Prospection of Potential Iron Deposit in Gandaki and Lumbini Province of Nepal Using Remote Sensing Technology

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KEYWORDS

Analytic Hierarchy Process (AHP), Suitability Analysis, Iron Deposit, Multi-Criteria Decision Analysis, Landsat-8, Principal Component Analysis (PCA), Remote Sensing (RS)

ABSTRACT

Integrated remote sensing and Geographic Information System provides an aid to find presence of metallic and non-metallic minerals. This approach was used to explore Iron deposits in districts of Gandaki and Lumbini province of Nepal in which 8 districts were identified as the reserves of iron ores namely Nawalpur, Palpa, Baglung, Parbat, Syangja, Tanahu, Arghakhanchi and Gulmi. These districts fall under various geological formation such as Suntar formation, Melpani formation. These formations are found to be rich in metallic minerals. Remote Sensing (RS) and Geographic Information Systems (GIS) offers a cost effective and attractive strategy in mineral prospection, notably for a mineral exploration project. Landsat 8 satellite images, processed through band rationing method highlights the hydrothermal alterations and Iron Oxide containing region. False Color Composite and Principal Component Analysis method highlights sedimentary rocks. Each method exaggerates spectral signatures which highlights the surfaces by different colors indicating presence of iron ores. Lineaments are also extracted from Landsat images combining with Digital Elevation Model (DEM). Lineaments are those structures that provide information about fault and fractures on the surface and helps to identify mineral deposition zones. The result produced through different RS techniques were introduced in GIS environment. Potential iron content region were identified by using Suitability analysis i.e. multi criteria decision analysis (MCDA). Map showing the potential iron ore deposit map was generated by integrating the results together reclassified into a common scale and overlaid with suitable weightage. Final output/map indicates the best possible sites for detailed study of iron ores. The study demonstrates the usefulness and effectiveness of remote sensing and GIS in iron and other mineral mapping.

1.INTRODUCTION

Hematite (Fe2O3), is the most abundant and important ore of iron. Among economic potential for 63 mineral commodities, different preliminary studies have hinted towards the presence of Iron ores and old mining sites by Department of mines and Geology of Nepal (Sah & Paudyal, 2019). Iron ores have been reported from several parts of Nepal including Lalitpur, Ramechhap, Tanahun,

Chitwan, Nawalparasi, Parbat, Baglung, Bitadi, Dahabagar, Bajhang districts (Paudel, 2019). Iron mineralization in Pokhari area of Hupsekot Rural Municipality-5, Nawalpur district was preliminarily studied by Deparment of Mines and Geology Nepal and hematite mineralization zone was traced under. The genesis of iron ore deposit of Dhauwadi-Pokhari is of sedimentary metamorphosed hematite magnetite type as the other important iron deposits of Nepal.

Nepal lies in the center of the 2,500 km Himalayan belt, which has favorable geography for various minerals. It has a very diverse and unique geography divided into five major morphogenetic zones; the Indo-gangetic plain, Siwaliks, Lesser Himalaya, Higher Himalaya and the Tethys Himalaya from south to north. Chronology of the Mio-Pliocene fluvial sediments of the Siwalik Group from southern Asia are seen to be a reserve for magnetic minerals. The Lesser Himalaya is made up mostly of the unfossiliferous sedimentary and metasedimentary rocks like slate, phyllite, schist, quartzite, limestone and dolomite ranging in the age of the Precambrian to the Oligocene (Devkota & Paudel, 2012).

Remote sensing technology is used in various aspects like Earth sciences, geography, archeology and environmental sciences where high spectral resolution remote sensing have developed spatial emphasis for mineralogical mapping. Landsat data have been used by many authors and researcher to locate and map the areas of hydrous minerals including iron ores. GIS (Geographic Information System) is being used to integrate several digital data such as geographical, geochemical, geological, topographical as well as remote sensing data for different studies and research (Partington, 2010). There have been a number of studies on the suitability analysis carried out using the GIS-based multi-criteria evaluation (MCE) procedures (Akinci, YavuzÖzalp, & BülentTurgut, 2013), (Chandio & Matori, 2011). The MCDA allows for the assessment of the individual contribution in knowledge driven approach with respect to the criterion. Relative weightings are assigned to the different evidential themes during knowledge-driven approach of potential mineral mapping using subjective approach and expert's opinion (Takyi & Jnr, 2018).

Landsat imagery has been intensively used for identification and prospection of minerals over the world. The Landsat images records the reflected energy in different absorption bands from the earth surface. Minerals either absorbs or reflect energy depending on their physical and chemical properties throughout electro-magnetic spectrum. The iron oxides minerals absorbs energy in between 0.45µm to 0.85µm, whereas hydrous minerals are characterized to absorb in 2.2 µm and reflects near 1.6µm (Hunt, April 1977). Different rationing techniques enhance spectral signatures and represents with different color based on used spectral bands and color composites.

2.STUDY AREA

Nepal is located in South Asia sharing boundary with China in the north and India in the south, Nepal is located in South Asia sharing boundary with China in the north and India in the south, east and west. The study area of the project includes 6 districts from Lumbini province and 5 districts from Gandaki province making a total of 11 districts of Nepal as our study area (Figure 1). The study area lies in latitude from 27° 51' 10.46" to 28° 30' 41.14" and longitude from 83° 6' 17.16" to 83° 18' 50.01". Among five morphogenetic zones of the Nepal from south to north, the study area comprises the Indo-gangetic plain, Siwaliks and lesser Himalayas. Iron ores (mainly hematite) have been reported from several locations of Lumbini province and Gandaki province including Labdi Khola (Tanahun), Dhauwadi - Pokhari (Nawalparasi), Falamkhani/ Dhuwakot (Parbat), Bhedikhor and Lukarban (Baglung) all lies within our study area. Among the well-known iron ore deposits, Dhoubadi-Pokhari mineralization of Nawalpur district lies in the study area.

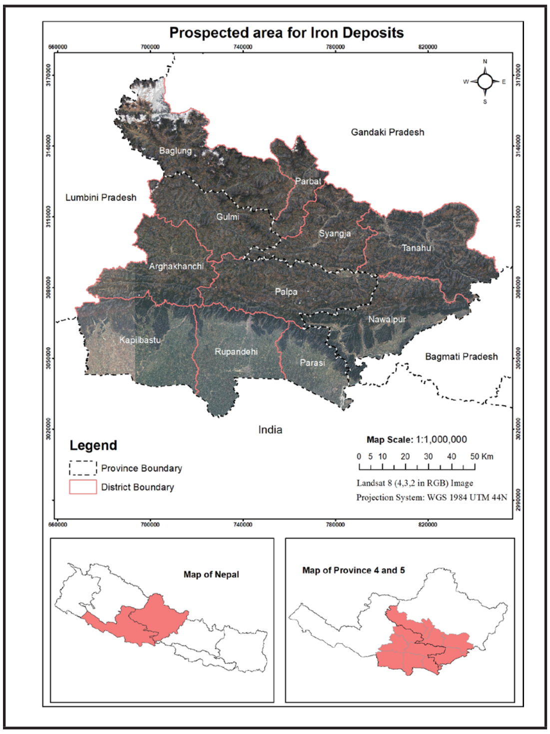

Figure 1: Study Area for prospection of potential iron ore deposits

3. MATERIALS AND METHOD

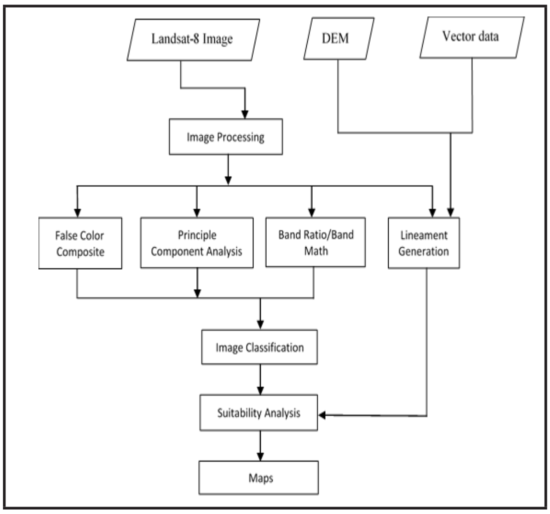

Figure 2: Methodological Flowchart of Prospection of Iron Ores

The Work flow can be divided into five steps; Data Analysis Data Processing, Classification of data, Suitability Analysis and Results and Map Generation. The Figure 2 shows the overall process workflow of this study.

3.1 Data Analysis

This study was performed using an integrated approach combining various raster and vector data sets. Table 1 below comprises the name of individual band name, wavelength and resolution contained by Landsat 8 TIRS/OLI image and were collected from USGS website (https://earthexplorer.usgs.gov/). Other relevant data such as topographic data, maps were collected from various data sources. The datasets were based on different datum and projection system in different data type format. These datasets from various sources were processed, cleaned, transformed to UTM projection system and adjusted according to the requirement of project.

Table 1: Landsat 8 Bands with corresponding wavelength and resolution.

Bands	Wavelength (μm)	Resolution (meters)
Band 1 - Coastal aerosol	0.43-0.45	30
Band 2 - Blue	0.45-0.51	30
Band 3 - Green	0.53-0.59	30
Band 4 - Red	0.64-0.67	30
Band 5 - Near Infrared (NIR)	0.85-0.88	30
Band 6 - SWIR 1	1.57-1.65	30
Band 7 - SWIR 2	2.11-2.29	30
Band 8 - Panchromatic	0.50-0.68	15
Band 9 - Cirrus	1.36-1.38	30
Band 10 - (TIRS) 1	10.6-11.19	100

3.1.1 Spectral Reflectance Curve

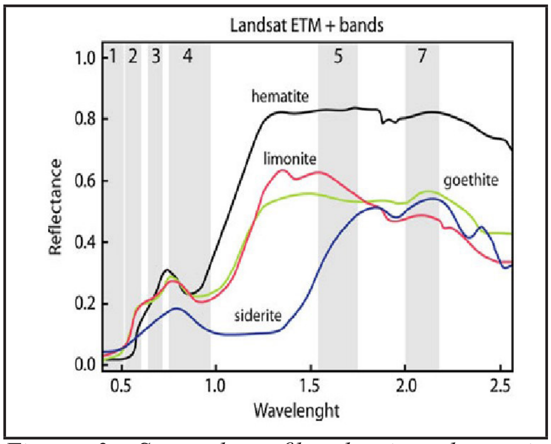

Figure 3: Spectral profile showing the main absorption features of some iron minerals (hematite, limonite, goethite, and siderite (spectra from USGS spectral library).

Different type of mineral shows different spectral anomalies with change in wavelength on spectral reflectance curve. Iron ores shows change in reflectance at different range of wavelength as represented in Figure 3. These changes are usually seen due to absorption or reflection of energy. Landsat-8 records these anomalies caused due to absorption that lies within the spectral range of 0.45µm to 0.85µm by Band 2, 3, 4, 5 and at wavelength 2.2µm by Band 7. Band 6 records the anomalies near wavelength of 1.6µm caused due to reflection of energy. Remote sensing techniques are used incorporating these bands to generate different color ratio composites which further enhance the spectral anomalies and represent potential iron ores by different colors.

3.2 Data Processing

The methodologies used in the study are based on using Landsat 8 images. False color Composite (FCC) is a method for clarifying the lithological discrimination, regional lineaments and structural pattern. Principal Component Analysis (PCAs) to produce uncorrelated output bands, segregate, noise components and to reduce the dimensionality of data sets in the way of showing iron ore concentrations. Band ratio methods have been used for exploring the iron ore rich localities separating them from the host rocks and creating an iron index map (Crosta & Filho, 2003), (Kargi, 2007), (Massironi, et al., 2008) (Amer & Kusky, 2010), (Hashim, Pournamdary, & Pour, 2011). Each method exaggerates spectral anomalies occurred due to presence of iron content on surface. These anomalies are represented by various colors such as dull pale yellow, greenish brown, red according to method applied to image.

3.2.1 False Color Composite (FCC)

The FCC on the Landsat 8 bands (7, 5, and 3) as red, green and blue color respectively of the study area highlighted the geological and lineament features and provided lithological discrimination between basement and sedimentary rocks. From FCC, sedimentary rocks containing iron composition appears as dull pale yellow and greenish brown color pixels (Salem & Gammal, 2015).

3.2.2 Principle Component Analysis (PCA)

Applying of PC2 and PC3 on Landsat 8 image shows a wide range of color reflecting the iron ore distribution and concentrations at the different sedimentary physiographic features. From PC3, the maximum iron concentrations of the study area appeared as yellow and the minimum iron concentrations are of deep brown color pixels (Salem & Gammal, 2015).

3.2.3 Band Ratio Image

The use of band ratios (4/2, 5/7, 5/4) and (4/2, 5/7, 4/5) of Landsat 8 OLI/TIRS as red, green, blue, respectively highlights the distribution and concentrations of the iron ore in the study area by red and pale red color pixels (Salem & Gammal, 2015).

FCC image of RGB= (5*6)/7, (4*6)/ (5*2), (5*6)/

(7*2) as red, green and blue color respectively shows hydrothermally altered rocks as black spots. FCC image of RGB=2, 6-7, 5-6 as red, green and blue respectively shows hydrothermally altered rocks as blue color pixels (Safaria, Pourb, & Hashim, 2017).

3.2.4 Lineaments

Lineaments can be generated automatically using proprietary application as well as can be created with semi-automatic approach. In the semi-automatic approach lineaments were created based on 4 Hill shades. These hill shades were created by using Digital Elevation Model (DEM) with varying the values in Sun angle 0°, 45°, 90°, 135° for different outputs. These generated outputs gets combined using spatial analysis tool to form one shaded image (B.S. Manjare, 2019). The fault and fractures gets digitized based on generated one shaded image..

3.3 Classification of data

The iron content region (region of interest) samples were collected for each technique used to identify iron content region based on color. The samples were collected from northern region of Hupsekot rural municipality of Nawalpur district. The Landsat 8 image was classified into two different class based on the samples collected. Supervised classification was applied on the image to classify image into two different class; one in Iron content region and other as Non Iron content region for each of processed dataset.

3.4 Geographic Information System

Application of Geographic Information System can manage a large quantity of spatially concerning information and facilitate integration of multiple data layers with spatial suitability models. Therefore, the integrated GIS-based MCDA process was used to evaluate land suitability for the possible iron ore deposit. Five components from processed results were used as the layers for MCDA process (Chandio & Matori, 2011). The AHP method is one of the multi-criteria decision-making approaches that is commonly used in land use suitability analysis (Akinci, YavuzÖzalp, & BülentTurgut, 2013).

3.4.1 Iron oxide containing region

Sabins (1997) introduced an ETM+ band-ratio "3/1" by dividing the digital number (DN) of the two bands to produce an image that enhances spectral differences and reduces the effect of topography. The induced procedure helps to locate the areas of iron oxides and hydrous minerals in given environments (Sabins, 1997).

3.4.2 Hydrothermal Alteration Zone

From the interaction of hot aqueous fluids with the rocks through which they circulate, hydrothermal alteration zone is formed by a complex mineralogical, chemical and textural change procedure under evolving physicochemical condition (Rahele Moradi, 2017), (Safaria, Pourb, & Hashim, 2017).

3.4.3 Sedimentary Rock Zone

Sedimentary rocks are rich in iron oxides including hematite and magnetite (King, 2020). The FCC, PC2 and PC3 combination exaggerates the sedimentary physiographic features (Salem & Gammal, 2015).

3.4.4 Lineament

Abundant amount of minerals has been recorded in fractures and steep terrain over the world. Lineaments helps to identify the faults and fractures where the abundance of minerals is usually found. A buffer zone of 250m around lineament feature is created for weighted overlay of lineament layer.

3.5 Weighting of Evidential Themes

The weights were determined after a thorough literature review on iron mineralization within the study area. Furthermore, consultations with geologists on minerals potential in Nepal was carried out during the weighting of the themes. Weightage of individual themes are illustrated in given Table 2. (Takyi & Jnr, 2018) (Chandio & Matori, 2011)

Table 2: Summary of weights attached to evidential themes

S.N.	Components	Weightage (%)
1	Iron Oxide Containing Zone	25
2	Hydrothermal Alteration Zone	10
3	Lineament	20
4	Sedimentary Rock Zone FCC	20
5	Sedimentary Rock Zone PCA	25

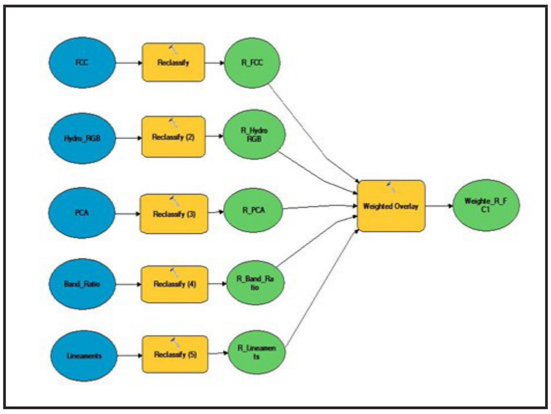

Figure 4: The Multi Criteria Decision Analysis (MCDA) model build in GIS

4. RESULT AND DISCUSSION

4.1 Interpretation of the processed Landsat 8 Imageries

4.1.1 False Color Composite (FCC)

The FCC on the Landsat 8 bands (7, 4, and 2) exaggerated the iron content region of Dhoubadi/Pokhari region that is appeared as dull pale yellow and greenish brown color can be seen as indicated by yellow circle in Figure 4. These region appears to have high iron concentration than other region represent by other spectral colours (Salem & Gammal, 2015).

Figure 5: False Color Composite of Landsat 8 image showing maximum iron concentration as dull pale yellow and Greenish brown with band combination of (7, 4, 2 as RGB) in Northern part of Hupsekot Rural Municipality.

4.1.2 Principal Component Analysis (PCA)

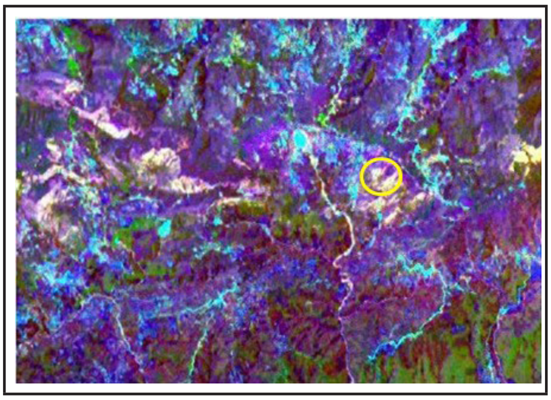

Figure 6: PCA applied on northern region of Hupsekot Rural Municipality

PCA reduces the correlation and improves the spectral signatures. PC2 and PC3 of Landsat 8 providing the iron distribution and concentration. The surface with high iron concentration is represented by yellow color as indicated by yellow circle and low concentration is represented by deep brown color in Figure 5 (Salem & Gammal, 2015).

4.1.3 Band ratio/Band math

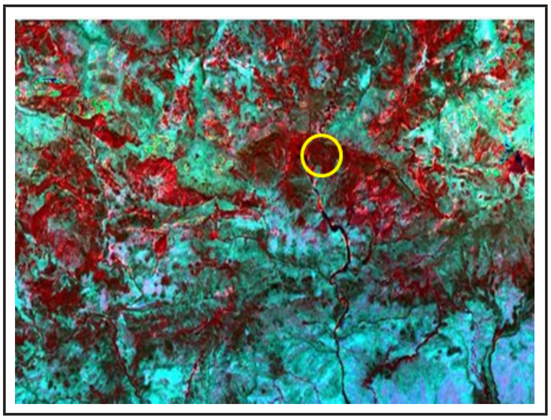

Figure 7: FeO containing region representd by red color in Northern part of Hupsekot Rural Municipality

The band ratios (4/2, 5/4, 5/7) in Landsat 8 image as red, green, blue, respectively enhanced the distribution and concentrations of the iron ore. Dhoubadi area appeared with maximum iron concentration (red color) as indicated by yellow circle and the surrounding areas with minimum iron concentration (yellow) in Figure 6 (Salem & Gammal, 2015).

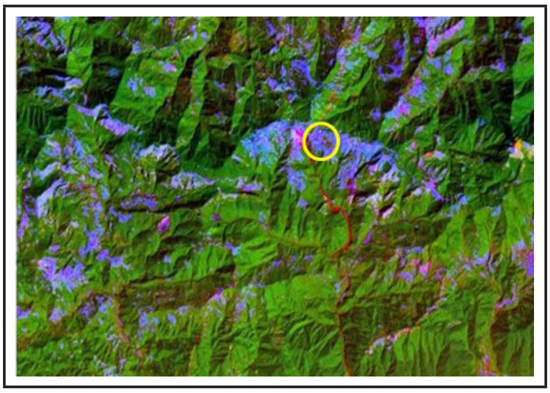

Figure 8: Hydrothermal Alteration Zone highlights the mineral deposits by blue color in northern part of Hupsekot Rural Municipality

Hydro thermal alteration zone represents mineral deposits. Using band math and using the bands (2, 6-7, 5-6) as red, green and blue combination intensifies the presence of mineral on the surface represented by blue color as indicated by yellow circle in Figure 7 (Salem & Gammal, 2015).

4.2 Iron deposits map

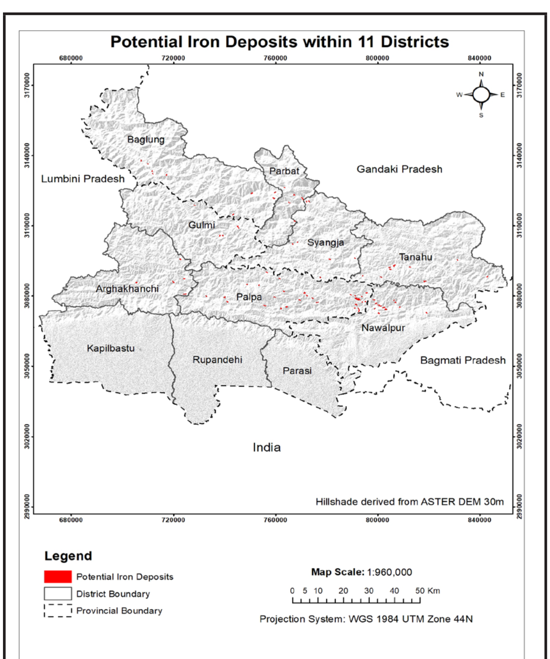

Figure 9: Map showing the distribution of potential iron ore deposit in 8 districts of former western development region of Nepal

The Figure 9 shows Siwalik and lesser Himalayan morphogenetic zone holds huge reserve for potential iron ore deposits. Among the 11 districts of the study area, 8 districts holds reserve for potential iron ore deposit as seen from the results, where maximum amount could be seen in lower Siwalik region and notable amount is distributed as we move north to lesser Himalayas.

4.3 Interpretation of the field geology

4.3.1 Existing Iron Ore Deposits

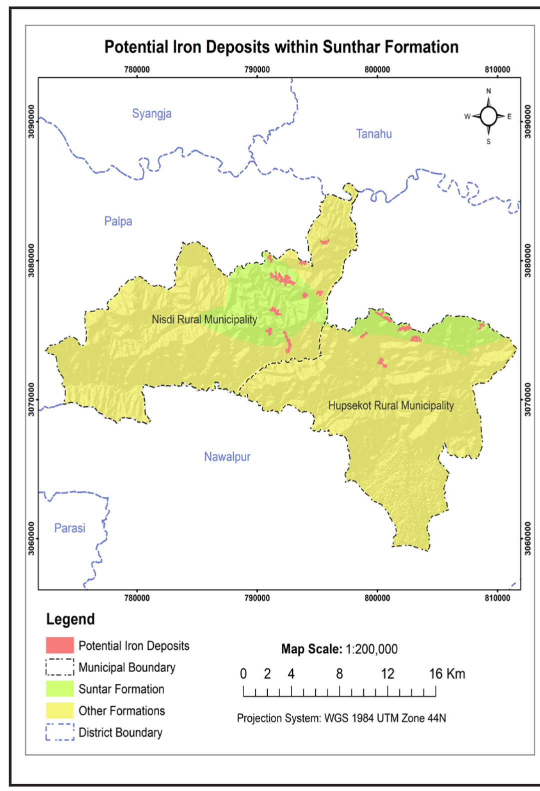

Figure 10: Potential Iron Deposits in Hupsekot and Nisdhi Rural Municipality are mostly observed in Suntar formation of Rocks

In course of time Geological investigations and mineral exploration activities carried out mainly by DMG since its establishment in 1961 till present day and partly by DMG/ UNDP, UNDP/ DMG/MEDP projects and Geological Survey of India. From the past studies it has been seen that that the chronology of the Mio-Pliocene fluvial sediments of the Siwalik Group from South Asia including Pakistan, India and

Nepal can be a source for magnetic polarity and magnetic mineral reserve (Gautam, Hosoi, Regmi, Khadka, & Fujiwara, 2000). Nepal is situated at the center of Himalayan belt, which has favorable geography for various minerals (metallic, non-metallic, and fuel) where local people had used different types of mineral resources in small-scale through ancient times (Kaphle, 2013). Extensively mining of metallic ores was practiced in different parts of Nepal for more than 100 years till 1951 (2007BS) but none of these mines are in operation since then. Iron ore has been excavated and used locally and traditionally since ancient times in different parts of Nepal. Traditionally iron ores were excavated in Baitadi, Bajhang, Jajarkot, Rolpa, Surkhet, Myagdi, Baglung, Parbat, Chitwan, Ramechhap, Okhaldhunga, Taplejung etc (DMG, 2011) (Amatya, 1996) (Poudyal, 2019)

4.3.2 Geological Settings of Results Obtained

Major portion of the study and the potential deposits lies within Surkhet Group and Tansen Group of geological settings of Nepal. The Tansen Group comprises rocks from the Permian to the Oligocene and is further divided into the Sisne Formaiton, Taltung Formation, Amile Formation, Bhainskati Formation and the Dumri Formation (Sakai, 1983). A geological formation or a formation is a body of rock having a consistent set of physical characteristics with respect to its adjoining set of rocks and which occupies a position in the layers of rock exposed in a geographical region. Surkhet group comprises rocks from Paleocene and lower Miocene and is further divided into Suntar, Swat and Melpani formations (Kayastha, 1992). Suntar Formation consists predominantly of dark gray to dark greenish gray metasandstone and purple to dark gray shale/slate mostly suitable for the occurance of metallic minerals and iron ores. Similarly, Suntar formation is composed up of bauxite paleosol occurs with kaolinite and hematite pisolites under the surface (Li, 2013). The Bhainskati Formation of Tansen Group comprises rocks from the Permian to the Oligocene age. Hematite bands are notably reported in the Bhainskati Formation also (Devkota & Paudel, 2012). Figure 9 shows that the potential iron ores are found within Surkhet group majorly within suntar formation.

4.4 Conclusion and Recommendation

Iron potential map of the study area has been produced through the application of Remote Sensing and GIS. This study helps to demonstrate the usefulness and effectiveness of the application of Remote Sensing and GIS in the exploration for Iron ores. The Landsat 8 imageries were used successfully for identifying Iron oxide containing region, hydrothermal alteration zone, Lineament and Sedimentary rock zones. Remote sensing and GIS can be used as powerful exploratory tools in the preliminary stages of mineral exploration because of its cost effectiveness, effective and efficient interpretation, environmental friendly and most of the data required are open source. This technique can be applied for the exploration of other metallic and non-metallic minerals too. As remote sensing and GIS can be useful for preliminary feasibility study of prospection of iron ore deposits, further detailed geological study/survey can be carried out to explore the amount and volume of possible iron ore.

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