

Oil-Mining and its Impact on Agricultural Land-Use and Crop Production in Sivasagar District, Assam

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ABSTRACT

In recent years, oil mining by the Oil and Natural Gas Corporation in the Sivasagar district has triggered a significant land-use/land-cover pattern change. A large portion of agricultural land along with forested areas have been converted into oil mining areas. The land-use/land-cover changes transform agricultural lands into mining areas, and the surrounding areas are also affected due to oil spills and industrial waste spread. A single oil rig is affecting large agricultural areas, which may not be in mining areas, due to which agricultural production is reducing in those areas. Oil exploration and extraction are associated with environmental risks and other problems. However, though there are efforts by oil-mining operators to minimize the risk by adopting advanced technologies, some difficulties remain unattended. Thus, this paper aims to study only one issue of how oil-mining activities have impacted crops' agricultural land use and productivity. Sivasagar District has a suitable physical setting for practising agriculture and tea plantation. The geological setting of the district is favourable for the occurrence, migration and entrapment of crude oil. In this study, various sources of primary and secondary data have been used to find out the impact on agricultural land-use due to oil exploration. Interpretation of Satellite data and analyzing the data using RS/GIS technique. Simple statistical techniques have been used to calculate the percentage of area affected and crop production. Oil mining activities have caused a reduction in agricultural land by 7.35% in Sivasagar District during 2012-24. The maximum decrease in agricultural land happened in Sonari Revenue Circle (11.36%) in the same period. These agricultural lands are converted into built-up areas for rig and equipment installations on surface, wastelands and water bodies, besides underground changes due to oil extraction.

KEYWORDS : Oil-mining, land-use, exploration, crude, RS/GIS technique etc.

1. Introduction

Oil is the most widely used form of commercial energy because of its relatively cheap cost, multiple utility and transportation conveniences to long distances. Although the history of mining minerals is as old as human civilization, oil was used as an energy source only after the 1850s. The first well was drilled at Titusville in Pennsylvania, the USA, in 1859. The Assam Railway and Trading Company drilled the first well in South Asia in Digboi in 1889. After Independence, the two major oil companies in the country, namely Oil and Natural Gas Corporation (ONGC, in 1956) and Oil India Limited (OIL, in 1958), was constituted by the Government of India in the public sector. These two companies play a significant role in exploring and exploiting oil and natural gas in Assam. The state produces nearly 50% of the country's total onshore production, having the highest success ratio in the world (70%). Assam was the second-largest producer of natural gas (utilized) by producing 6% and the fourth-largest producer of petroleum (crude) by producing about 13% in the total production of respective category in the country during 2011-12 (Indian Minerals Yearbook 2012, p.3). It is estimated that 58% of the hydrocarbon reserves has not been explored. All major oil and gas fields of Assam are located in the southern part of the Upper Brahmaputra Valley along with the Naga thrust fault covering the districts of Tinsukia, Dibrugarh,

Sivasagar, Jorhat and Golaghat.

Available literature has shown that the increase of mining activity for oil exploration and exploitation has significant impacts on land-use, especially agricultural land-use. These impacts can be considered as a chain of interrelated impacts rather than occurring in isolation. The expansion of the mine area changes the nature of present land-use, which ultimately results in various environmental and socio-economic consequences. These impacts depend on the mining phase, the size and complexity of the operation, and the effectiveness of the adopted mitigation measures. The direct impact on land-use is significant only in the drilling phase. Still, changes are substantial when production starts from exploratory wells and up-gradation of the entire area to a complex-whole oil field. These activities require a large amount of land for their operation. Therefore, clearing of forest cover and absorption of agricultural land is needed. Mining operations are causing a change in air and water qualities; and soil characteristics, affecting cropping patterns and production.

During the exploratory and drilling phases of mining operation, the activities led to land degradation, which affects the agricultural land-use pattern. Though 3-D seismic survey causes subsidence of land, it is conducted at a smaller scale and temporary, carried out by another division of the same organization as pre-exploration or inventory activity. Therefore, this activity has no significant impact on land-use change. In contrast, the increasing number of access roads to the drilling sites and frequent movement of heavy and bulky vehicles cause land compactness, reducing soil moisture, water holding, and infiltration capacities of soil and affecting soil texture. The disposal of effluent mud and oil spill over the ground reduces nutrient availability in the soil and changes the PH value of the soil. The large-scale ground clearing for installing facilities and construction of various processing plants results in topsoil erosion. Thus, agricultural productivity and land quality are affected, which indirectly leads to agricultural land-use change. Sivasagar District is one of the significant oil-producing and oil-bearing districts of Assam, having the most productive division of ONGC known as Assam Asset. This division has three major fields: Rudrasagar, Lake and Geleki fields, and 12 minor oil fields (Fig. 1). A significant amount of the state's production comes only from Assam Asset, which started in 1957. This Division of ONGC produced 1.4 MMT crude oil and 367.63 MM m3 of gas during 2004-05. The Rudrasagar prospect was discovered in 1960, Lake field in 1964 and Geleki field in 1968. Apart from these, the district has another major oil field known as the Moran oil field operated by Oil India Limited (OIL), discovered in 1956. Therefore, the history of crude oil production in the district already crossed four decades in 2006. For such study, Remote Sensing and GIS techniques can play a major role. The earlier many studies by Zubair (2006), Joshi and Rawat et al. (2005), Chauhan and Nayak (2005), Mahajan and Panwar (2005), Gawande and Srivastava et al. (2002), Sarma, et al. (2001) have carried out using remote sensing data and GIS technique. It is a well-known fact that the application of remote sensing data and GIS technique along with intensive ground truth collection is the most convenient method of land-use/land-cover change detection. In contrast, impact analysis can be carried out by the application of quantitative and statistical techniques. A noticeable change in land-use pattern has been seen here during this period. Significant amounts of agricultural land along with forested areas have been converted into mining areas. An assessment of the land-use change impact of oil mining is needed to launch any land-use planning for sustainable development and agricultural land degradation where extensive mining activities are taking place. Such degradation is also causing various environmental issues in the study area, which are of great concern and mapping of these areas is very important for planning and developmental purpose.

2. Objectives

The objective of this paper is to analyze the impact of oil mining activities by the Oil and Natural Gas Corporation on agricultural land use and productivity in the Sivasagar district. The study focuses on quantifying changes in land-use/land-cover patterns due to oil exploration, which has led to a significant conversion of agricultural and forested land into oil mining areas, with additional effects on surrounding lands due to pollution from oil spills and industrial waste. Using primary and secondary data sources, satellite data interpretation, and RS/GIS techniques, the paper aims to measure the extent of agricultural land affected, calculate the reduction in crop productivity, and examine the specific areas most impacted, such as Sonari Revenue Circle, where agricultural land saw a notable 11.36% decrease between 2012-2024.

3. Scope and Methodology

Date Type	Special Resolution	Date of Acquisition
PAN-sharped Landsat 7 ETM ⁺	15m	28 th November, 2000
ASTER (Advanced Space brone	15m	21 st November,

Thermal Emission and Reflection Radiometer)		2007
IRS (Indian Remote Sensing satellite) P6 LISS III	23.5m	13 th February, 2012
PAN-sharpened Landsat 8	15m	5 th March, 2016

Step-I: Classification of land-use/landcover was done using ERDAS Imagine 9.2, ArcGIS 9.3 software. Geo-rectified imagery was used as input after necessary radiometric rectification of the images. The 30 m spatial resolution imageries, Landsat 7 ETM+ (2000) and Landsat 8 (2016), were enhanced to 15 m spatial resolution using corresponding PAN bands. Supervised Maximum Likelihood Classification method was adopted for the preparation of land-use/landcover maps. The land-use classification scheme was adopted from the National Land-use Landcover Mapping manual using multi-temporal satellite data of National Remote Sensing Agency, Dept. of Space, Govt. of India, 2006. The areas of surface installations of oil fields, exploratory and development wells were digitized from Google Earth Imagery 11 for the years of 2000, 2007, 2012; on the other hand, PAN-enhanced Landsat 8 imagery of 2016 and Google Earth imagery of 2014 were used for the year 2016 to digitize drilling sites. The Universal Transverse Mercator (UTM) projection with data of WGS 1984, 46°N parallel was used to prepare the maps.

Step II: Analysis of land-use change was done by taking satellite imagery of 2000, 2007, 2012 and 2016. Thus, the maps prepared for these years shows the land-use changes that have taken place during these periods for comparative analysis. A trend analysis was done to examine the nature of temporal changes in relative area coverage of agricultural cropland, agricultural plantation, oil mining area and other land-use/landcover types.

Step III: The household survey data on socio-economic was collected from the field using questionnaires and then analyzed using simple statistical methods to calculate the percentage changes and relevant secondary data from the census of India on population, cropland and area under cultivation, wasteland, built-up area, wetland, forest cover etc. from state statistical handbooks were calculated to find out their percentage changes. Relevant articles from different sources on the topic were consulted to examine the results attained from the empirical data.

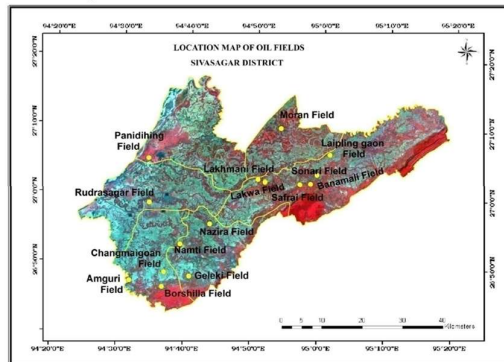


Fig. 1. Location of Oil Fields in Sivasagar District.

4. Oil mining and oil-bearing areas

Already drilled oil mining areas were about 927.68 ha (1971-2011) in Sivasagar District. This record excluded the total surveyed area and the areas with evidence of oil but yet to be explored or acquired for mining purposes. It also did not include leased-in land for mining purposes, where digging is yet to be started. Sivasagar District consists of three administrative subdivisions. The largest division is Charaideo (45.98%) in terms of geographical area, followed by Sivasagar (37.46%) and Nazira (16.56%). However, 49.97% of the district's total oil mining area was confined in the Charaideo subdivision [Table 4.1(a)]. It was about 463.60 ha. About 327.51 ha of mine is in the Nazira subdivision, approximately 35.30% of the district's total oil mining area. The rest, 14.72% of the area, lay in the Sivasagar subdivision occupying 136.57 ha. Nazira and Charaideo subdivision covers a maximum portion of the old alluvial plain of the district and Naga foothill zone. Unlike this, the Sivasagar subdivision covers the entire northern flood plain of new alluvium, portions of middle old alluvial plain and a small part of the southern foothill zone. Therefore, Charaideo and Nazira subdivisions cover the maximum oil mining areas in the district due to the favourable geological structures. The highest mining activity is going on in the Nazira

subdivision.

Table 1 shows that Sonari Revenue Circle encompassed 43.40% of the total mining area among all six revenue circles of the district in 2011. Both Sonari and Nazira Revenue Circles covered 78.7% of the total mining area. The rest four revenue circles included only 21.3% of the district's total oil mining area. Marmora and Sivasagar had 6.58% and 6.15%, respectively, while 4.56% of the area lay in Amguri and Demow, covering 4.02% of the total oil mining areas.

Table 1. Revenue circle-wise distribution of Oil Exploration Area (drilled) in Sivasagar District, 1971-2024

Revenue Circle	% wise distribution of Area	Area in Hectare
Demow	4.02	37.29
Sivasagar	6.15	57.03
Amguri	4.56	42.26
Sonari	43.40	402.58
Nazira	35.30	327.51
Mahmora	6.58	61.01
District Total	100.00	927.68

Source: Revenue Department, Deputy Commissioner's Office, Sivasagar District, 2022.

The table also shows that almost 100% of the oil mining areas of Nazira subdivision lay in Nazira Revenue Circle, and 86.84% of the mining area of Charaideo subdivision lay in Sonari Revenue Circle. Oil and Natural Gas Corporation Limited became a major operator engaged in oil mining activities in the district. It dug 99.35% (921.50) of the district's total oil mining areas during 1971-2011. About 0.65% (6.187 ha) of oil mining areas were under Oil India Limited in the same period. However, an oil field means "an area of land or seabed underlain by strata yielding petroleum, especially in amounts that justify commercial exploitation" (Oxford Dictionary). Table 2. shows that the total area of oil and gas fields in Sivasagar District is 108185 ha which occupies 40.55% of the district's total geographical area (2015). Moran oil field under Oil India Limited occupies 42942 ha and is the largest oil field in the district. Lakwa oil field is the second- largest oil field which occupies 17249 ha in Sonari Revenue Circle. Geleki oil field (2794 ha) with its extension of Geleki Reserve Forest (2050 ha) and satellite oil fields, i.e. Namti oil field (3555 ha), Mkeypore-Santak-Nazira oil fields (7700 ha), and Changmaigoan oil field (6283 ha), are the group of largest oil fields in this area. Rudrasagar oil field covers 7050 ha with its satellite fields Panidihing oil field occupies 535 ha and Charali oil field occupies 5105 ha, Amguri oil field 5275 ha and Sonari oil field occupies 3000 ha. There are other small fields, such as Charaideo oil field occupies 1150 ha, Dipling oil field covers 1010 ha, Sapekhathi oil field covers 925 ha, Sarojini oil field covers 879 ha. Barshilla oil field covers 622 ha in Sivasagar District. The areas under Petroleum Mining Lease are initially granted to the oil-mining operators for 20 years, and further renewal takes place. Therefore, further conversion of other land-use categories into built-up mining inevitably occurs since built-up-mining area (surface installations) covers only 0.73% of total oil-bearing areas until 2016, and only 0.86% were explored and dug till 2011 in Sivasagar District. Notably, the minimum land requirement for each drilling site is 1.56 ha. (125 m x 125 m). However, the simple growth rate of oil mining built-up area is 5.89% during 2000-2016 (base year: 2000) in the district. This rate is 19.54% in Sonari Revenue Circle and 3.23% in Nazira Revenue Circle during the same period.

Table 2. Area Distribution of Oil and Gas Fields in Sivasagar District, 2015

Oil and Gas Fields	Area in Hectare (including Petroleum Mining Leased area)
Rudrasagar	7050
Geleki	4844
Namti	3555
Mekeypore-Santak-Nazira	7700
Lakwa	17249
Charaideo	1150
Sonari	3000
Sapekhathi	928
Amguri	5275
Changmaigoan	6283
Panidihing	535
Charali	5163
Barshilla	622
Sarojini	879

Dipling	1010
Moran	42942
Total	108185

Source: ONGC, OIL & Directorate of Geology and Mining, Guwahati (Govt. of Assam)

5. Land-use/Land Cover Pattern of Sivasagar district during 2016

The land-use/landcover map for 2016 has been prepared from PAN-sharpened Landsat 8 imagery of 15 m spatial resolution captured on 5th March 2016. The land-use statistics have been derived from the map (Fig. 2).

Cropland: Cropland still occupies the largest geographical area (908.88 sq. km) area in Sivasagar District. This land-use category is seen in the south-eastern, northern, eastern and the entire central part of the district. Cropland is found mainly in the north-eastern part and along with the river banks in 2016. Though the total area under cropland is gradually decreasing, it covers 34.07% of the total geographical area.

Plantation: Plantation covers 429.01 sq. km area and 16.08% of the total geographical area in the district. The large tea estates are confined in the southern part of the central alluvium plain and Naga foothill zone. Small tea cultivation is scattered and spread all over the central alluvium plain in the district.

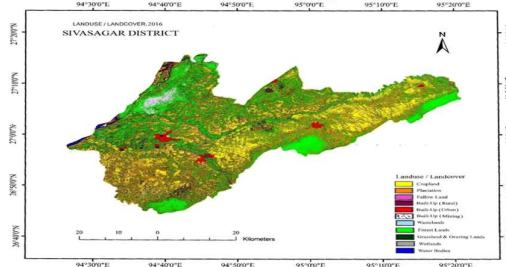


Fig.2. Land-use/landcover map of Sivasagar District, 2016

Fallow Land: Fallow land covers 9.61 sq. km and 0.36% of the districts total geographical area. This land-use class is mainly confined to the western part of the district.

Built-up (Urban): Urban built-up area occupies 25.43 sq. km. It covers 0.95% of the district's total geographical area. The main urban agglomeration is concentrated in the northern part of the district and expanding northward, southward and eastward. The other urban agglomerations are found in the southern and central parts. These seven agglomerations are also rapidly growing. The emergence of several small suburban areas can be seen in the south-eastern and eastern parts of the district.

Built-up (Rural): Rural built-up area occupies 383.08 sq. km. and remains as a fourth-largest land-use class. It covers 14.36% of the district's total geographical area. Though rural habitation is concentrated in the central part, it is scattered all over the district, including the southern part and foothill zone.

Built-up (Mining): Mining built-up areas occupy 7.91 sq. km. and 0.30% of the circle's total geographical area. This land-use category is confined in the north-eastern, central and northern parts of the district.

Wastelands: Wastelands cover 13.38 sq. km. and 0.50% of the total area. Wastelands are found mainly in the north-western part of the district, while a few small patches of wastelands can be seen in the south-western part alongside the fallow lands.

Forest Lands: Forest covers 672.49 sq. km area in Sivasagar District. This landcover class occupies 25.21% of the district's total geographical area and remains the second-largest land- use/ landcover class. Large pockets of forest areas are mainly concentrated in the southern part of the district, basically in the Naga foothill zone. Open forests are found in small patches in the eastern and northern parts of the district.

Grassland and Grazing Lands: An area of 62.29 sq. km. of Sivasagar District falls under grasslands and grazing lands. This landcover class occupies 2.33% of the district's total geographical area. This category is scattered over the southern, eastern and northern parts of the district. The eastern and northern parts of the district have natural grasslands of reeds. Besides, Guatemala grass occupies the south-eastern part of the district.

Wetlands: Wetlands are found in the northern flood plain. These cover 74.81 sq. km. and 2.80% of the district's total geographical area. Panidihing Bird Sanctuary occupies the maximum area of this landcover class. However, the area under wetlands is reducing.

Water Bodies: Water bodies occupy 81.11 sq. km. and 3.04% of the district's total geographical area. A slight reduction in the area under water bodies can be seen in Sivasagar District during 2012-16. In this regard, the main reason is the low and shrinking water level in the rivers (because of scanty rainfall) at the time of imagery acquisition.

Table 3. Conversion of Agricultural land to Built-up (Mining), Wasteland and Water Bodies due to Oil Mining Activities during the periods 2000-07 to 2012-24.

Revenue Circle	2000-07		2007-12		2012-16	
	Hectare	%	Hectare	%	Hectare	%
Nazira	798	6.63	702	5.83	833	6.92
Sonari	2824	9.88	2734	9.57	3245	11.36
Sivasagar	5326	4.91	7626	7.03	7971	7.35

Source: Supervised Classifications of PAN-sharpened Landsat 7 (2000), ASTER (2007), LISS III (2012) & PAN-sharpened Landsat 8 (2016) Imagery.

Sonari and Nazira Revenue Circles were taken as sample units. Oil mining areas are carved out from both urban and rural land-use in the case of the district. These data include both exploratory and developmental wells, fully developed fields with group gathering stations, colonies, processing plants, experimental drilling sites, abandoned wells, over-ground pipelines, mud disposal pits, land degradation areas etc. Table 3 shows that about 7.35% of the district's agricultural land reduced due to oil mining activities in 2012-16. Sonari Revenue Circle experienced a maximum decrease (11.36% in 2012-16) in agricultural land. The conversion is almost continuously occurring during 2000-16 due to extensive exploration activities, and it will continue because of the government's plan for further exploration in unexplored areas. The conversion in Sonari Revenue Circle is higher than the district's overall in all four-time periods. The percentage was calculated concerning the total agricultural land of each administrative division. It was 9.88% in 2000-07, 9.57% in 2007-12 and 11.36% in 2012-16. The conversion decreased by 0.31% during 2000-07, and it was increased by 1.79% during 2007-12. The change due to conversion in Nazira Revenue Circle was also showing similar fluctuating trends. It was 6.63% in 2000-07 and was decreased by 0.08% in 2007-12. The conversion in 2007-12 was 5.83%. In 2012-16, this was increased by 1.09% and reached 6.92%. Unlike these two revenue circles, the overall conversion in the district was increasing. It was 4.91% in 2000, 7.03% in 2007 and 7.35% in 2012 respectively. The conversion was decreased in Sonari and Nazira Revenue Circles in 2007-12 but increased in Mahmora, Sivasagar, Amguri and Demow.

Table 3.1: Landuse Changes in Sivasagar District

Land use Classes	2000-2007 (in %)	2007-2012 (in %)	2012-16 (in %)
Cropland	-3.70	-4.82	3.18
Plantation	4.90	-0.68	0.16
Fallow Land	-1.93	3.27	-5.31
Built-up (Urban)	0.48	0.06	0.17
Built-up (Rural)	1.03	4.28	1.34
Built-up (Mining)	0.01	0.004	0.001
Wastelands	-0.22	0.40	0.08
Forest lands	0.62	-3.11	0.95
Grassland& Grazing Lands	-2.57	0.29	0.30
Wetlands	-0.23	0.48	-0.53
Water Bodies	1.61	-0.18	-0.35

Source: Supervised Classifications of Landsat 7 (2000), ASTER (2007), LISS III (2012) & Landsat 8 (2016)

Land-use/land-cover in Sivasagar District has undergone significant changes during the last sixteen years at different points of time. Contrary to the increasing trend seen in built-up (urban), built-up (rural) and built-up (mining), other land-use classes show fluctuating trends.

At some point in time, a decrease in the plantation happened due to increased built-up (mining) and grasslands. However, the conversion of open forest, cropland, and fallow land to tea plantations result in an overall rise in the plantation. Wetlands decreased due to the increase in built-up (rural). Wastelands increased is due to the rise in built-up (mining) and extensive exploration for crude oil (seismic survey) and forest clearing. Despite expansion in urban built-up, it occupies less percentage share within the urban land use. The increase of surface installations in the district's oil-bearing fields does not have a large percentage share during the last sixteen years. However, it can increase significantly due to the enormous expansion of oil-bearing fields, discoveries of petroleum reserves in new oil fields, and the government's plan to explore new areas in the Assam-Arakan Basin.

6. Effects of oil mining on agricultural land

The sample villages were from the surrounding areas of Geleki and Changmaigoan oil fields. These productive wells fields are scattered all over the villages. These villages also have many exploratory and abandoned wells. Almost entire areas of these villages have undergone seismic surveys in different periods.

Table 3 shows that land acquisition was more in 1999-2009, 62.20% of households lost their agricultural land,

whereas only 15.85% of households lost their land in 2009-2013 while 21.95% lost their land before 1999. New exploratory drillings are mainly in the already acquired and previously abandoned dry fields. Therefore, the number of new land acquisitions was less during 2009-2013. To reduce land, acquisition-mining operators have adopted horizontal drilling and lateral drilling methods for drilling new wells. Table 3 shows 85.38% of households have lost paddy fields where winter rice was cultivated extensively, and about 9.76% of households have lost tea-cultivated land. In recent years mining operators have avoided tea-cultivated land. About 4.88% of households have lost their residential land. Productivity of each crop shows a decreasing trend in the villages. About 82.07% of households were affected by wet paddy cultivation. Due to these cultivated areas, crop yields and production has decreased. The yield of wet paddy was 281.2 kg/bigha before oil exploration, which has reduced to 232.59 kg/bigha in 2013. The change was 48.61 kg. Since almost all farmers cultivate banana and areca nuts in their homestead gardens, these two crops were highly affected due to various oil-mining activities. Smog emission and flared gases were primarily responsible in this case, and about 83.67% of households experienced a reduction in banana production. The average yield of bananas was 131 fruits per plant before oil exploration; it reduced to 69 fruits per plant in 2013. About 85.68% of households estimated a decrease in areca nut production. The average yield of areca nuts was about 586 nuts per plant before oil exploration, which has reduced to about 266 nuts per plant in 2013. Since the cultivation of coconut was not widespread and small tea cultivation was still at the infant stage, the affected areas under these two crops were significantly less. Therefore, only 20.72% and 19.92% of households are affected by coconut and tea cultivation, respectively. The average yield of coconut was about 75 nuts per plant before oil exploration, and now it is about 25 nuts per plant in 2013. At the same time, the average yield of tea was 70 kg/bigha before oil exploration, which has decreased to 48 kg/bigha in 2013. 67.73% of households found a reduction in bamboo production. Sericulture was also affected to 18.33% of households. Thus, the study reveals that most of the crops and yields have decreased after the oil exploration in these areas.

7. Land utilisation and cropping pattern

Table 4. Agricultural land-use pattern and its changes from 1999-00 to 2010-24 in Sivasagar District.

Year	Grazing, cultivable wasteland, land under misc trees	Fallow Land	Net Area Sown	Total Cropped Area	Area Sown more than once
1999-00	29719	15670	128993	147286	18293
2004-05	19937	11498	149426	157121	7457
2010-24	29211	7641	136822	155042	18220

Source: Deputy Director’s Office of Economics and Statistics, Sivasagar Dist.& Statistical Handbook Assam, 2012

Table 5. Crop area Change in Sivasagar District, 2004-05 to 2012-24

Crops	2004-05		2008-09		Change %	2014-15(ha)		Change%
	ha	%	ha	%		ha	%	
Summer Rice	198	0.19	85	0.08	-0.11	172	0.17	-0.02
Autumn Rice	1614	1.58	405	0.40	-1.18	129	0.13	-1.45
Winter Rice	98450	96.53	105920	103.76	+7.23	95535	93.59	-2.94
Rape& Mustard	1024	1.00	1104	1.08	+0.08	1887	1.85	+0.85
Potato	895	0.88	622	0.61	-0.27	745	0.73	-0.15
Banana	1782	1.75	1576	1.54	-0.21	1569	1.54	-0.21
Orange	61	0.06	97	0.10	+0.04	293	0.29	+0.23

Total Reported Cropped Area (tea is excluded) in the base year 2004-05= 102081 hectares

Note: Percentage is calculated to the Total Reported Cropped Area in the base year.

Source: Deputy Director’s Office of Economics and Statistics, Sivasagar Dist. & Directorate of Economics and Statistics, Assam.

The secondary data collected from the Deputy Director’s Office of Economics and Statistics, Sivasagar District, Assam, also shows major crops cultivated in Sivasagar District in winter rice, summer rice, autumn rice, plantation crop tea, areca nut, coconut, rape and mustard, potato and banana. The areas under other crops are negligible; each of those crops occupies less than 0.5% of the total cropped area. Winter rice was the primary crop by occupying 91.95% of the total cropped area (tea plantation area is not included in the total cropped area), followed by areca nut (3.08%), banana (1.3.5%), rape and mustard (1.2%) and potato (1.02%). The area under coconut was 0.48%. Orange, autumn rice and summer rice covers only 0.25%, 0.2% and 0.05%, respectively. It reveals that area sown

more than once is very less in the district since these three types of rice are cultivated in the same paddy fields but different seasons. The comparison of statistics may not be of the same base year. Even this analysis also proves a reduction in agricultural land and production of various crops in the periods 1999-00 to 2014-15. The secondary and satellite data mismatched due to the non-availability of the same period of data for the same periods.

8. Conclusion

The conversion is almost continuously occurring during 2000-16 due to extensive exploration activities, and it will continue because of the government's plan for further exploration in unexplored areas. The conversion in Sonari Revenue Circle is higher than the district's overall in all four-time periods. The percentage was calculated concerning the total agricultural land of each administrative division. It was 9.88% in 2000-07, 9.57% in 2007-12 and 11.36% in 2012-16. The conversion decreased by 0.31% during 2000-07, and it was increased by 1.79% during 2007-12. The land acquisition was more in 1999-2009, 62.20% of households lost their agricultural land, whereas only 15.85% of households lost their land in 2009-2013 while 21.95% lost their land before 1999. New exploratory drillings are mainly in the already acquired and previously abandoned dry fields. The major crops cultivated in Sivasagar District are winter rice, summer rice, autumn rice. Tea, areca nut, coconut, rape and mustard, potato and banana are the major crops and fruits cultivated in the district. However, winter rice cultivated area occupies 91% of the total cropped area; therefore, mostly wet paddy cultivation is adversely affected in terms of reducing cultivated areas, crop yields and production. Banana and areca are also highly affected. Effects of oil mining activities are insignificant in the areas 4 km away from the oil mining sites. Productivity of each crop shows a decreasing trend in the villages. About 82.07% of households were affected by wet paddy cultivation. Due to these cultivated areas, crop yields and production has decreased. The yield of wet paddy was 281.2 kg/bigha before oil exploration, which has reduced to 232.59 kg/ bigha in 2013. Landuse/landcover study finds that all classes in Sivasagar District change over time. In sixteen years, during 2000-16, human modification on natural landscape got momentum. Increase in plantation (4.38%) and built-up (rural) (6.65%) are distinguishable. However, a decrease in cropland (5.34%), fallow land (3.97%), grassland and grazing lands (1.98%), and forest lands (1.54%) explains an increase in plantation and built-up (rural). Oil mining activities caused a reduction in agricultural land by 7.35% in Sivasagar District during 2012-16. In the same period, the maximum reduction in agricultural land happened in Sonari Revenue Circle (by 11.36%). These agricultural lands are converted into a built-up area (surface installations), wastelands and water bodies. Households (62.20 %) lost most agricultural land during 1999-2009, and 21.95% of households lost before 1999 due to extensive land acquisition. About 15.85% of households lost their land in recent five years till 2013. After the introduction of horizontal drilling and lateral drilling methods, the operators avoid acquiring residential land for drilling purposes since these new methods make it possible to access multiple reservoirs from a single site. About 32.67% of households in oil mining areas are affected due to land acquisition. Approximately 85.38% of households have lost paddy fields due to this process. Wastes created due to drilling mud and cuttings are disposed of in onsite pits. Tarpaulins cover the pits; however, it does not entirely prevent the overflow of effluent mud during the rainy season. Saltwater is also injected into the deeper subsurface layer. There is associated waste such as sludge, sand produced during production, treating, stoning and transporting crude oil and gas. These are also disposed of like other wastes. Thus, phases of oil exploration and extraction are associated with environmental risks and problems. However, the oil-mining operators attempt to minimize the risk as far as possible by adopting more advanced technologies.

References

- [1] Assam Company Limited. Anagram's Research Report. 2008.
- [2] Census of India. District Census Handbook, Sivasagar 2011. Directorate of Census Operations, Assam, Guwahati-07. 2014.
- [3] Chauhan HB, Nayak S. Land use/land cover changes near Hazira Region, Gujarat using remote sensing satellite data. *J Indian Soc Remote Sens.* 2005; 33:413–20.
- [4] Directorate of Economics and Statistics Assam. Statistical Hand Book Assam 2012. Government of Assam, Guwahati-28. 2013.
- [5] Directorate of Economics and Statistics Assam. Area, Production, Price and Value of some Horticulture crops in Assam from 2003-04 to 2012-13. Government of Assam, Guwahati-28. 2015.
- [6] Directorate of Economics and Statistics Assam. Statistical Hand Book Assam 2014. Government of Assam, Guwahati-28. 2015. pp. 3-5, 19, 20, 22-23, 344.
- [7] Gawande RR, Srivastava AK, Jeyaram A. Geological, geomorphological, hydrogeological and land use/land cover studies around Kamthi area, Nagpur district, Maharashtra using remote sensing techniques. *J Indian Soc Remote Sens.* 2002 ;30:95–104.

- [8] Indian Bureau of Mines. Indian Minerals Yearbook 2012 (Part- I) STATE REVIEWS (Assam). Ministry of Mines, Govt. of India, Nagpur. 51st Edition. May 2014.
- [9] Joshi PK, Rawat GS, Padaliya H, Roy RS. Land Use-Land Cover Identification in an Alpine and Arid Region (Nubra Valley, Ladakh) Using Satellite Remote Sensing. *J Indian Soc Remote Sens.* 2005;33(3):371–80.
- [10] Mahajan S, Panwar P. Land Use Changes in Ashwani Khad Watershed Using GIS Techniques. *J Indian Soc Remote Sens.* 2005;33(2):227–32.
- [11] Ministry of Petroleum and Natural Gas. Annual Report 2013-14. Govt. of India, New Delhi. Available from: www.petroleum.nic.in. Accessed 28 Feb, 2015.
- [12] Oil and Natural Gas Corporation Limited. Corporate Sustainability Report 2009-10. Available from: [www.ongcindia.com](http://www ONGCIndia.com). Accessed 07 Nov, 2014.

- [13] Sarma VV, Muralikrishna G, Malini BH, Nageswara Rao K. Land-use/landcover Change Detection through Remote Sensing and its Climatic Implications in the Godavari Delta Region. *J Indian Soc Remote Sens.* 2001;29(1&2):84–91.
- [14] Sharma P. A Sociological Study of an Oil Industry in Assam. Dept. of Sociology, NEHU, Shillong. 2001.
- [15] Zubair AO. Change Detection in Land Use and Land Cover Using Remote Sensing Data and GIS: A Case Study of Ilorin and Its Environs in Kwara State [PhD thesis]. University of Ibadan. 2006. Available from: www.geospatialworld.net/uploads/thesis/OpeyemiZubair_ThesisDOC.doc.