ISSN 2349-7831

International Journal of Recent Research in Social Sciences and Humanities (IJRRSSH)
Vol. 10, Issue 2, pp: (107-116), Month: April - June 2023, Available at: www.paperpublications.org

STUDIES ON LAND USE AND LAND COVER CHANGE IN AIZAWL DISTRICT, MIZORAM

Remlalruata

Department of Geography and Resource Management, Mizoram University, India

DOI: https://doi.org/10.5281/zenodo.8042670

Published Date: 15-June-2023

Abstract: **The Assessment of land use and land cover change is important for the development of a policy by the government. Land cover change is still a very interesting and hot topic in todays world even in Mizoram. For supporting decision-making processes, identifying LULCC and comprehending the underlying forces are crucial. We examined and analyze the changing variation of land use and land cover during the period of 2000 to 2020 using Three Landsat Thematic Mapper (TM) 4-5 C1 level-1 satellite imagery for 2000, 2010 and Landsat 8 OLI/TIRS C1 level-1 imagery for 2020. Accuracy assessment were taken out and land cover changed was also calculated using ArcMap 10.4. The results showed that there were a lot of changing in the LULC classes. During 2000 to 2020, agriculture land decreased by 8.78%, Barren land increased by 7.89%, Built-up land increased by 21.52%, Dense Forest decreased by 34.71%, Medium Dense Forest increased by 3.83%, Open Forest increased by 19.4% and waterbody decreased by 9.14%. Therefore, land use and land cover change should be given some in-depth interest for the future generations.**

Keywords: **Land use and Land cover, Land Use Land Cover Change, approach, management, Aizawl.**

1. INTRODUCTION

Due to several environmental concerns, land use and land cover changes (LULC) are becoming significant regional and worldwide issues. Urbanization, which has caused a sharp increase in population, has also contributed to the growth of urban areas, a change in the patterns of land use and cover, and the conversion of productive land and vegetation to other land uses. Widespread deforestation and ongoing land-use changes have had a significant negative impact on the ecosystem on several different environmental scales. Most urban centers have been impacted by these changes, both directly and indirectly. The management of natural resources is seriously threatened by its effects on climatic conditions, biodiversity, and physical systems. The repercussions of LULC change include uncontrolled urban growth, environmental pollution, soil erosion, surface runoff, land desertification, urban heat islands, climate change, and ozone layer depletion due to greenhouse gas emissions, according to several studies. These effects also include destroying and losing fertile lands and natural habitats. As a result, tracking spatiotemporal LULC changes provides crucial information for making decisions about how to plan effectively, manage natural resources, and achieve sustainable development.

All primary production systems depend on the land, a finite resource. For the assessment of natural resources, remote sensing and other geospatial technologies are crucial. It also keeps track of environmental modifications. The phrase "land use" refers to the purpose that a plot of land serves, such as agriculture, preservation of the natural environment, or recreation. Monitoring and mapping are involved.The term "land covers" refers to the material that covers the surface of the earth, including plants, water, urban infrastructure, and bare soil. It has to do with scheduling and managing resources. It offers the ground cover data for baseline thematic maps and can be used for changing detection through monitoring.

Land and the resources it is associated with play a significant role in determining how people live and economies develop. The biodiversity and ecosystem of the surrounding area are eventually impacted by how land resources are used. Depending on how it is used across time and space, this impact may eventually lead to either a favorable or unfavorable pattern of land use. Due to the built-in system of land plans utilized throughout the years, the district's land use pattern has undergone significant changes over the past few decades, most of which have been unproductive and environmentally unfriendly. To keep up with the fundamental needs of the study region, proper techniques of utilizing, conserving, and planning land resources are required. A methodical approach to land use planning is necessary for the sustained use of the available resources. Therefore, there is a pressing need to study and the development of appropriate strategic plans and policies based on trustworthy and solid technology to identify new options.

Through the use of satellite remote sensing (SRS) data and geographic information system (GIS) methods, land use and other natural resource management have been successfully handled for many years.In comparison to traditional ground survey methods, remote sensing data has made it feasible to swiftly produce a range of spectral, temporal, and spatial resolution pictures that may be used to spot changes on the earth's surface. Maps of land use and land cover have been produced using satellite-derived remotely sensed data as inputs. By contrasting multi-temporal land cover distributions, the LULC mapaids in the monitoring of change dynamics. The information gives planners, managers, and policymakers a scientific foundation on which to build. Therefore, accurate and current LULC data are required for tracking and studying change dynamics. Numerous studies have effectively mapped and analyzed changes in land use/land cover using data from sources such as Landsat TM (4 and 5), Landsat ETM+ (7), and many more.

Study Area

The Indian state of Mizoram, which borders Bangladesh to the west and Myanmar to the east and south, is situated in the far northeast of the country. Assam and Manipur in the north and northeast, as well as Tripura in the northwest, define its tiny border with the state of northeast India. With Aizawl serving as the state capital, it includes 26 administrative blocks and eight districts. 10.92 lakh people dwell there in total, with 2.9 lakh (26.6%) residing in Aizawl city (2011). The majority of people 98% are Christians. Mizoram is known as the "country of highlanders" because of its sparse population distribution and preponderance of highland communities. The literacy rate is 91.85%, the sex ratio is 975, and the population density is only 52/km^2. The Himalayan Mountain range's eastern flank is where Mizoram is situated. The Indo-Myanmar Arc includes it as a crucial component. Northeastern India is home to the Arakan- Yoma and Patkoi Hills, which are made up part of the Mizoram Hills. These hills range in elevation from 500 to 800 meters above mean sea level (AMSL), with the Blue Mountain (Phawngpui) having the highest elevation at 2,157 meters (ISFR 2011a). Mizoram's hills are extremely delicate. It occupies 21,087 km^2 in total or 0.64 percent of the country's total land area. The Northeast hill states biogeographical zone includes the area to the south of the Brahmaputra River. Mizoram is a landlocked nation that straddles latitudes of 21˚58’ to 24˚35N and 92˚15 to 93˚29N.

The North-Central region of the State is where the Aizawl district is located. The Aizawl district is situated between latitudes 23°21' N and 24°24' N and longitudes 92°39' E and 93°03' E (Fig. 1). The district is situated in the middle of the state and extended on the northern parts of the state. It is encircled by the Mamit district in the west, the Serchhip and Lunglei districts in the south, the State of Manipur in the north, and Champhai district in the east. A significant portion of the district's North-Western boundary is shared with the Kolasib district. The district is 1,132 meters above the mean sea level on average. It is the second-largest district in the state in terms of area, with 3,576 km^2. The district extends 128.7 kilometers north to south and 72.4 kilometers east to west.

The hottest and coldest months are June and January, with temperatures ranging from 10°C to 32°C. The annual average rainfall is roughly 2,300 mm, and the wind characteristics can be described as mild. The district, along with Mamit and Champhai districts, is located along the Tropic of Cancer (23°30'), so the area's climate should be hot and muggy. However, because of the region's hilly, moderately high-altitude terrain, abundant rainfall, and steady, mild wind, a pleasant climate exists here all year long. Although there are sporadic rains in the months of March and October as well, the early monsoon rains typically start falling in the month of April and last through September. The majority of sub-tropical crops like paddy, maize, cash crops like sugarcane, ginger, chillies, oilseeds, and several other horticulture products like oranges and other citrus fruits and bananas are produced. Figure 1 shows the location of the study area.

International Journal of Recent Research in Social Sciences and Humanities (IJRRSSH)
Vol. 10, Issue 2, pp: (107-116), Month: April - June 2023, Available at: www.paperpublications.org

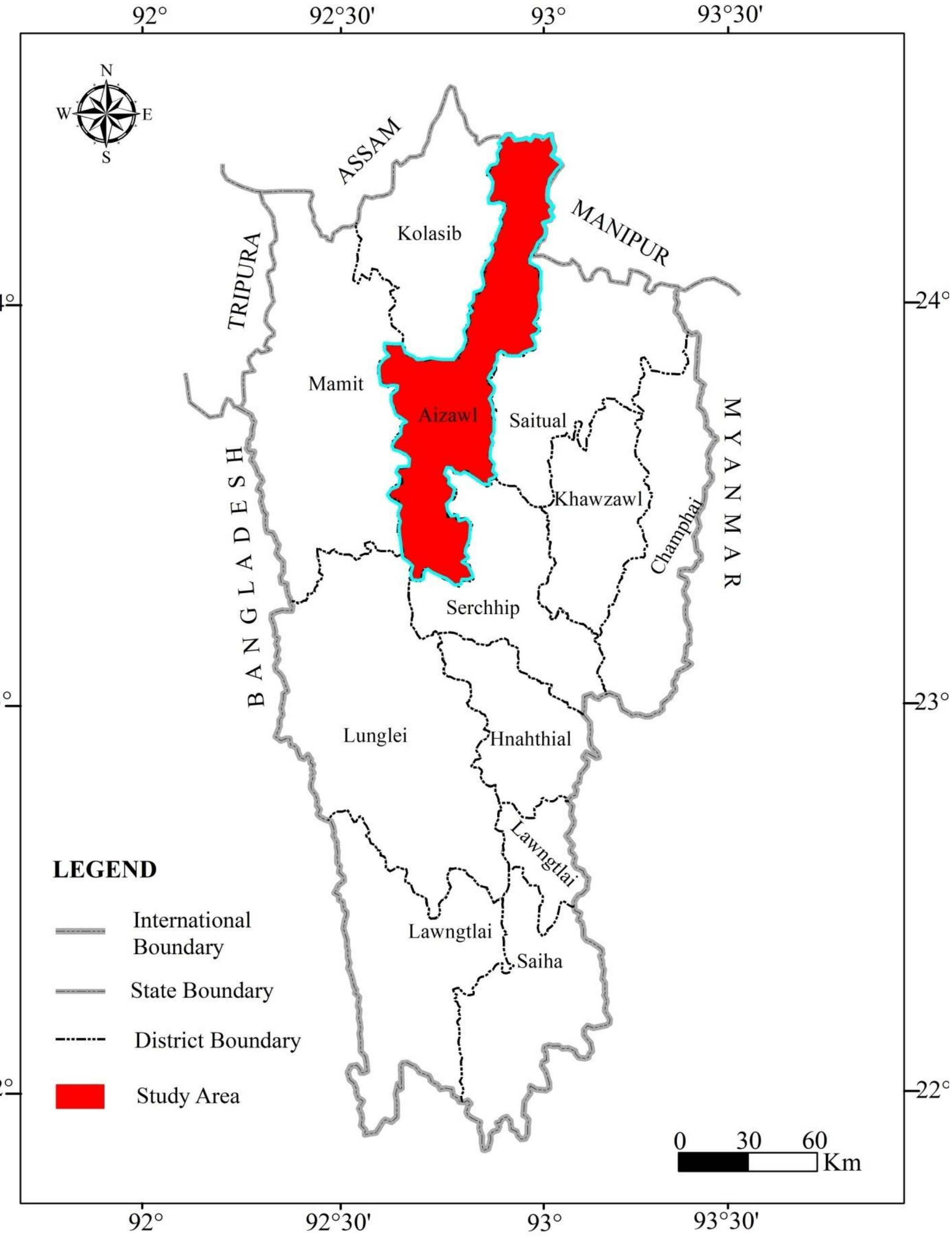

Figure 1: The Study Area

2. METHODOLOGY

Three LULC maps were produced using the supervised classification method and a maximum likelihood algorithm. By using Landsat sensor data and a multi-sector supervised classification method, land cover maps for the chosen years are produced (Lucas et al., 2007). The satellite images from Landsat 5 (TM) and Landsat 8 (OLI TIRS), which have seven and eleven bands, respectively, were created using composite bands (Zha et al., 2003).It is important to finish processing the computation of fundamental techniques such as the composite band, copy raster, remove clouds, mosaic to a new raster, extract by mask, and maximum likelihood image classification before beginning the processing of supervised classification (Su et al., 2010). The entire process was accomplished using software named ArcMap 10.4®.

Results evaluation is a crucial step in verifying the dependability and accuracy of image classification methods. The confusion (error) matrix methodology and the receiver operating characteristic (ROC) curve are the two main techniques for determining whether a categorized image is accurate. We found that classification accuracy of more than 85% was

ISSN 2349-7831

International Journal of Recent Research in Social Sciences and Humanities (IJRRSSH)
Vol. 10, Issue 2, pp: (107-116), Month: April - June 2023, Available at: www.paperpublications.org

excellent and reliable, as suggested by prior studies, using the error matrix method. The confusion (error) matrix technique uses an array of values that are displayed in rows and columns to show how many pixels or polygons are assigned to a specific land cover class in comparison to the actual class that is present on the ground. Producer and user accuracy were calculated in accordance with recommendations to obtain the average accuracy. User accuracy is the likelihood that a classified pixel on each map accurately represents the actual class on the ground or real-world location, whereas producer accuracy is the likelihood of correctly classifying a reference pixel. The confusion matrix is evaluated using the kappa coefficient and the overall accuracy. The kappa coefficient is the proportion of correctly classified pixels subtracted from the actual proportion predicted by chance (K). When determining the degree of agreement or correctness, it employs a discrete multivariate technique. The kappa coefficient ranges in value from -1 to 1, but it often lies between 0 and 1. In order to determine the type and scope of LULC change, we used the post-classification change (PCC) detection approach, which has been used in the past by numerous urban planning and environmental studies. To obtain the geographic distribution of land use land cover and change dynamics in the research area, an overlay approach was used in conjunction with the GIS technique.

3. RESULTS

Accuracy Assessment:

Accuracy assessment refers to the precise number of pixels in a classified image that corresponds to reality—that is, how many have been correctly classified using the algorithm. Understanding the accuracy of the results and utilizing them to implement different policies depends on it (Lu et al., 2004). In light of the information assembled from the possibility table, various logical measurements, like overall accuracy, producer's accuracy, and user's accuracy, have been utilized to ascertain the grouping accuracy according to alternate points of view (Richards, 1996; Stehman, 1997).

The results of the LULC change analysis showed both the current dynamics of change in each land cover class and past changes in land use and cover. Urban planners and managers might learn a lot from the LULC data on the type, location, and rate of change in the study area. Using supervised maximum likelihood classification, the land use/land cover maps for the years 2000, 2009, and 2018 were labeled. According to Table 1, the results for the kappa coefficients and overall accuracies for all the classified LULC maps from the years 2000, 2010, and 2020 were found to be over 70% and 0.76, respectively.

Table 1: Accuracy assesment

LULC Classes	2000		2010		2020	
	User	**Producer**	**User**	**Producer**	**User**	**Producer**
Agricultural Land	50	66.7	88.9	100	90.9	90.9
Barren Land	44.4	66.7	42.9	50	100	33.3
Built-up	100	90.9	100	90	100	100
Dense Forest	100	77.8	71.4	62.5	100	87.5
Medium Dense Forest	66.7	44.4	45.5	55.6	78.6	91.7
Open Forest	66.7	66.7	100	63.6	75	31.6
Waterbody	80	100	87.5	87.5	100	87.5
Overall Accuracy	74.14		75.9		74.14	
Kappa Coefficient	69.44		71.6		68.7	

Status of LULC

This suggests a credible and precise classification of photos for assessing changes in land use and land cover. Between 2000 and 2020, it was noted that Aizawl's land use and land cover patterns significantly changed, with the built-up regions exhibiting consistent expansion during that time. At the same time, the forest area and water bodies declined in the district, while low-density vegetation cover grew. The spatial distribution of each LULC in 2000, 2010, and 2020 is shown in Figure 2, 3 and 4 respectively. Each stage has a varied rate and amount of change, and the three maps show the many stages that each land cover class has gone through. Table 2, which displays the statistics of the four LULC classes and the changing dynamics during the three-time nodes, presents the quantitative outcome. As a result, between 2000 and 2018, the district's built-up area continued to increase steadily, while other LULC classes underwent considerable modifications. It shows a

International Journal of Recent Research in Social Sciences and Humanities (IJRRSSH)
Vol. 10, Issue 2, pp: (107-116), Month: April - June 2023, Available at: www.paperpublications.org

rise in the built-up area from 511.63 km^2 in 2000 to 857.59 km^2 in 2010. From 2000 to 2010, this represents a rise from 22.67 to 38 percent of the total area. In 2020 saw a substantial increase in the developed area, reaching 999.26 km^2 (44.19 percent of the total area), reflecting growth of 15.33 percent and 6.19 percent during the first and second periods, respectively. The outcome shows that the built-up area increased by around 21.52 percent between 2000 and 2020, going from 22.67 percent of the total area in 2000 to 44.19 percent in 2020. Throughout the study period, there was an inconsistent change in the dense forest cover and water bodies. From 827.59 km^2 in 2000 to 511.41 km^2 in 2010, dense forests extent dropped before swiftly dropping to 44.22 km^2 in 2020. According to this, the area will decrease from 36.67 percent in 2000 to 1.96 percent in 2020.

The rapid population growth brought on by rural-to-urban migration and the rise in cash crop cultivation is both responsible for the expansion of the built-up area and the lightly dense vegetation covered in the region. Between 2000 and 2010, open forests increased from 51.35 km^2 to 229.43 km^2. According to the results, the area will increase from 2.28 percent in 2000 to 10.17 percent in 2020. Throughout the entire study period, there was little change in the agricultural land in the study area; they went from 289.71 km^2 (12.84 percent of the total area) in 2000 to 91.84 km^2 (4.05 percent of the total area) in 2020, on the other hand, we also found that there are huge changes takes place in water bodies in Aizawl's district. From 218.94 km^2 in 2000 to 12.56 km^2 in 2020. Figure 5 shows graphically the historical land use/land cover results for 2000, 2008, and 2018.

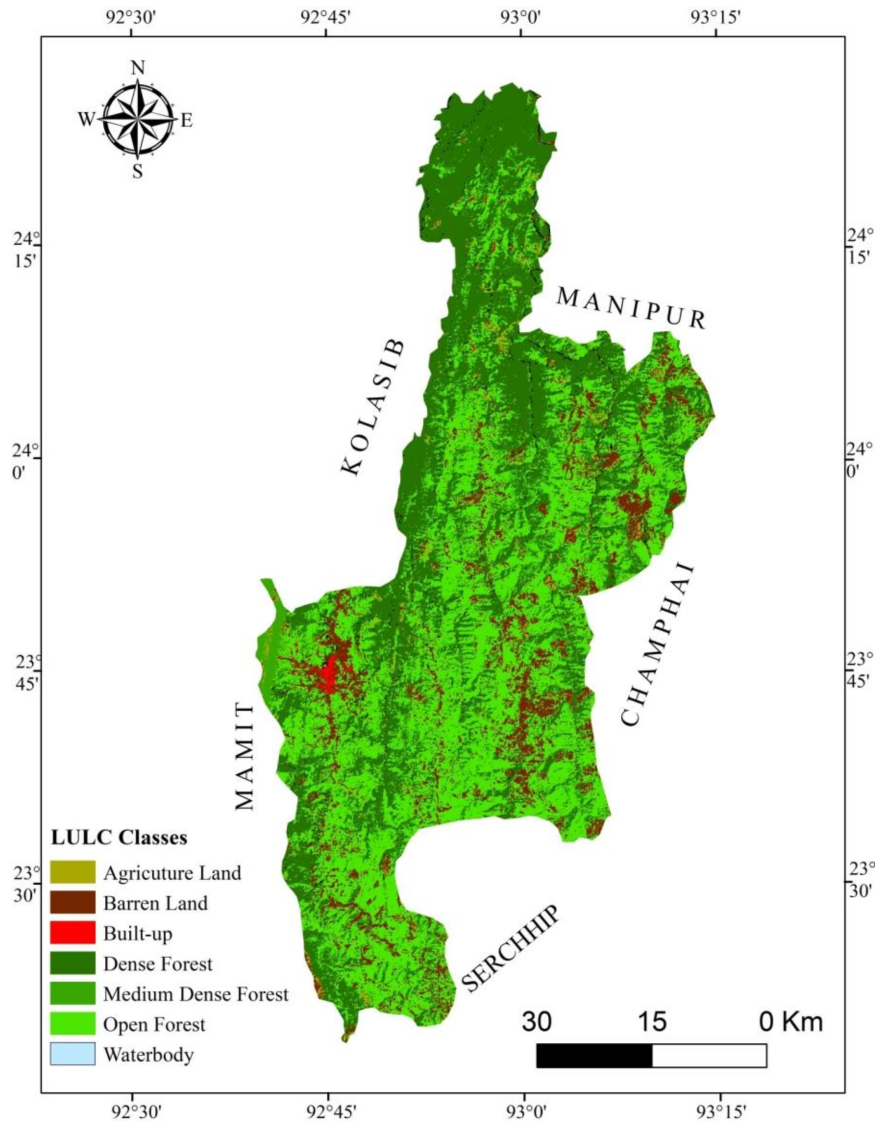

Figure 2: Land Cover in 2000

ISSN 2349-7831

International Journal of Recent Research in Social Sciences and Humanities (IJRRSSH)
Vol. 10, Issue 2, pp: (107-116), Month: April - June 2023, Available at: www.paperpublications.org

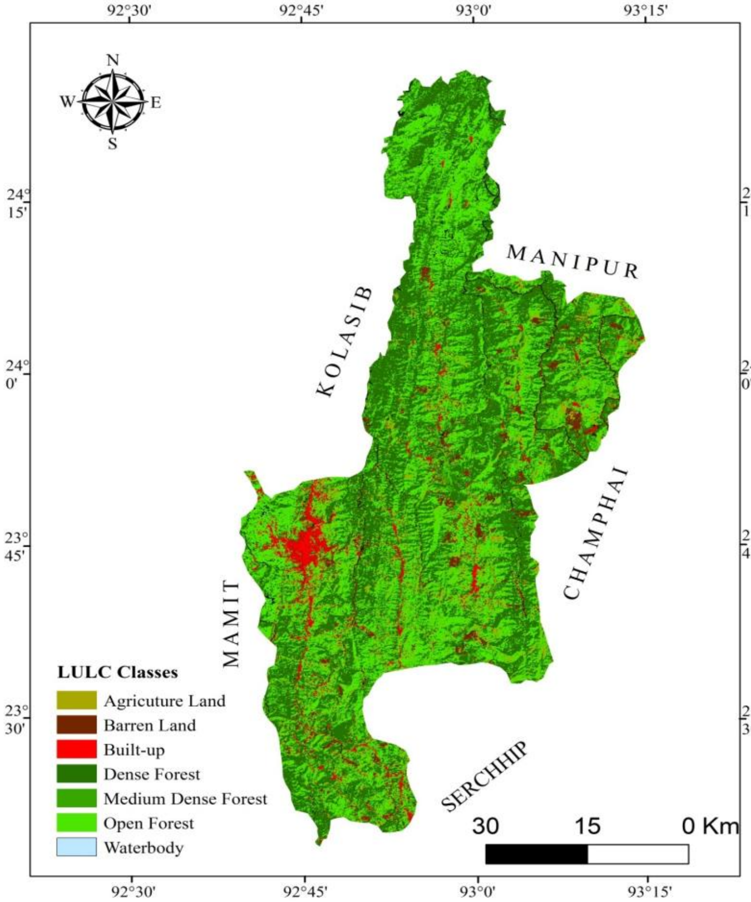

Figure 3: Land Cover in 2010

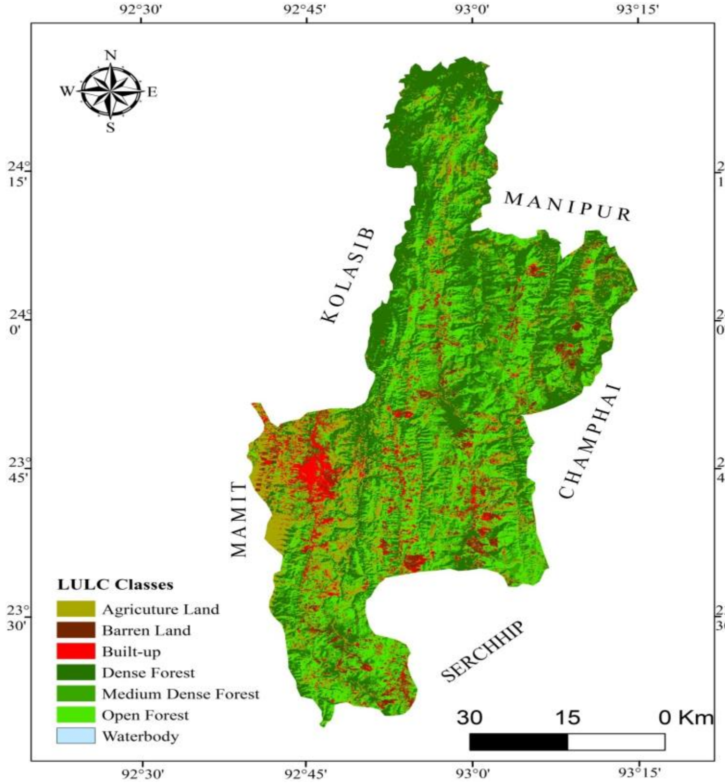

Figure 4: Land Cover in 2020

ISSN 2349-7831

International Journal of Recent Research in Social Sciences and Humanities (IJRRSSH)
Vol. 10, Issue 2, pp: (107-116), Month: April - June 2023, Available at: www.paperpublications.org

Table 2: Land cover change area.

LULC Classes	2000		2010		2020	
	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)
Agricultural Land	289.71	12.84	155.52	6.89	91.48	4.05
Barren Land	51.35	2.28	71.47	3.17	229.43	10.17
Built-up	511.63	22.67	857.59	38	997.26	44.19
Dense Forest	827.59	36.67	511.41	22.66	44.22	1.96
Medium Dense Forest	51.25	2.27	74.68	3.31	137.76	6.1
Open Forest	306.44	13.58	532.8	23.61	744.2	32.97
Waterbody	218.94	9.70	53.44	2.37	12.56	0.56
Total	2256.91	100	2256.91	100	2256.91	100

Table 3: Land cover changed dynamics

LULC Classes	Area Changed (2000-2010)	Changed (%)	Area Changed (2010-2020)	Changed (%)	Area Changed (2000-2020)	Changed (%)
Agricultural Land	-134.19	-5.95	-64.04	-2.84	-198.23	-8.78
Barren Land	20.12	0.89	157.96	7	178.08	7.89
Built-up	345.96	15.33	139.67	6.19	485.63	21.52
Dense Forest	-316.18	-14.01	-467.19	-20.70	-783.37	-34.71
Medium Dense Forest	23.43	1.04	63.08	2.79	86.51	3.83
Open Forest	226.36	10.03	211.40	9.37	437.76	19.40
Waterbody	-165.50	-7.33	-40.88	-1.81	-206.38	-9.14

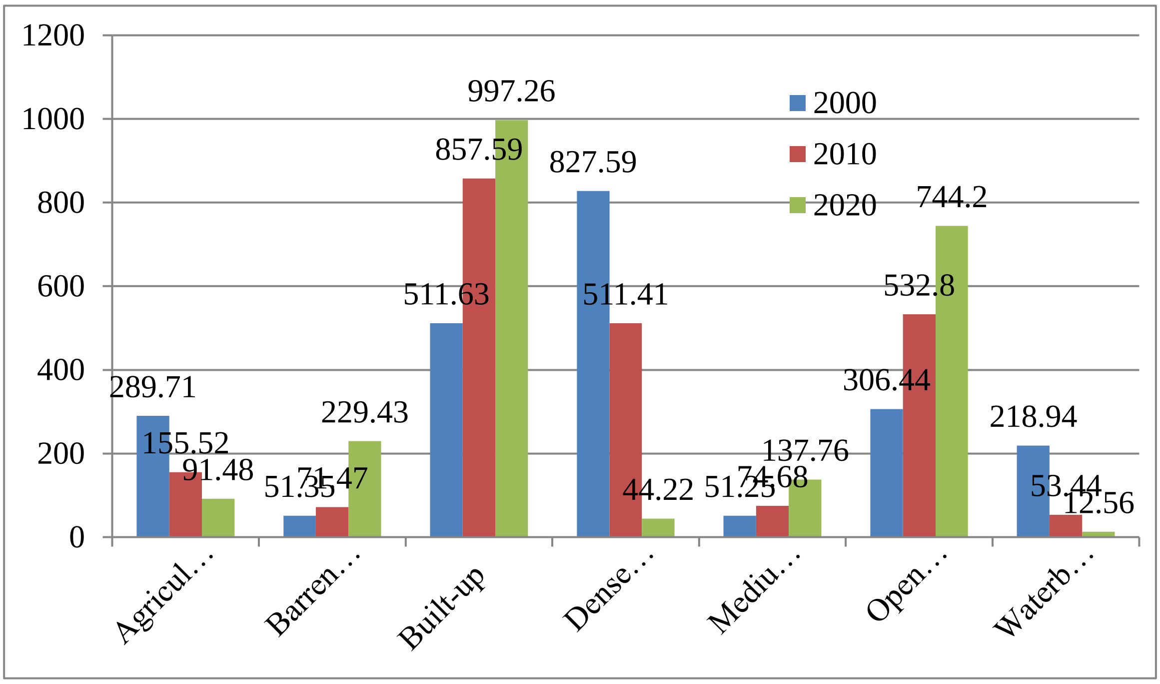

Fig. 5. Land use and land cover change

ISSN 2349-7831

International Journal of Recent Research in Social Sciences and Humanities (IJRRSSH)
Vol. 10, Issue 2, pp: (107-116), Month: April - June 2023, Available at: www.paperpublications.org

4. CONCLUSION AND RECOMMENDATIONS

For our way of life, the land is a crucial natural resource. Monitoring LULC changes can assist in planning and putting land cover preservation measures into action. The study uses ArcGIS software tools and Landsat TM 4-5 and 8 OLI/TIRS satellite photos to quantify and compute the change in Aizawl Districts land cover between 2000 and 2020. The society and ecosystem of this research area are significantly harmed by changes in land use. The shortage of agricultural land, greenery, and forests has been caused by the rapid urbanization of areas. Due to the growth of residential areas, the area used for agriculture, vegetation, and forests diminished, and this trend in land-use change impacted how people lived. Farmers and fishermen work in small businesses, drive auto-rickshaws, and do other related tasks. To enhance output, farmers utilized pesticides and hybrid seeds, which polluted the environment. Due to growth and overpopulation, wetlands and forests have been transformed into urban areas. Waterbody has also gotten fuller due to urbanization and farming. For the purpose of supplying fuel and infrastructure demands, trees are cut down. The data were processed and analyzed using GIS and RS before being utilized to build the map.

According to research, there have been changes to the forest, the vegetation cover, and the urban area, and the percentages are represented in table 2 and 3. These alterations demonstrate the impact of people on the studied region. Results give the line departments crucial information about the evolving LULC scenario. The study offers the following recommendations for managing and planning appropriate land use and land cover:

One of the sensible alternatives for rabi cropping in rice fallows would be to implement cooperative shallow tube well micro-irrigation facilities with pump sets. The economic benefits of crop rotation with short-term pulses (black gram, green gram, etc.) include lower fertilizer costs and improved soil quality.

Due to the difficulty in accessing irrigation water at high altitudes, hill agriculture is primarily rain-fed. However, by making wise fertilizer recommendations, high-yielding and short-duration rice varieties can be introduced with effective procedures. Short-term direct-seeded breeds of ahu-rice may be sown in rain-fed uplands and hills.

Short-term legumes, such as lucerne, glyricidia, etc., can be produced to preserve the long-term soil health of wastelands while also providing pasture crops for livestock.

Despite the region's favorable humid environment and adequate rainfall, it is regrettable to say that wasteful water use for agriculture, fisheries, and animal husbandry still exists in the area. The state soil and water conservation departments may promote the use of structural water harvesting devices, small ponds, or earthen dams to collect rainwater. One of the main obstacles to slowed agricultural growth is steep slopes in hills. Different terracing techniques, such as contour terraces, bench terraces, half-moon terraces, etc., are effective soil conservation methods. The implementation of need-based agricultural planning in priority areas based on soil quality, drainage characteristics, the intensity of crop growth, and the seriousness of erosion hazards may be further supported by various watershed development projects.

For the purpose of disseminating scientific knowledge and methods, the stakeholders may be encouraged to participate in practical demonstration/training programs, self-help group formation, farm management committees (FMC), etc.

The agricultural economy's sub-sector of animal husbandry, which offers gainful work, contributes significantly to the rural economy by benefiting small and marginal farmers, women, and agricultural laborers in particular. Smallholders in Assam are mostly responsible for raising livestock. The majority of rural households—nearly 90%—keep some kind of livestock. Traditional livestock farming has been mostly used for agricultural purposes. Agriculture operations come first, and milk production comes second. Although a few commercial dairy farms exist on the outskirts of cities and towns, there are very few commercial livestock farms in rural areas.

The insufficient market accessibility in terms of the availability of high-quality agricultural inputs and appropriate linkages to the farmers is one of the main agriculturally related restrictions in the research area. The provision of better seeds, planting supplies, food, livestock, vaccines, soil testing, agricultural extension, loans, and market facilities is crucial. Additionally, regulations for post-harvest management of agricultural, horticultural, animal husbandry, and fishery products with reasonable selling prices must be in place. For manufacturers to receive larger net profits with reasonable benefit-to-cost ratios, there must be a direct connection between the market and the consumers.

As a supplemental source of income, the state border department may encourage farmers to work in agriculturally related businesses such as apiculture, rural crafts, sericulture, mushroom production, floriculture, etc.

In the research area, afforestation programs have been implemented due to the degradation of forest lands and the areas surrounding them. As part of afforestation projects, several commercial tree species are planted in public or private plantations, including plantations of teak, Michelin, gamari, and toona.Also, recovering the badlands through afforestation programs is conceivable. Also suggested plants for this framework incorporate Albizia procera, Ficus spp., Grevelia robusta, Gmelina oblongifolia, and others. As part of such programs, additional native tree species may be planted locally.

With the optimal use of available farm-level resources, the agricultural productivity of the region will undoubtedly increase significantly with the use of modern farm mechanization techniques and proper extension services. The necessity of the hour is to design forward-looking land-use strategies as well as monitor and maintain the quality of natural resources while keeping in mind the link between the land, man, and animals as well as the production vs consumption situation for food.

REFERENCES

[1] Archana, Sandeep, K.K. (2013). Land use / Land cover mapping of IGNP Command area in Bikaner District of Rajasthan. *Int. J. of Engineering Science & Research Technology*. 2(2):209.

[2] Belal, A. A., and Moghanm, F. S. (2011). Detecting urban growth using remote sensing and GIS techniques in Al Gharbiya governorate Egypt. *Egyptian Journal of Remote Sensing and Space Science*, 14(2):73-79.

[3] Chandrashekhar, M.B., Sarnam S., Roy, P.S. (2003). Geospatial modeling techniques for rapid assessment of phytodiversity at landscape level in western Himalayas, Himachal Pradesh. *Curr. Sci*. 84:669.

[4] Chavez, P., Sides, S. C., and Anderson, J. A. (1991). Comparison of three different methods to merge multiresolution and multispectral data- Landsat TM and SPOT panchromatic. *Photogrammetric Engineering and Remote Sensing*, 57(3):295-303.

[5] Chishugi, D. U., Sonwa, D. J., Kahindo, J., Itunda, D., Chishugi, B., Losembe, F., and Sahani, M. (2021). How Climate Change and Land Use / Land Cover Change.

[6] Das, N., Mondal, P., Sutradhar, S., and Ghosh, R. (2021). Assessment of variation of land use/land cover and its impact on the land surface temperature of Asansol subdivision. *Egyptian Journal of Remote Sensing and Space Science*.

[7] Fu, Q., Jiang, Q.,and Wang, Z. (2012). A comprehensive evaluation of regional agricultural water and land resources carrying capacity based on DPSIR concept framework and PP model. *IFIP Advances in Information and Communication Technology*, 370(3):391-398.

[8] Khan, R., and Jhariya, D. C. (2018). Assessment of land-use and land-cover change and its impact on groundwater quality using remote sensing and gis techniques in Raipur City, Chhattisgarh, India. *Journal of the Geological Society of India*, 92(1):59-66.

[9] Kushwaha, S.P.S., Suchismita, M., Hari, P.V., Suresh, K. (2010). Sustainable development planning in Pathri Rao.

[10] Lallianthanga, R.K., Goswami, D.C. (1997). Land Use satellite mapping of land cover patterns in Mizoram, India : A case study of Serchhip rural development block, Aizawl district. *Indian Journal of Landscape Sys. & Eco. studies*. 20:64-68.

[11] Lallianthanga, R.K., Goswami, D.C. (1998). Satellite Mapping of Shifting cultivation in Mat Watershed, Aizawl District, Mizoram : An Agro- Environmental perspective. *Proc. of NAGI's (En.Region) National Conference on Environment & Sustainable Development*.

[12] Lambin, E. F., Geist, H. J., and Lepers, E. (2003). Dynamics of land-use and land-cover change in tropical regions. *Annual Review of Environment and Resources*, 28(4):205-241.

[13] Li, Z., Deng, X., Huang, J., Zhang, R., and Huang, J. (2013). Critical studies on integrating land-use induced effects on climate regulation services into impact assessment for human well-being. *Advances in Meteorology*, 41(2).

[14] Lu, D., Weng, Q.A. (2007). Survey of image classification methods and techniques for improving classification performance. *Int. J. Remote Sens*. 28:823-870.

[15] Lucas, R., Rowlands, A., Brown, A., Keyworth, S., and Bunting, P. (2007). Rule-based classification of multi-temporal satellite imagery for habitat and agricultural land cover mapping. *ISPRS Journal of Photogrammetry and Remote Sensing*, 62(3):165-185.

[16] Meyers, M. (1994) sub-watershed using geospatial techniques. *Journal of Communication*.

[17] Nagendra, H., Southworth, J., Tucker, C. (2003). Accessibility as a determinant of landscape transformation in western Honduras: linking pattern and process. *Lands Ecol* 18:141-158.

[18] Prasad, G., and Ramesh, M.V. (2018). Spatio-Temporal Analysis of Land Use/Land Cover Changes in an Ecologically Fragile Area—Alappuzha District, Southern Kerala, India. *Natural Resources Research*, 28(2):31-42.

[19] Rawat, J. S., and Kumar, M. (2015). Monitoring land use/cover change using remote sensing and GIS techniques: A case study of Hawalbagh block, district Almora, Uttarakhand, India. *The Egyptian Journal of Remote Sensing and Space Science*, 18(1):77-84.

[20] Richards, J.A. (1996). Classifier performance and map accuracy. 57(3):161-166.

[21] Riebsame, W.E., Meyer, W.B., and Turner, B.L. (1994). MODEL-ING LAND USE AND COVER AS PART OF GLOBAL ENVIRONMENTAL CHANGE. *Climatic Change*, 28(10):45-64.

[22] Riggio, J., Kija, H., Masenga, E., Mbwilo, F., Van de Perre, F., and Caro, T. (2018). Sensitivity of Africa's larger mammals to humans. *Journal for Nature Conservation*, 43:136-145.

[23] Sati, V.P. (2014). Land-use/cover changes in the kewergadhera sub-watershed, Central Himalaya. In: Grover VI (eds) Impact of global changes on mountains, CRC Press, Taylor & Francis Group, 298-311.

[24] Su, X., He, C., Feng, Q., Deng, X., and Sun, H. (2010). A supervised classification method based on conditional random fields with a multiscale region connection calculus model for SAR image. *IEEE Geoscience and Remote Sensing Letters*, 8(3):497-501.

[25] Teixeira, Z., Teixeira, H., and Marques, J. C. (2014). Systematic processes of land use/land cover change to identify relevant driving forces: Implications on water quality. *Science of the Total Environment*, 11(3):470-471.

[26] Trung, N.H., Le, Q.T., Mensvoort, M.E.F., Bregt A.K. (2006). Application of GIS in land-use planning, a case study in the coastal Mekong Delta of Vietnam. In: Proc. International Symposium on Geoinformatics for Spatial Infrastructure Development in Earth and Allied Sciences, Ho Chi Minh, Vietnam.

[27] Tucker, C.J., Townshend, J.R., and Goff, T.E. (1985). African land-cover classification using satellite data. Science, 227(4685):369-375.

[28] Wang, C., and Chang, H.T. (2020). Hotspots, heat vulnerability and urban heat islands: An Interdisciplinary Review of Research Methodologies. *Canadian Journal of Remote Sensing*, 46(5):532-551.

[29] Xiubin, L. (1996). A review of the international research on land use/land cover change [J]. Acta Geographica Sinica, 6.

[30] Zha, Y., Gao, J., and Ni, S. (2003). Use of normalized difference built-up index in automatically mapping urban areas from TM imagery. *International Journal of Remote Sensing*, 24(3):583-594.