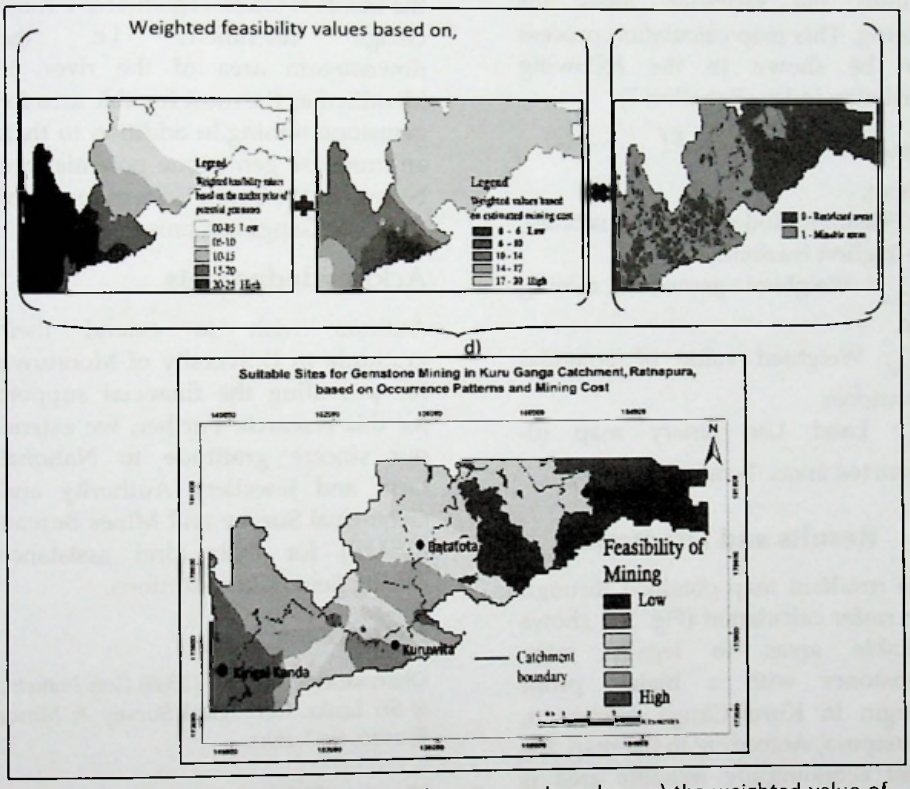

Figure 2: Evaluation of Kuru Ganga Catchment area based on, a) the weighted value of the potential gemstones, b) gemstone mining cost c) capability for mining and d) feasibility of gemstone mining

The layers depicting weights assigned for the values of potential gem varieties and estimated mining cost in the study area vary within the ranges of 0-25 and 0-20 respectively. Thus, the summation of these two layers provides a combined value range of 0-45 in the resultant layer. The combined weighted map was multiplied by the binary map depicting minable and restricted areas to mask (i.e. to assign null values) the restricted areas for mining. This map calculation process can be shown in the following feasibility index (Equation 2).

$$(W_{GLC} + W_{GV}) x B_{LU} = FI \quad \ldots\ldots (2)$$

where,

FI: Feasibility Index(0-least feasibility, 10- highest feasibility)

W_{GLC}: Weighted gemstone mining cost

W_{GV}: Weighted value of potential gemstones

B_{LU}: Land Use binary map (0- restricted areas, 1- minable areas)

4. Results and Discussion

The resultant map obtained through the raster calculation (Fig. 3d) shows suitable areas to legally mine gemstones with a higher profit margin in Kuru Ganga catchment, Ratnapura. According to the map, the most economically minable area is located in the South Western region of the catchment. The reasons being the abundance of gem varieties found in this particular region and the low mining cost they incur.

The methodology adopted in this study can be extended to other gem mining areas with appropriate number of sample locations. The accuracy of the results can be further improved by employing geophysical, geotechnical and geochemical studies. Usage of highly accurate sample separation method such as heavy media separation (HMS) can also used to improve the accuracy of the results.

5. Conclusion

According to the results of this study, the South Western region of the Kuru Ganga catchment, i.e. the downstream area of the river, is identified as the most feasible area for gemstone mining.In addition to that, an immense gem stone potential can be seen in the South Eastern region of the Kuru Ganga catchment.

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