Changes in Land Use and Possible Future Recommendations using Geospatial Techniques - A Case-Study of West Bardhaman District

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Abstract:

Coal Mining and Agriculture are two ends of a spectrum. Each serving as a backbone to the Indian Economy. Mining industry provides huge employment opportunities as well as a support system for various other industries, while agriculture provides for food security of the nation. There is a need to find a balance between sustainable working of both the industries, because we are totally aware of the impacts of mining on agriculture, especially on the lives of local communities around the mining area. It is necessary to understand the landscape dynamics of the region to plan for a sustainable development. Geoinformatics serves as an essential tool for planning and analyzing for restoring the landscape, environment and livelihood and culture of local communities.

Keywords: Coal Mining, Land Use change detection, GIS and Remote Sensing, Accuracy assessment, Weighted Overlay, Site Suitability Analysis.

1. INTRODUCTION

Agriculture continues to be an essential sector in the Indian economy. However, according to the Central Statistics Office (CSO), Ministry of Statistics & Programme Implementation, the agriculture and allied sectors contributed about 16.1% to India's GVA (Gross Value Added) during 2018-19 and there has been a consistent downfall in the total GVA of the country from 18.2 percent in 2014-15 to 16.5 percent in 2019-20, which reflects the transformation of the Indian economy with more development towards the manufacturing and service sector which demands for energy. India's energy supply is heavily reliant on fossil-based sources, notably coal. (Spencer T. *et al*,.2018) The Raniganj coalfield under the E.C.L is the country's oldest producer of non-coking coal and with its high quality and low ash content, the Raniganj coal is highly demanded by various industries all over India.

Post Independence, demand for coal went up exponentially. Coal kindled the growth of rail, steel, river ferries, power generation, brick kilns, industrial boilers, etc. in the region. The steel, railways, and to some extent power, had their own captive mines but for the rest it was a free coal market. (*The Economic Times*, 30 May 2020).

The Asansol and Durgapur subdivisions are the important industrial zones of this district, (Barddhaman District Gazetteers) generating huge employment but mining industry on the other hand creates a pool of land looser's. Few people from local communities get some form of employment in the mines or monetary compensations as per legal provisions but the payments are often delayed, and people with fewer skills are often trapped in the curious cycle of need and greed and land up in informal mining activity, risking their lives and also posing a threat to the environment.

The agriculture sector in this mining region is fading away. The displacement of peasants and also traditional subsidence farming has lead to large scale unemployment. From a traditional agriculture base, the local communities are shifting towards non-agricultural sector, especially mining. Having to compromise with the traditional and cultural integrity of the region, gives rise to lifestyle disruption and informal mining activities. (Kuntala lahiri dutt, informal coal mining in eastern India, 2003) To conserve agriculture for food security and sustainability within communities, especially in rural areas where poverty is prevalent, we first need to manage our lands sustainably, restore degrading areas, and improve irrigation and storage technologies. In this paper we shall be using geoinformatics technique to assess the land-use land cover change and also the impact of mining on the rural agricultural lands. Geoinformatics also serves as an essential tool to study the spatial distribution of land cover accurately prior to planning and estimation for land restoration or further developments.

2. OBJECTIVES

- Assessing the land-use land cover and change detection based on LANDSAT satellite data.
- Monitoring vegetation health of the region using NDVI
- Land suitability analysis for farming using Weighted Overlay tool

3. STUDY AREA

The study area comprises of Asansol and Durgapur subdivisions, of Paschim Bardhaman district, which is predominantly an urban-mining-industrial zone. The area under study is approximately 1822km/sq. The location map of the area is given in Figure 1. Situated at the banks of the river Damodar it is also a hub for many industrial setup. With rapid urbanization and industrialization in the area socio-economic structure is shifting from agrarian to mining culture, which although a good sign for the country’s economic growth, it is adversely affecting the environment and livelihood of local communities.

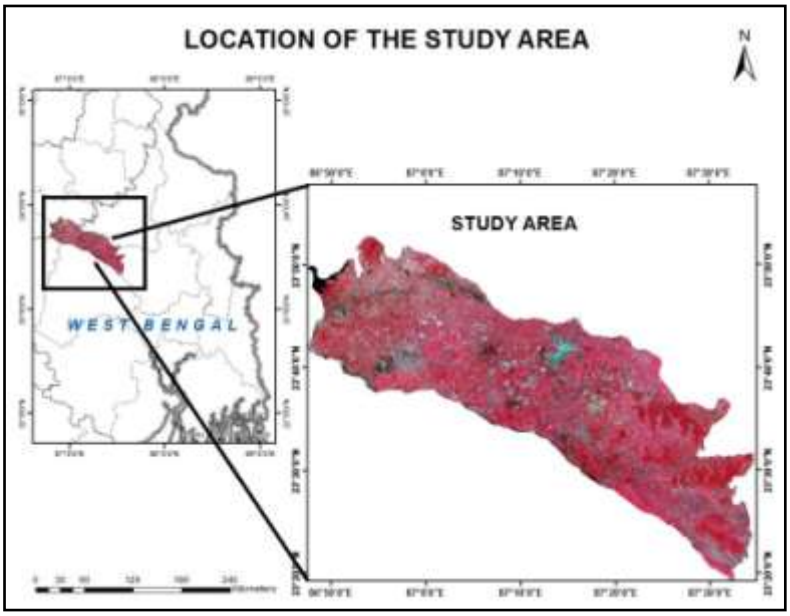

Figure 1. Location map of study area in Landsat 8 OLI natural color composite image of RGB432

Hence, to understand the severity of mining and rapid urbanization and industrialization in the region Remote Sensing techniques have been used to analyze the change in Land use-Land cover and also land suitability analysis for farming lands have been performed . Coal mining not only adversely affects the agricultural land but it is a threat to the landscape as a whole. The region's monitoring is not only essential to find the best suited lands for agriculture and reclamation but to monitor for hazards such as land subsidence, coal fire, effect on ground water etc.

4. MATERIAL AND METHODS

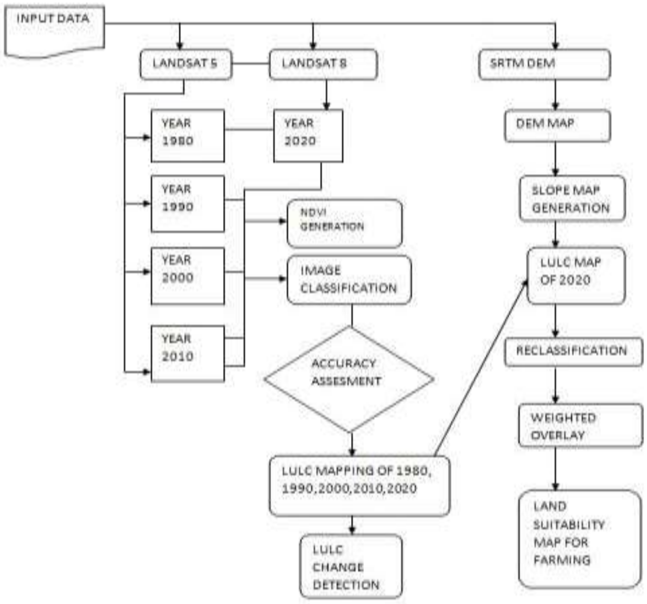

Figure2. Methodology for analysing land use land cover change and vegetation density;land suitability mapping for farming using weighted overlay

- The **Arcmap10.2 software** has been used to derive the maps.
- **NDVI Generation**: The Normalized Difference Vegetation Index is calculated using Red band and Near Infrared band. NDVI is used to quantify vegetation greenness and is useful in understanding vegetation density and assessing changes in plant health. (USGS.gov)
- **Image Classification** and **Accuracy Assesment**: Supervised image classification was used to derive the LULC map and accuracy assesment was done using Google Earth model to measure how many ground truth pixels are correctly classified, for which 100 random points were generated in Arcmap and opened in Google Earth. (Tilahun A, et al.,2015) The following formulas were used to derive the accuracy assesment:

Equation1……… $\text{Individual accuracy} = \frac{\text{Reference value}}{\text{row total}}$

Equation2………. $\text{Total (overall) accuracy} = \frac{\text{Number of correct plots (Value)}}{\text{Total number of plots (Value)}} \times 100$

Kappa can be used as a measure of agreement between model predictions and reality (Congalton 1991) or to determine if the values contained in an error matrix represent a result significantly better than random (Jensen 1996). Kappa was computed using the following Equation:

$$K = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+}Xx_{+1)}}{N^2 - \sum_{i=1}^{r}(x_{ii} \times x_{+i})}$$

(Tilahun A, et al.,2015)

- **Land Suitability mapping**: The components taken for suitability mapping were DEM Map, Slope Map that was generated from DEM and LULC classes of 2020. Then using the weighted overlay tool, land suitability map was generated. (Rojas.M.P, 2016). In order to map the area for site suitability using the Weighted Overlay tool, all the raster classes including Slope map and LULC map were reclassified and given new values, depending upon the importance and impact of the object on the site. In this case, the land suitability mapping was derived for farming therefore Slope of the land was given the highet weight of (8), followed by water body and so on. Adding up all the reclassed value would give a suitability map.

5. RESULT AND DISCUSSION

5.1. Land-Use Land-Cover Classification

The Land-Use and Land-Cover classification based on supervised image classification has been

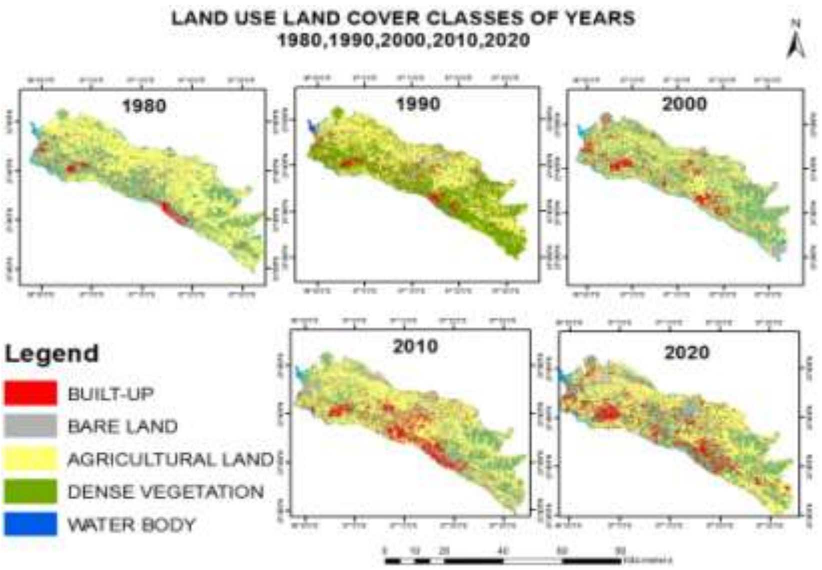

Figure 3. Land Use Land Cover classes from the year 1980-2020

represented in Figure 3., shows a gradual change in land use land cover over the years from 1980-2020. Bare lands that cover most of the central region has become prominent over the years, signifying increase in mining activity. The prominency of agricultural cover is seen gradually decreasing over the years and built-up area emerging.

The following table shows areal change in each class of Land Use- Land Cover

LULC (in hectares)	1980	1990	2000	2010	2020
Built-up area	1572.66	10849.14	15371.82	20522.97	25225.92
Bare land	3319.74	11605.41	12436.29	19249.38	13395.96
Agricultural land	24296.22	71826.12	74327.04	87930	79970.31
Dense vegetation	14731.56	83787.48	72746.64	52530.84	55668.69
Water body	1628.55	3728.52	7319.79	1968.39	7940.7

Table1: Areal change of land use Land cover in hectares

The land use land cover classification has been done on the basis of U.S.G.S. Landuse Classification.(U.S. Geological Survey Circular 671). The built-up area consist of settlements, market place, industrial units and all man-made objects. (Rahman S. et al.,2020) There has been steady increase in the built-up area since 1980 from 1572ha to 25225ha in 2020, which shows a rapid urbanization. The bare land consist of non-vegetated land and also includes lands sed for mining and qarring activity. From 3319ha it has increased to 12436ha in the year 2000, but we see a decrease in area of bare lands in the year 2020, which is possibly due to land reclaimationsand restoration being planned out and worked upon. The agricultural land has been seen at an increasing trend but after the year 2010 it has declined from 87930ha to 79970ha. which clearly represents the growth in built-up areas and also people shifting from farming to other forms of employment.

The western part of the map shows gradual decrease in vegetation cover as a result of clearing of forests and agricultural lands for mining activity. The Eastern region has a good amount of vegetation even now. To have a better understanding of how the land use and land cover have changed over the years, Change detection mapping (Figure 4) of 1980 and 2020 has been performed.

The confusion matrix(error matrix) below showing the correlations between the ground truth and classified image

LULC classes	1980		1990		2000		2010		2020	
	Producer accuracy	User accuracy	Producer accuracy	User accuracy	Producer accuracy	User accuracy	Producer accuracy	User accuracy	Producer accuracy	User accuracy
Built-up	100	72.73	100	66.67	85.71	75	100	75	81.25	100
Agriculture	86.44	100	80	100	81.63	90.91	87.8	94.74	91.11	95.34
Dense Vegetation	97.06	94.29	100	82	85.71	78.95	93.75	93.75	92	92
Bare land	75	75	85.71	100	100	100	72.73	80	100	73.33
Water	100	100.00	66.67	100	100	66.67	100	100	100	75

body										
Kappa coefficient	0.86		0.91		0.89		0.85		0.872	

Table 2. Accuracy assesment of land-use land cover classes

Accuracy assessment is an essential step in the processing of a digital image obtained by remote sensing. The overall accuracy of the classified image signifies, the pixel classified for each class(LULC) to the corrusponding land cover obtained from the ground but in this case the Google Earth map. Producer accuracy is the measures of omissions that signify how well the the real land use and land cover can be classified. User's accuracy measures error of commission which signifies the likelihood of a classified pixel that correctly matches the corrusponding real location. (Rwanga S. Sophia et al., 2017)

Interpretation of kappa (K) (from Landis and Koch 1977)

K	Interpretation
<0	Poor agreement
0.0-0.20	Slight agreement
0.21-0.40	Fair agreement
0.41-0.60	Moderate agreement
0.61-0.80	Substantial agreement
0.81-1.0	Almost perfect agreement

Kappa coefficient is a measure of how the classified values are compared to the values assigned by chance. It can take values from 0 to 1. If Kappa (K) coefficient is 0, it means there is no agreement between the classified image and the referenced/ground data. If K is 1, then the classified image and the ground data are accurate. (SCGIS, Remote Sensing, 2016)

5.2. LULC Change Detection

The LULC Change detection allows to study the region's history and its present status, to plan and predict about future prospects and development in that region.

Built-up areas around Asansol, Kulti, Durgapur have increased.(Figure 5) In the table given, (Table 3) around 97km/sq of agricultural land were changed to built-up area, dense vegetation also changed to built-up area (96.16km/sq). Regions around Nabagram, Pandeshwar and Kulti shows a big patches of bare land which represents non-vegetated land and area extensively used for mining activity. Around 85 km/sq of agricultural land have turned into bare lands.

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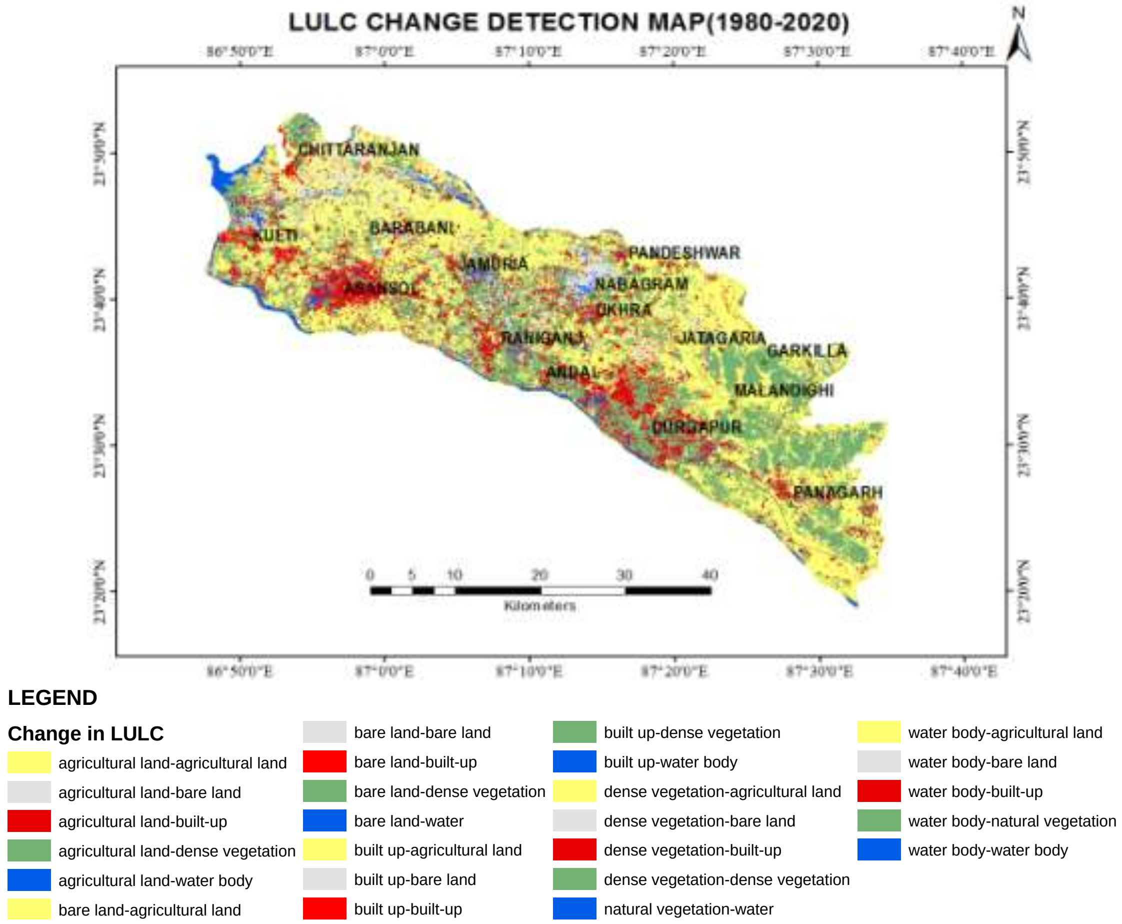

Figure 4. Land Use-Land Cover change over the years from 1980-2020

Change 1980-2020	Area Change(km/sq)	Change 1980-2020	Area change(km/sq)
agriculture-agriculture	561.885279	built up-dense veg.	25.555518
agriculture-bare	85.358603	built up-water	7.950042
agriculture-built-up	97.035289	dense veg.-agriculture	173.395173
agriculture-dense veg.	202.850994	dense veg.-bare	27.040857
agriculture-water	23.806439	dense veg.-built-up	96.165484
bare-agriculture	36.744836	dense veg.-dense veg.	275.752887
bare-bare	10.833906	dense veg.-water	16.678806
bare-built-up	31.953901	water-agriculture	22.428274
bare-dense veg.	44.58511	water-bare	7.146883
bare-water	8.508257	water-built-up	5.305264
built up-agriculture	4.334143	water-dense veg.	7.586228
built up-bare	3.391705	water-water	21.845398
built up-built-up	21.602904		

Table 3. Areal Change of Land Use- Land Cover over the years (1980-2020)

5.3. NDVI Classification

The NDVI classification based on LANDSAT 5 for the years, 1990,2000 and 2010 and LANDSAT 8 for the year 2020 was mapped (Figure. 5) which shows vegetation index declining over the years. NDVI Index is a good indicator of land degradation.(Genesis T. et al., 2015)

According to Earth Observatory (NASA), a healthy vegetation absorbs most visible light and absorbs major part of near-infrared light and the opposite happens in case of an unhealthy vegetation.

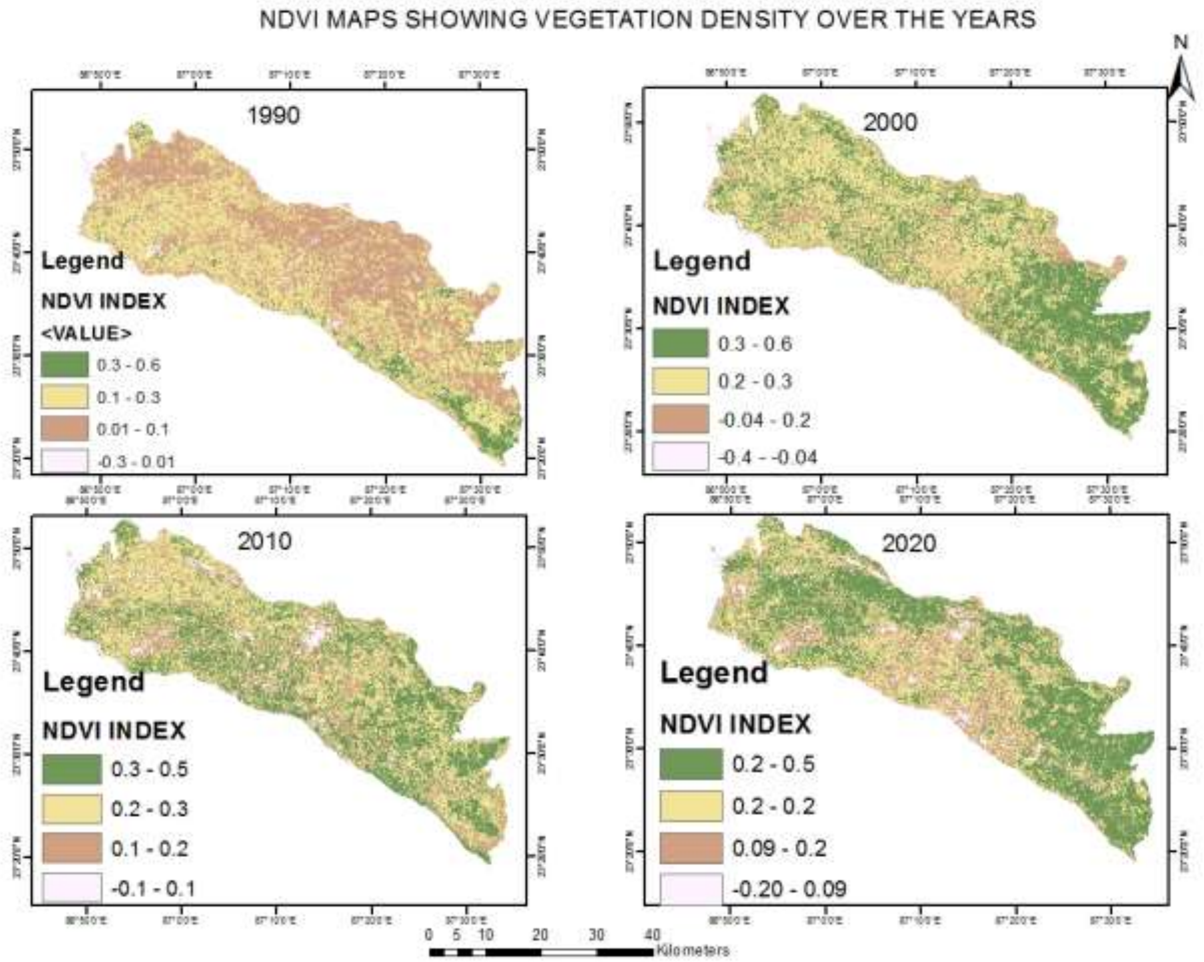

Figure.5 NDVI Classification based on LANDSAT 5(1990,2000,2010) and LANDSAT 8(2020)

NDVI values range from +1.0 to -1.0. Areas of barren rock, sand, or snow usually show very low NDVI values (for example, 0.1 or less). Sparse vegetation such as shrubs and grasslands or senescing crops may result in moderate NDVI values (approximately 0.2 to 0.5). High NDVI values (approximately 0.6 to 0.9) correspond to dense vegetation such as that found in temperate and tropical forests or crops at their peak growth stage. (Remote Sensing Phenology)

In 1990 the high to moderate NDVI Values ranges from 0.3-0.6 which has decreased to 0.2-0.5 microns in the year 2020, indicating loss of dense vegetation cover and converting to sparse vegetation. Decline in the vegetation index also indicates deteriorating plant health in the region which clearly is the impact of mining activities. The areas of bare land and sands have increased over the years indicating increase in mining areas and loss of vegetation. NDVI images also makes the location of mining grounds visible.

a. Land Suitability Analysis for farming

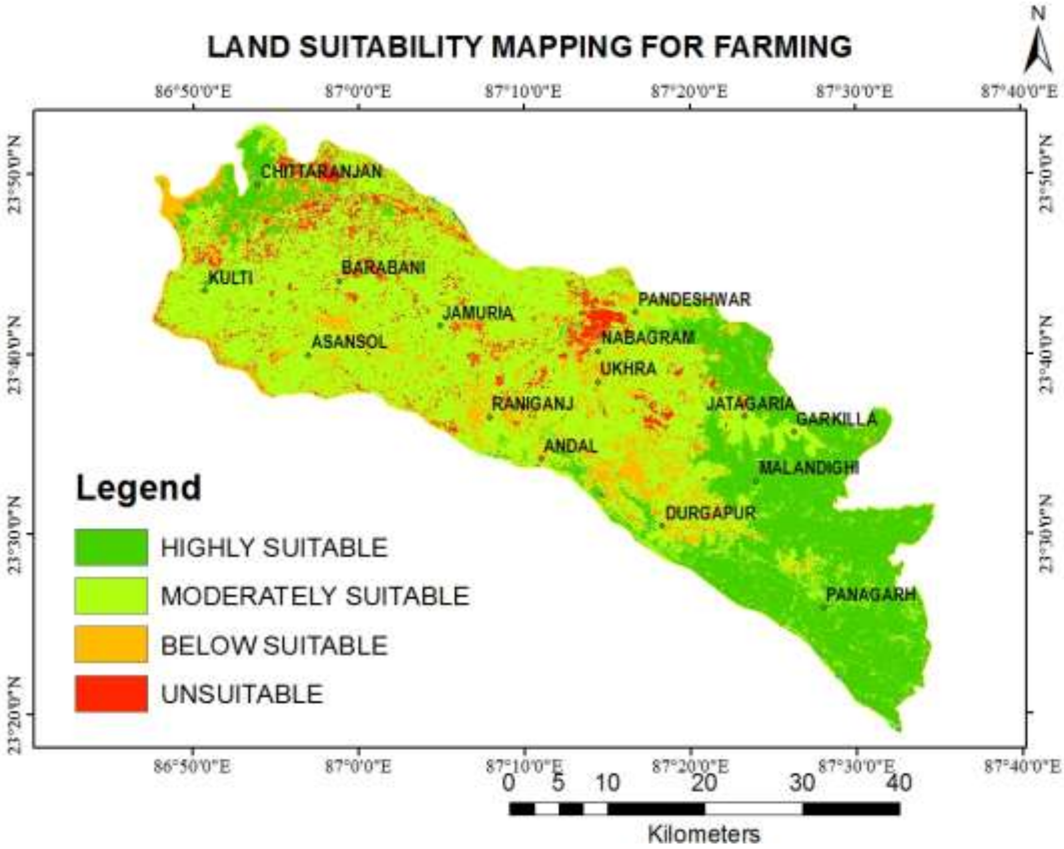

Figure 6. Land Suitability analysis for farming

A land suitability map was derived using Weighted Overlay tool in ArcMap, where the result shows that the eastern region of the map has highest land suitability for farming and also this area has not been much affected due to mining activity which would allow good agriculture produce. The central part comprising of important cities of this region: Asansol, Kulti Andal are moderately suitable for farming, though compromising with plant health, the local communities would atleast have some sort of support. The Below suitable and Unsuitable classification consist of areas of mining and built-up which might not allow farming grounds, areas around Nabagram. Ukhra, Asansol, Raniganj are mining and industrial zone which makes the land totally unsuitable for agriculture. Although with necessary reclaimation practices the closed mines can be used for farming again.

CONCLUSION

Remote sensing and G.I.S techniques prove to be very useful before land - use planning future implementation of suitable measures. This study vividly describes the change of agrarian land to a mining field . Although mining has started its journey since time immemorial , but it's impact is depicted in recent times from the perspective of environmental concern , land degradation , deterioration of soil quality etc. With proper land reclamation techniques , application of alternative farming methods and last but not the least good governance from administrative body , this region would come back to its previous form. In this region , production of good quality coal is essential for surrounding industrial belt , but it's negative effects on agricultural land and on surrounding environment can not be overlooked.

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