Research Article
Volume 15:1, 2025

Journal of Civil and Environmental Engineering

ISSN: 2165-784X
Open Access

Geo-Spatial Approach Urban Expansion Land Use Change and Prediction Using (QGIS) Plugin Model in Wukro, Tigray Region, Northern Ethiopia

Fikre Hagos[1*], Daniel Teka[2], Mewcha Amha[1] and Gebreyohanns Zenebe[3]

[1]Department of Geo-Informatics, Institute of Geo-Information and Earth Observation Sciences (I-GEOS), Mekelle University, Tigray, Ethiopia

[2]Department of Land Resources Management and Environmental Protection (LaRMEP), College of Dryland Agriculture and Natural Resources, Mekelle University, Tigray, Ethiopia

[3]Department of Environmental Protectio, Institute of Climate and Society, Mekelle University, Tigray, Ethiopia

Abstract

Urban expansion is a spatial phenomenon that was indicates population growth, economic expansion, the importance of life on town/city etc. The use of current and historical data in urban expansion analysis is necessary in urban spatially and temporally using remotely sensed data, GIS and statistical relative data's. Four Landsat images (*i.e.* 1985, 1995, 2005, and 2015) TM, ETM+, and OLI sensors data used to determine urban expansion land use change The images were classified using ERDAS Imagen Maximum Likelihood supervised classification technique. The LULC classified into built-up area, cultivated lands, plantation, rivers and shrub land. The overall classification accuracy was 86.0% for 1985, 86.4% for 1995, 87.32% for 2005 and 89.32% for 2015. To demonstrate the reliability of the MOLUSEC QGIS model were implemented to analysis an urban expansion trends, urban expansion simulated process sand pattern in the study area. The obtained results provide a good rule for modeling urban expansion process, understanding urbanization contributing factors and predicting the future patterns. Furthermore, the resulting the current paper to be used for decision makers and urban planners to identify past and present urban expansion trends to prepared for the future urban demands. Finally, using the same model the urban expansion will simulated for 2025. Accordingly, the built-up area of town predicted to be 585 ha for 2025.

Keywords: Urban expansion model • MOLUSCE • QGIS

Introduction

The process of urban expansion may involve both horizontal and vertical expansion of the physical structure of urban areas. And it can result in loss of agricultural land, natural beauties, range lands, parks and sceneries [1]. The rate of urbanization is very fast in developing countries than developed. This can be more explained when we compare the current urban expansion rate with the historical trends and the urbanization rate of developing countries with that of developed countries to note their difference in rate of growth [2]. Ethiopia has a 2.3% of annual growth rate and having 4.6% average annual urban growth rate [3]. A study conducted by Dejene N [4], hypothesized that because farmers in peri-urban area of Sebeta town constrained with scarcity of land for widely engage in agricultural activities. Those studies were concluded that the land security among peri-urban farmers who possess land near by the town and a prediction to loose in the future due to further expansion of the town. Some farmers located near to the town was sell their agricultural land to low prices for urban settlements expropriation. Therefore, the peri-urban communities dominated by low-income earners that rely on resource from rural areas and cities in constructing their livelihood. Wukro is one of the fastest expanding towns in Tigray, where this study conducted, has also experienced greater changes. This ongoing expansion process captures the views of peripheral farmers who affected to leave their farmland and property. Recent in GIS and remote sensing tools and methods enable researchers to model and predict urban expansion more efficiently than traditional approaches. However, urbanization in the developing world in overall is progressing much faster than in developed countries, which may reach 3% or even 4% a year [5]. The fast rate of urbanization in developing world would attributed to rural–urban migration, economic

***Address for Correspondence:** Fikre Hagos, Department of Geo-Informatics, Institute of Geo-information and Earth Observation Sciences (I-GEOS), Mekelle University, Tigray, Ethiopia, Tel: 251914123470; E-mail: fikergis@gmail.com*

Received: 17 January, 2024, Manuscript No. JCDE-24-125173**;** **Editor assigned:** 22 January, 2024, PreQC No. JCDE-24-125173 (PQ); **Reviewed:** 06 February, 2024, QC No. JCDE-24-125173; **Revised:** 18 February, 2025, Manuscript No. JCDE-24-125173 (R); **Published:** 25 February, 2025, DOI: 10.37421/2165-784X.2025.15.585

growth and development, technological change, and rapid population growth (6). Ethiopia is one of the least urbanized nations in the world. It has only 16% of its population living in urban centers [6]. Therefore, the effect of this process of urban expansion on the surrounding farming community needs to be clearly identify in order to reduce the negative impacts for the futures. Because, having accurate, timely and reliable information about the spatial and temporal urban expansion land use provides better information for urban planners and decision makers to design strategies and solutions to manage the impacts of land use and land cover changes.

The objectives of this study was to quantify and map LULC change due to urbanization between 1985 up to 2015, to examine the key drivers for urban expansion growth in the study area, to assess the perception of dislocated rural people from their farm lands around Wukro Town and Predict study area urban expansion for next 2025. According to Rahman [7], an open source QGIS plug in (MOLUSCE), is a new approach for urban simulation design to analyze, model, and simulate land use/cover changes. The plugin incorporates well-known algorithms, which can have used land use/cover change analysis.

Materials and Methods

Description of the study area

Wukro town is located in the northern part of Ethiopia between latitude of 13°45’ to 13°49’ N and longitude of 39°34’ to 39°37’ E (Figure 1). The elevation ranges from 1935 to 2138 m.a.s.l. The minimum and maximum daily temperature ranges between 13°C to 28°C respectively with its averages of 20.5° C and the average annual rainfall is between 81,177.2 mm, and the study area coverage 2021.04 hactare. The town is 820 km far from Addis Ababa and 46 km from Tigray regional State capital Mekelle city on the main highway that continues northward direction through Adigrat Axum and Shire.

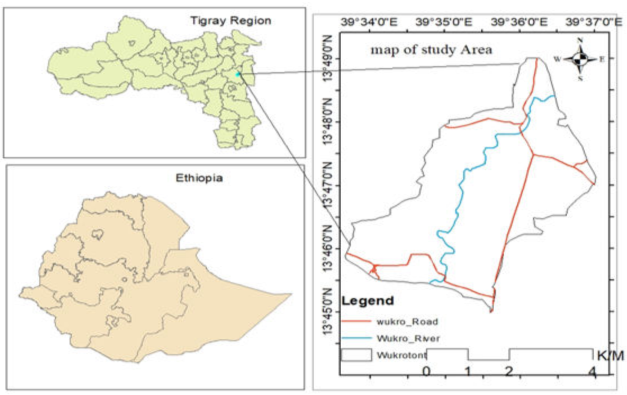

Figure 1. Location of study area.

Data collection and analysis

In this study, both primary and secondary datasets were collect.

Primary data: Ground truth points, as an input for image classification and accuracy assessment, were collect using Global Positioning System (GPS) from the ground. In addition, open and close ended questionnaire, structure and semi-structured interviews, Focus Group Discussions (FGD), field observation with the displaced farmer and municipality experts, civil administration experts and community leaders were conducted. The FGD members selected from influential elders purposely based on their approaches and experience and impacts of farmlands for urban expansion.

Secondary data: In LULC change detection studies, appropriate selection of imagery acquisition dates is an integral component of the analysis. Then, cloud free Landsat data (1985-2015) with 30 m × 30 m resolution downloaded from United States geological survey free after registration. The Landsat imagery of the study area includes Landsat Thematic Mapper (TM) imagery for (1985 and 1995), Enhanced Thematic Mapper plus (ETM+) for 2005 and Landsat 8 (OLI) for 2015. A Six of the existing spectral bands (1, 2, 3, 4, 5 and 7) were included in the analyses due to their constant spatial and spectral resolutions for the years 1985, 1995, and 2005. The thermal band (Band 6) omitted because of its lower spatial resolution. In addition, Landsat 8 Operational Land Imager (OLI) consists of eleven spectral bands with a spatial resolution of 30 meters for Bands 1 to 7 and 9 for the year 2015 were included in the analysis (Table 1).

Path/Row	Sensors	Acquisition date/year	Resolution (m)	Sources
168/051	Landsat 4-5 TM	7-3-1985	30 m	USGS

168/051	Landsat 4-5 TM	15-03-1995	30 m	USGS
168/051	Landsat 7 TM+	20-03-2005	30 m	USGS
168/051	Landsat 8 TM	18-03-2015	30 m	USGS
168/051	SRTM DEM	20-03-2015	30 m	USGS

Table 1. The path/row, sensor, acquisition dates, resolution images used in the study.

Image classification

Remote sensing image classification is a relevant method that can provide information on the extent and rate of urban expansion [8]. ERDAS Imagen 2014 software were used for the land use land cover change image supervised classification the ground control points were collected in the field of observation for taken training sample set, for classification is created using the combination bands (stake Images) for the 1985, 1995, 2005, and 2015 images. We used maximum likelihood classification it assumes the statistics for each class in each band were normally distributed and calculated the probability that a given pixel belongs to a specific class. Accordingly, the images classified for the particular years with five-land use class (namely built up, cultivate land, plantation, river and shrub land). Once the homogeneous, intermediate, and heterogeneous areas defined, supervised classification performed on each of.

Supervised classification ground control points collected from the field were used as a training sample set and it was created using the combination of bands 5, 3, 2 (for the 2015, 4, 3 2 (for 1985, 1995 and 2005) images since these band combinations allow visualization of the image in false colors. For 1985, 1995 and 2005 image were used for ground truth points collectors accordingly a request for the community they were lived on the study area from 1980 until now, and Google Earth referenced as back site for verification of the land use change. Therefore, we used to the most popular and widely types of image classification technique in remote sensing Maximum Likelihood (ML) classification methods.

Post classification This method was simple and obvious for land change detection constructed on the comparison of independently image classification initially (1985 to 1995, 1995 to 2005 and 2005 to 2015). Classified images were often clearly desirable to smooth the classified output to show only the dominant classified classes [9]. Maps of classified land use changes can have produced by the researcher, which shows a complete matrix of changes from times one to time two. Based on this matrix, if the corresponding pixels have the same category label, the pixel has not been changed, or else the pixel has been changed [10].

Accuracy assessment was the final stage of image classification process, it was considering as basic part of any image classification and general term for comparing a classification to geographical data that were assume to be true, in order to determine the accuracy of the classification process [11]. The comparing a land use map produced using remote sensing imagery to a reference/ground truth GPS point for each land use classes can perform it. During the field, 200 ground truth points for 1985, 388 for 1995, 504 for 2005, and 824 for 2015 points collected. Accordingly, 75% from the total ground truth points used for image classification and the remaining 25% for accuracy assessment.

Land use land cover change analysis after classified the Landsat images using supervised techniques and measuring the classification accuracy, LULC change analysis carried out. Change statistics was compute by comparing image values for the periods 1985-1995, 1995-2005, 2005-2015, and 1985–2015 calculated based on Long K [12]. Land cover change equation, *i.e.*, The gain values computed by subtracting the persistence value from the total area of final year and the loss value also computed by subtracting the persistence value of the total area of the initial year. The net change was calculate as the difference between gain and loss. The values presented in terms of hectares and percentages. The percentage LULC changes calculated using the following equation.

percentage of LULC change=(Area final year-Area initial year)/ Area initial year × 100)

Where: Area was extent/coverage of each land use land cover types. Positive values suggest an increase whereas negative values imply a decrease in extent areas. The LULC change rate was computed using the following formula suggested by Schulz et al.

$$R=(1/\Delta t) \ln (A_2/A_1) \times 100$$

Where r is the annual rate of change in %, Δt is the time interval in years during the LULC change being assessed, In is the base of the natural logarithm function, and A_1 and A_2 are initial and final LULC areas respectively.

Preparation of input data for molusec model is an open Source software it is well suitable to analyzing land use land cover change among special time. The model land use/cove transition potential or regions to simulate land use modifications in this study, to detect the change of land use between two periods that means the initial time and final times using dependent variable and independent variables.

Dependent variables in the Model are to prepare the LULC change maps for the year of 1985, 1995, 2005 and 2015 used as dependent variables to carry out the logistic regression model analysis. Those maps classified in to five-land use class. The conversion rule based on the assumption that land cover change from cultivated land to built-up area.

Slope analysis according to Triantakonstantis G [13], low slopes make suitable to urban expansion and road construction or less expensive. Consequently, in most cases the slope <15% are mostly taken as suitable for urban expansion construction, and slope >15% are unsuitable. Therefore, from the range 0-5% slope that indicated less slope and more suitable to expanding build up area 5-10% slope is moderate suitable 10-15% slope less suitable area and >15% sloped areas were unsuitable area for urban expansion.

Road analysis road accessibility is one of the important parameters for urban growing as it provides linkage between the settlements. The distance to existing urban area was important because the significantly affect moving costs, the locations must be adjacent to built-up areas (existing neighborhood), in the low-density population areas, within 30-40 m from the center of the major road [14]. According to WTM office of Wukro Town municipality office the proposed urban expansion sites should not be far away from 30 meters from the centers roads. Therefore, in the study straight-line distance with maximum 30 m is calculated and reclassified accordingly.

Independent variable four independent variable were prepared from the STRM-DEM-30 m those are Slope map, distance from the main road, distance from River and population density of the study areas.

Model prediction and validation for lulc at last phase, the model run for land change prediction to a specified next year for land cover changes for urban expansion. MOLUSCE QGIS plug in model been run for to determine the amount of land use change using the two years' land use map 1995 and 2005. The method examine accurately how much land use would be expected to transition from the later year (2005) to prediction year (2015) based on a simulation of the transition potentials into the future transition probabilities data. Thus, a map for 2015 of study area has been simulate in order to compare with the actual land cover map of 2015. Finally, the validation process, which allows to determining the urban expansion prediction land use map in relation to a map of reality (Figure 2). Modeling of LULC changes for future time is important to know the possible scenarios.

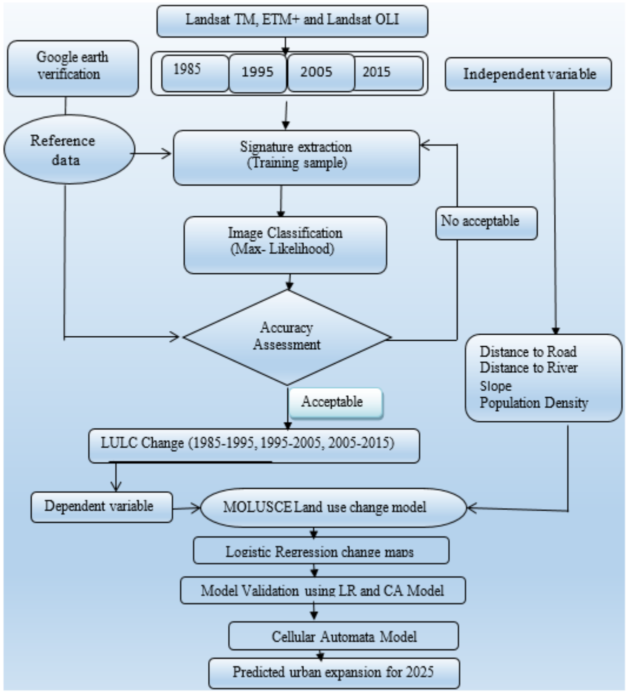

Figure 2. General methodology flow chart.

Results and Discussion

General background of the respondents

This par to deals with the description of general characteristics of sample respondents from; farmers, who were dislocated from their farmlands, key informants who were interviewed and others deal with the official administrative/experts response to the questionnaires, Focus Group Discussions (FGDs), interviews and some others also deal with the official (municipal) document analysis for last 30 years (1985-2015). As we see in Table 2, of the respondents 40 (61.5%) indicated that the male and the rest and 25 (38.5%) were female share taken the majority of the sample respondents were males.

Age of respondent's	Frequency	Percent
20-30	11	16.92%
31-40	16	24.60%
41-50	18	27.69%
>51	20	30.77%
Total	65	100

Table 2. Household heads respondents.

Land use land cover for urban expansion (1985-2015)

The urban expansion LULC in 1985 was classify for urban expansion in to five class these are built-up area, cultivated land, plantation, and River and Shrub lands. As clearly shown in (Figure 3A), the LULC classification results of the study area in 1985 were. Built-up Area, cultivated land, plantation, River and shrub lands were with 143.01 ha (7.64%), 1490.4 ha (73.73%), 171.32 ha (8.48%), 62.14 ha (3.07) and 154.53 ha (7.07%) respectively.

Urban expansion in 1995 the land cover in the year of 1995 show that the proportion of LULC for Cultivated lands 1469.21 ha (72.70%), built up area 169.2 ha (7.69%), plantation area 165.51 ha (8.19%), river 61.8 ha (8.37%) and shrub lands 155.32 ha (3.06%). The results of LULC for 1995 (Figure 4B), shows that, built up areas were increased and the cultivated lands were decreased from the period of 1985. The rate of increment was greater in the Built up areas. While the remaining land use classes such as plantation, river and shrub lands show general trend of decrease in the period 1995.

Urban expansion in 2005 in the year of 2005, the area of built up coverage was 229.23 ha (11.34%) of the total area and cultivated, lands account 1405.8 ha (69.5%). The remaining land category is under the plantation, River and shrub lands 165.3 ha (8.18%), 59.58 ha (2.93%), 162.52 ha (8.04%) respectively. The results of LULC show that the area under cultivated lands and plantation coverage declined in the period of 2005 whereas the built-up area shows an increasing trend in Figure 5. Moreover, resettlement policy was takes place throughout the country in 1989 and 1990 for the urban land management as well as to provide better infrastructure facility. This high population growth was one of the major factors for urban expansion of town.

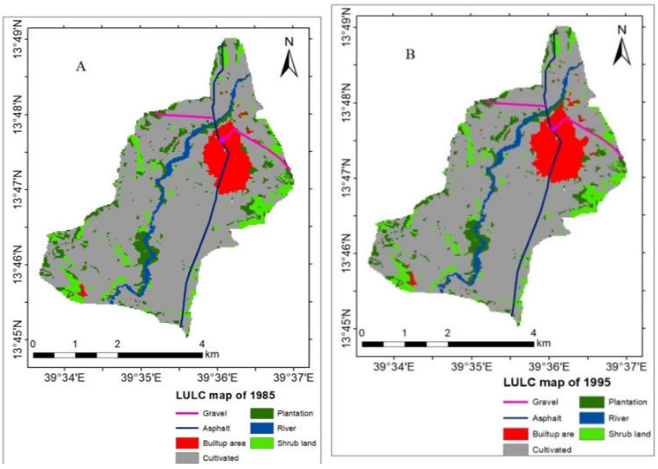

Figure 3. LULC change map (A) for 1985 and (B).

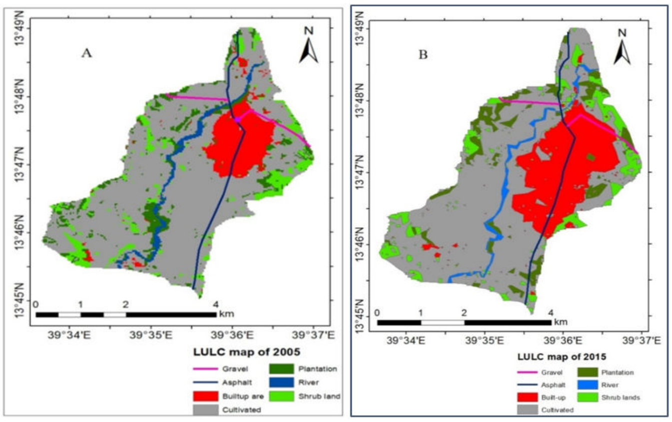

Figure 4. A) LULC map of 2005 and (B) LULC map of 2015.

Urban expansion in the period of 2015 the built-up area covers 470.70 ha (23.29%) of the total area and cultivated lands cover 1169.73 ha (57.9%), plantation 152.82 ha (7.56%), river 52.47 ha (2.6%) and shrub lands 175.32 ha (8.67%). In the year 2015, it well noted that the cultivated lands, plantation and rivers decreased, while built-up and shrub lands were increase as compared from the year of 1995. The increment of Built up area was due the urban expansion which was started in 1985 to 2015 urbanization was due the rise of population pressure show in Figure 5.

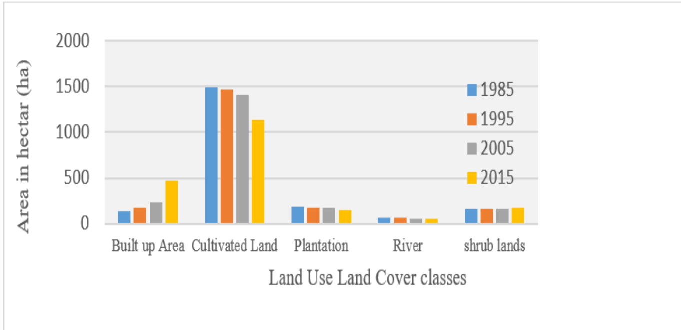

Figure 5. LULC change map for 2015.

The overall LULC change patterns, area in hectares, and percentage coverage of wukro town between 1985 and 2015. According to Hasan, most of residents depend on farming lands, these low income and poor groups contribute to forming productions [16]. Even though urban expansion on the fringe areas has rapidly, expanded but municipal office cannot give enough attention and financial resources to pay the farming communities. Hence, the results were gotten and analyzed, from the land use classes for the various years indicted that the area was undergoing obviously rapid urbanization as the study Adjacent and to a large extent to corroborated by the socio-economy survey [17]. Therefore, in this year of 2005-2015 was high urban expansion because it had a high demand for urban settlements and investment areas (Table 3).

Land use class	1985		1995		2005		2015	
	Area (Ha)% coverage		Area (Ha)% coverage		Area (Ha)% coverage		Area (Ha)% coverage	
Built up area	143.01	7.64	169.2	7.69	229.23	11.34	470.7	23.29
Cultivated land	1490.4	73.73	1469.21	72.7	1404.3	69.5	1169.73	57.9
Plantation	171.32	8.48	165.51	8.19	165.41	8.18	152.82	7.56

River	62.14	3.07	61.8	8.37	59.58	2.93	52.47	2.6
Shrub lands	154.53	7.07	155.32	3.06	162.52	8.04	175.32	8.67
Total area	2021.04	100	2021.04	100	2021.04	100	2021.04	100

Table 3. The LULC change map 1985-2015.

Accuracy assessment

To produce of LULC maps from the Landsat imageries were validate by created confusion matrices from which producer accuracy, user's accuracy, overall accuracy and kappa coefficient (k) were compute. Based on the supervised classification results for the year 1985, 1995, 2005 and 2015 we taken 50, 97, 126 and 206 ground truth points from the total ground truth collected 200, 388, 504 and 824 ground truth data 25% from the total GCP point of each land use used for the accuracy assessments. The overall accuracy performed for each study period was 86%, 86.46%, 87.30 and 89.32%respectively. As mentioned by Anderson JR [18], for a reliable land cover classification, the minimum overall accuracy value computed from an error matrix should be greater than 85%. Therefore, the overall accuracies for both maps were above 85% based on Anderson's criteria show the below (Table 4).

Years	Overall accuracy	kappa
1985	86.00%	0.77
1995	86.40%	0.75
2005	87.32%	0.77
2015	89.32%	0.84

Table 4. All accuracy assessment of the LULC maps 1985, 1995, 2005, and 2015.

Urban expansions trends and direction using the satellite images of 1985, 1995, 2005 and 2015 it was possible to identify the trend of urban expansion in the study area. It was established and expanding on a flat area, mainly to the direction of south West, south, and east directions. Spatially the land use change from the year 2005 to 2015 was dramatically the built up was increased as compared from the previous year trends of 1995 to 2005 shown in Figure 6. To define pattern of changes in built-up area directional changes were worked out in built-up area from the cross junction of the town. During the last decade, the town has been expanded 470.70 ha towards the southern direction. So, using GIS and Remote sensing technology to know where directions, how much the area coverage was transformed from rural to urban.

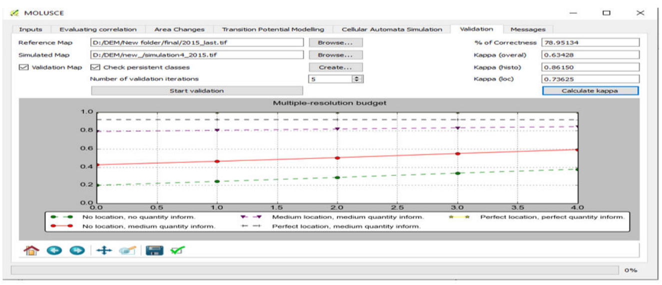

Figure 6. Urban expansion trend direction map for 1985-2015.

The rate of built-up area extraction the rate of urban expansion for the specified periods was calculate using the method devised by Mohan et al., The rate of urban expansion from 1985-1995, 1995-2005, and 2005-2015 was 18.144%, 35.48%, and 104.35% respectively. From this result, we can accomplish the rate of urban expansion (Built up) from 1985 to 2015 with an interval of 10 years was rapid (0.04%, 3.66%, and 11.9%). However, the cultivated lands and plantation areas decreased. The amount of change increased gradually from 143.01 ha to 470.70 ha (1985-2015) (Table 5).

Year	Urban expansion rate	Rate of urban expansion (%)
1985	143.46	1995–1985, 2005–1995 and 2015–2005
1995	169.47	18.13%
2005	229.59	35.46%
2015	470.7	105.02%

Change (ha/Year)

Table 5. Urban expansion in (%) in (1985–2015).

Impact of urban expansion on farming community

As to responses from the sample respondent, document analysis as well as scholars, there are many impacts of urban expansion to its periphery prime agricultural farmlands. Has been pointed out, it was advising to participate the stakeholders in a development programs. In this regards, as (Table 6) shown, about sixty-two (95.4%) of the respondent households were a lost agricultural lands for urban expansion program and three (4.6%) of the respondents were not lost own lands they said that we were rent from another farmer. In question 2 the respondents indicated that sixty-one (93.8%) said that yes, four (6.2%) indicated that no the reason was they said we were do not participated on urban expansion program because we are under Wereda Kilte-Awlaelo Administration.

Variables	Frequency		Percent%
Do you lost your agricultural land for urban Expansion?	Yes	62	95.40%
	No	3	4.60%
	Total	65	100%
	Yes	61	93.80%
	No	4	6.20%
	Total	65	100%

Table 6. Impact of urban expansion on farming community.

Displacement farmers from

Their farmlands according to the available documented from the office of municipality and authorities were contributing in the process of expropriation of farmlands in the study area on the past three decades' years (1985-2015). The cultivated land coverage decreased by 320.67 ha in the given periods. However, the urban expansion was highly increased to 470.70 ha (23.29%). Hence, as indicated the sample household respondents most of the displaced farmers lost their frame lands for urban expansion. Then, we taken selected 78-sample farmer households from the surrounding areas that farm household's (512) were display from their farmlands due to the urban expansion process between the years of 1995 to 2015. Therefore, we can imagine how much farmland going in leased from the farmers and how many household going to displaced in this study area. As we can show in Table 7 from the total household conducting survey sixty-eight (87.2%) of the respondents were displaced from their farmlands, one (1.3%) were displaced from they were rented from other farmers, six (7.7%) also from family, three (3.8%) no farming land but, they worked in farmer's households. As pointed out by Donnay A [19], farmers have no more other sources of incomes other than their farmland. For this reason, several farm households (farmers) who have lost their farmlands were becoming jobless. According to him, there is no yet a social security system for farmers displaced from their farmlands. Finally, those who represented in missing value indicate those farmers who have totally lost their farmlands and give way for urban land use. Thus, they earn their livelihood by engaging on daily labour and other alternative activities in the town. These households almost 96.2% from the total sample household were landowners.

Status	Frequency number	Percent
Own farm lands	68	87.20%
Rent farm lands	1	1.30%
Family farm lands	6	7.70%
No farm lands	3	3.80%
Total	78	100%

Table 7. Land ownership status of households.

Main drives for urban expansion in Wukro town

In Wukro town Urban, expansion process influenced by multitude of driving forces like geographical location, urban population growth, increased accessibility of public infrastructures and several economic opportunities were to forced rapidly expanded. One of the main drivers was urban population growth joined with unplanned rural-urban migration thinking better job opportunities, better income generation, and improved life styles and considering as modernization living in the towns especially for youngers [20]. Beyond this being, economic strategic location of the town for trading and other economic activities contributes its hand for the large number of population. This in turn leads for the expansion and construction of built-up areas either industrial or residential. Urban expansion and associated LULC changes resulted from a combination of geographical and socio-economic factors such as population growth, policy and economic development. Moreover, based on response of the key informants, the extension of urban infrastructures like roads and other public facilities has significantly demanded urban expansion to all direction of the town. Therefore, population growth of Wukro town can thought reason associated with urban expansion influx of population from neighboring wereda and peripheral rural villages. This is true for Wukro town in which urban population raised from 13045 to 45214 in 1984 and 2015 respectively. Proximity to Mekelle city Regional states and it was a center of training and meetings. The methods of urban land acquisition have its own impact on horizontal expansion of the town towards the periphery. Thus, population growth was certainly the greatest driving force in the observed land use/land cover dynamics particularly built-up areas. Another deriving factor for such high level of urbanization is the land ownership case.

Urban population growth (1985-2015) Population growth of Wukro town was fairly increase from 1985 to 1995. In 1985, the population was rising to 13045. This figure reached about 16421 in 1995. The result of 1985 census show the population of the town reached to 45,124. Data of past and current population trends and projecting population growth into the future helps to determine the level of municipal services needed for future growth. The population census data from Central Statistics Agency of Ethiopia used to calculate total population growth between 1985 and 2015. The current census for the town (2015) show that had a growth rate of 15.93% annually in average for the last 30 years ago (Table 8) presents population growth of the census years from 1994 to 2015. According to CSA data and office of finance Wukro data trends generally indicated persistence of high population growth in 1995 to 2005 year the causes was more peoples were immigrant from the surrounding of the Weredas, Tabias and from Eretria in the case of Ethiopian-Eritrean war.

Year	Absolute growth	Growth rate%	Annual growth rate%
1985	13045		
1985-1995	16421	25.88	2.59
1995-2005	30210	83.97	8.4
2005-2015	45124	49.37	4.94

Table 8. Population growth and annual growth rate.

Comparison of urban expansion and population growth

In urban population dynamics growth, the factors that were the population of certain area to change over time. These factors were fertility, mortality and migration. It is obvious that population growth has a direct relationship with urban expansion. In this case, when the population of the town in 1985 was 13045, the built up area of the town was 43 hectares. The population was increased to 16421 in 1995 similarly the built up was expanded to 169.2 hectare. In 2005 the population became 30210 and the built up was expand to 229.23 hectare and the population is bringing to 45214 in 2015 the built up area also expanding to 470.70.

From 1985-1995, the population of the town was increased by 25.88%, 1995-2005 it was projected to 83.97% and from 2005-2015 the population was increasing by 49.37%. Therefore, in 2015 year the built-up was very highly expansion that means more than 2 times than 1995-2005, the reason was high urban settlement demands and from the last 2005, most of the investors come to the town to invest in different investments. The town also a training center for government and non-government organizations. So, that more hotel and restaurants were constructed in the town. These factors, not only caused high population growth, but also the total area of the town was extended outward and became double bringing many changes in the existing land use of the town (Table 9).

Year	Built up (ha)	Urban population	Built-up growth (%)	Population growth (%)
1985	143.01	13045		
1995	169.2	16421	18.3	25.88
2005	229.23	30210	35.49	83.97
2015	470.7	45124	105.35	49.37

Table 9. Comparison of population growth and built up growth.

Model prediction for LULC changes to 2015 future urban expansion prediction in the area, based on the MOLUSEC QGIS plug integrated of cellular automata founded between 1995 and 2005, was used transitional potential modeling to prediction the future (2015) urban expansion changes. In addition, constraints and driver variables (factors) created for defining the rules highly affected the simulation results, as they are sensitive to small changes. We used such as slope, population density, distance from the river and distance from the road. The urban LU change trend detected when comparing the predicted land use map for the year 2015 with the actual LU map of 2005. Visual analysis of the predicted maps tells that urban/built-up areas were occurring at very high rate of growth. This is particularly true in the area surrounding the existing region. In order to better, understand the trend of the change in the future, the predicted land use maps were studies with reference to the class area metrics.

Model validation LULC change model is incomplete without validating real data. Consequently, the results of LU/LC simulated need to compared with actual map. The validation process of the model performed for the duration of 1995-2005. The candidate cells and their development status of 1995-2005 were first determined. For each candidate cell, the probability of change computed with the fitted model. Accordingly, the Open sources plugin (QGIS-MOLUSCE) model was validated by using two maps those the first one LULC change map or actual map of the year 2015, and the second predicted (simulated) LULC change map for 2015. The spatial variable area population density, distance from river, distance from main road and slope of the study an input variable to use for predicted urban expansion 2015. Therefore, to comparison of the actual LULC map for the year 2015 with the cellular automation simulated map based on the Kappa statistic value show in Figure 7, as well as a comparison of each area of the simulated LULC types used for model validation. Between 2015, actual map and simulation map show that there was good agreement between the predicted map result and the actual map value of the LULC types for the base year 2015. Furthermore, a visual interpretation of the simulated map and actual maps for the year 2015 demonstrates that was similarity between the two maps these results indicate that the Cellular Automata model was effective simulating LULC change in 2015.

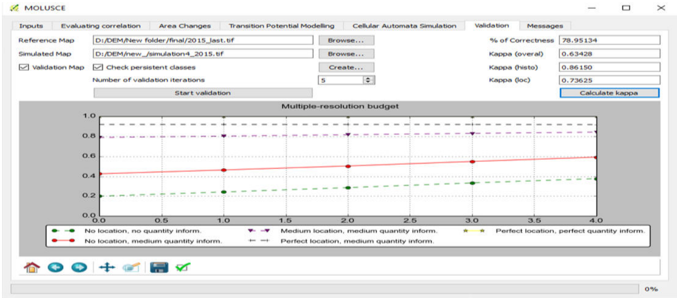

Figure 7. MOLUSCE model validation for 2015.

Model validation refers to comparing the simulated and reference maps. In that case, it is necessary to validate the projected/simulated map with the base/reference map. Therefore, model validation was an important step in case of prediction land change modelling. The accuracy of the model has been illustrating by the output image where it computed and specified both successes and incorrect alarms. Therefore, the accuracy of the model was in logistic regression 78% as shown below Table 10 in this specific study area.

Simulation methods	% of correct prediction	Kappa
Logistic Regression	78.95	0.86

Table 10. Kappa statistics for 2015.

Transition matrix for 1995 to 2005 Lu change was most of the agricultural land use would converted to urban expansion. The integration of the LULC modeling approach, remote sensing data, demographic and independent variable data can professionally use to simulate the future urban expansion LULC change. Hence, the urban expansion phenomena in spatial distribution, direction, and time can be monitored and the transition probability rates, proposed by the MOLUSCE plug applications. The (Table 11) showed transition matrix which presented the replaced of land use to other land use. The highest probabilities of change, at (0.539275), are that transport converted to residential area, while the lowest probabilities presented in lake. Cultivate area has been replaced by urban land use activities such as Built up (0.0810) and plantation (0.0810). While it replaced from river may due to Built-up (0.0210). Some shrub lands replaced into urban area uses (0.0564). Urban expansion has led to rapid land use change and contributes to remarkable increase of residential areas from this situation happened due to the regeneration of urban land use in Wukro town (1995 to 2005) 10 years. Therefore, according to Triantakonstantis M the model was very good agreement between the actual and predicted 2015 land use with kappa of 0.73.

	Built-up	Cultivated	Plantation	River	Shrub lands
Built-up	0.917415	0.065379	0.010897	0.000382	0.00592
Cultivated	0.083608	0.847127	0.037662	0.016568	0.015034
Plantation	0.089097	0.40211	0.388042	0.09027	0.030481
River	0.02916	0.57976	0.075472	0.313894	0.001715
Shrub lands	0.056395	0.539275	0.067472	0.005035	0.331823

Table 11. Transition matrix for land use change 1995 to 2005.

Actual base maps *vs.* simulated maps in this section, the comparisons between the actual based map of (2015) and simulated maps of year 2015 performed. The main objective of model validation was to find out whether the simulation is giving any abrupt results or not. This justifies the Modelling output in terms of reality. For validating the simulated maps, two different approaches have adopted. The first one is visual approach. This approach helps to reveal the spatial patterns in a fast look. The visual approach is subjective show in Figure 8A and B.

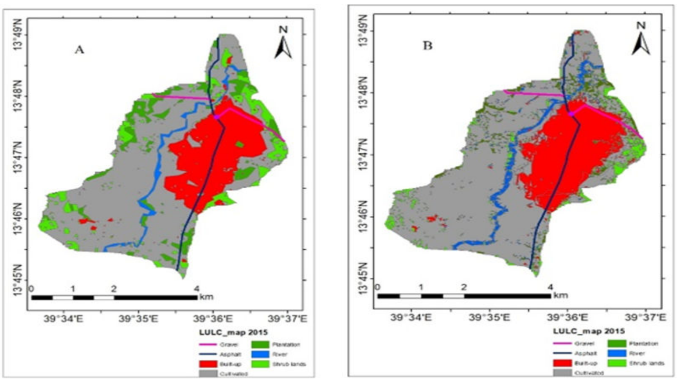

Figure 8. (A) Actual LULC map for 2015 (B) Simulated LULC map for 2015.

Another one is statistical approaches this approach is important because it explains the state in a quantitative way. The simulation land use change map although, adjacent had been greatly expansion of built up areas, however, the conversion between other land cover classes was limited. This had been related to the power of driving variables united in the model where the accuracy of the MOLUSCE plugin mode validation. In addition, the length of time periods between the lands cover maps should have uniform and this is one of the requirements of MOLUSCE QGIS Plugin urban simulation analysis. However, especially in case of land use applications this is difficult to manage due to uneven temporal availability of satellite data.

Predicted urban expansion map for 2025

As explained in general methodology flow chart, after the successful simulation of changes in 2015, the future LULC change for the year 2025 predicted by using a land-use transition matrix for 2005 to 2015. However, an assumption was set of modeling for the year 2025 in such a way that if the accuracy of the model acceptable, future prediction would do. After validation results, however, the model achieved a lower and unacceptable accuracy. The modeling of urban expansion in Wukro for 2025 could be possible to predict. This implies that smaller urban clusters would extend to external fringes and join larger clusters, the reason to decreasing the agricultural lands. The clear alteration as predicted in the future 10 years identified very well from the model's visual outputs for a predicted year. These graphical results precisely found that by approximately the year 2025, more cultivated land would have converted to urban expansion. Hence, based on the urban expansion predictions of land use change map for the next 2025 year the prediction results based on MOLUSCE plugin Model indicate the area coverage built-up had sharply increase from 470.70 ha to 585 ha 1169.73 ha to 1080.13 ha cultivated lands decrease, 152.82 to 135.74 ha. The plantation will be Increasing, 52.47 to 55 ha the river area also increases and from 175.32 to 162.17 ha decrease the shrub lands this means that the main development in the built-up areas is predicted to occur in the surrounding areas of Wukro town shown (Figure 9).

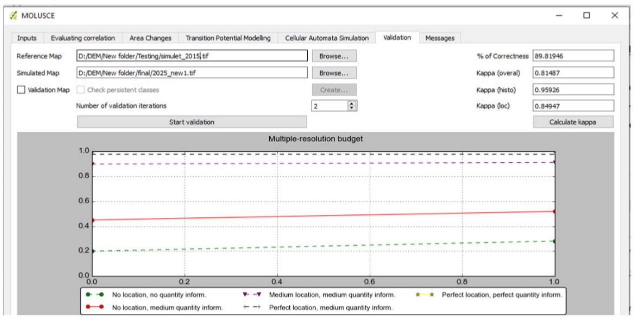

Figure 9. Model validation for 2025.

Therefore, according to Pontius Jr proposed validation in quantity and allocation parameters for validating accuracy of model performance. Whereas provision disagreement the amount of difference between the reference and comparison map is due to less than optimal match in the spatial allocation of the categories. The simulation results of urban growth should be accurate and represent the actual local site-specific patterns close to reality urbanization process.

Land use class	2015		2025	
	Area (Ha)	%coverage	Area (Ha)	%coverage
Built up area	470.70	23.29	585	28.95
Cultivated land	1169.73	57.9	1080.13	53.44
Plantation	152.82	7.56	135.74	6.72
River	52.47	2.6	55	2.72
Shrub lands	175.32	8.67	162.17	8.17
Total area	2021.04	100	2021.04	100

Table 12. Area of urban expansion prediction for 2025.

They help in interpreting, modeling, predicting urban expansion and to understanding, the future consequences land use change map (Figures 10-12).

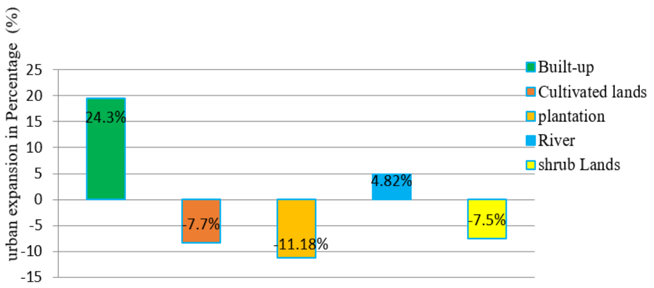

Figure 10. Urban expansion prediction map for 2025.

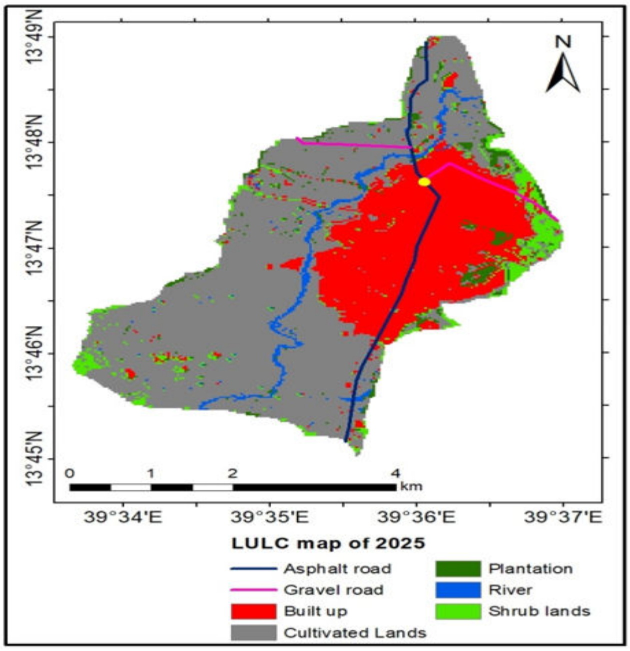

Figure 11. Urban expansion prediction map for 2025.

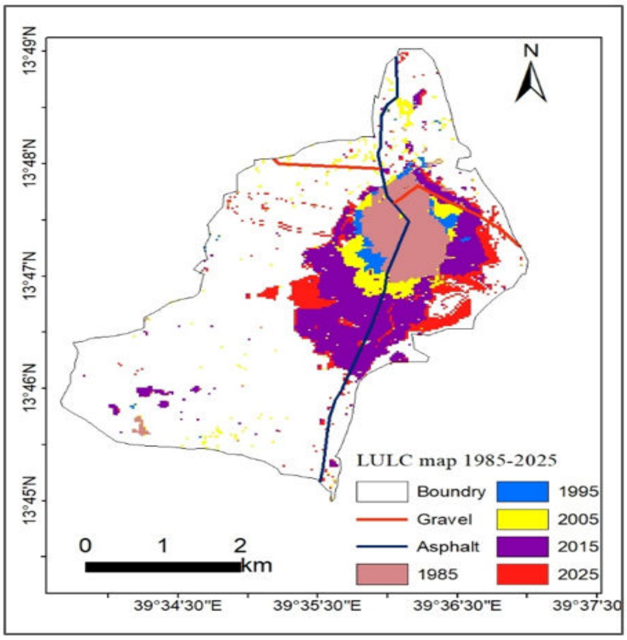

Figure 12. Urban expansion from 1995 to 2025.

Conclusion

The urban expansion LULC change results have shown to increase in built-up areas in the study area was physical expanded. We also provided the instructions and data needed to produce land use change map. In the first section, for periods of 1985, 1995, 2005 and 2015 remotely sensed data and GIS techniques applied to generate land use land cover maps through a maximum likelihood supervised image classification algorithm. From the remote sensing imagery classified result, the study showed that the proportion of built up areas were increased. The conversion of cultivated land to urban expansion areas could related to increment of population and faster economic development in town. However, The MOLUSEC QGIS urban prediction model accuracy to generate transition potential maps has an acceptable value of 78%. Simulated results of 2015 quantified that much of agricultural land converted to build up areas regardless of the driving factors, which have negative impacts on the simulation process, the predicted map MOLUSCE model shown that similar with the actual land cover map of 2015. Although, performance of model validation using a three-map comparison also confirmed that LCM showed a lower accuracy in predicting land use changes correctly in this study area. According, to LULC change model prediction for the year of 2025. The urban expansion is continuing like this trends the built-up areas will be developed in 585 ha (28.95%), cultivated lands decreased 1080.13 ha, and plantation, river and shrub lands were 135.74 ha, 55 ha and 8.17 ha. The result show that it is possible to simulate land use change based on remote sensing data and MOLUSCE plugin simulation model, coupled with the geospatial technology has indicated the descriptive capability of urban expansion trends prediction. The spatial temporal land use model has provided and quantifies for the future land use change characteristics that related to involve and share their ideas to produce a better collaborative planning for community and environment. Finally, this study presents an urban expansion modeling status for the studied area. The obtain results can be used to decision makers and planners to recognize the present and past urban expansion to prepare and plan for future urban demands.

Acknowledgments

We acknowledge to Mekelle university, institute of geo-information and earth observation science. Therefore, we would like to express our sincere gratitude to Mekelle university for providing us financial support to accomplish the study.

References

1. Abdissa, Feyera, and Terefe Degefa. “Urbanization and changing livelihoods: the case of farmers’ displacement in the expansion of Addis Ababa.” The demographic transition and development in Africa: the unique case of Ethiopia (2011): 215-235.
2. Wondimu Robi, Ethiopia. “Rapid Urbanization and Housing Shortage in Africa: The Opportunity within the Problem for Ethiopia.” (2011).
3. Bekele, Haregewoin. “Urbanization and urban sprawl.” Royal Institute of Tecnhology: Stockholm, Sweden (2005).
4. N Dejene, “Rapid urban expansion and its implications on livelihood offarming communities on peri-urban area: the case of sebeta town” *J Hum Environ* 30 (2011): 49-54.
5. Soubbotina, Tatyana P. Beyond economic growth: An introduction to sustainable development. World Bank Publications, 2004.
6. Ethiopia. Office of the Population, and Housing Census Commission. Summary and statistical report of the 2007 population and housing census: population size by age and sex. Federal Democratic Republic of Ethiopia, Population Census Commission, 2008.
7. Rahman, M Tauhid Ur, Faheemah Tabassum, Rasheduzzaman, and Humayra Saba, et al. “Temporal dynamics of land use/land cover change and its prediction using CA-ANN model for southwestern coastal Bangladesh.” *Environ Monit Assess* 189 (2017): 1-18.
8. Pham, Hai Minh, Yasushi Yamaguchi, and Thanh Quang Bui. “A case study on the relation between city planning and urban growth using remote sensing and spatial metrics.” *Landsc Urban Plan* 100 (2011): 223-230.
9. Singh, Ashbindu. “Review article digital change detection techniques using remotely-sensed data.” *Int J Remote Sens* 10 (1989): 989-1003.
10. Roy, Poritosh, Daisuke Nei, Takahiro Orikasa, and Qingyi Xu, et al. “A review of life cycle assessment (LCA) on some food products.” J Food Eng 90 (2009): 1-10.
11. Foody, Giles M. “Status of land cover classification accuracy assessment.” *Remote Sens Environ* 80 (2002): 185-201.
12. Long, Hualou, Guoping Tang, Xiubin Li, and Gerhard K. Heilig. “Socio-economic driving forces of land-use change in Kunshan, the Yangtze River Delta economic area of China.” *J Environ Manage* 83 (2007): 351-364.
13. Triantakonstantis, Dimitrios, and Giorgos Mountrakis. “Urban growth prediction: a review of computational models and human perceptions.” *J Geogr Inf Syst* 4 (2012): 555.
14. Yin, Jie, Zhane Yin, Haidong Zhong, and Shiyuan Xu, et al. “Monitoring urban expansion and land use/land cover changes of Shanghai metropolitan area during the transitional economy (1979–2009) in China.” *Environ Monit Assess* 177 (2011): 609-621.
15. Hasan, Muttaqin, Kohei Nagai, Yasuhiko Sato, and Tamon Ueda. “Tensile stress-crack width model for plain concrete damaged by freezing and thawing action.” *Proc JCI* 24 (2002): 109-114.
16. Lunetta, Ross S, Joseph F Knight, Jayantha Ediriwickrema, and John G. Lyon, et al. “Land-cover change detection using multi-temporal MODIS NDVI data.” *Remote Sens Environ* 105 (2006): 142-154.
17. Anderson, James Richard. A land use and land cover classification system for use with remote sensor data. Vol. 964. US Government Printing Office, 1976.
18. Longley, Paul A., Jean-Paul Donnay, and Michael J. Barnsley, eds. Remote sensing and urban analysis. Taylor and Francis, 2001.
19. Gebregergis, Weldegebriel Mebrahtu, Habtamu Atelaw Gebre, and Barana Babiso Badesso. “Dynamics of land use land cover change and urbanization in Jigjiga Town, Ethiopian Somali Regional State, Eastern Ethiopia.” *Remote Sens Environ* 6 (2016): 127-135.
20. Pontius Jr, Robert Gilmore, and Marco Millones. “Death to Kappa: birth of quantity disagreement and allocation disagreement for accuracy assessment.” *Int J Remote Sens* 32 (2011): 4407-4429.

How to cite this article: Hagos, Fikre, Daniel Teka, Mewcha Amha and Gebreyohanns Zenebe, et al. "Geo-Spatial Approach Urban Expansion Land Use Change and Prediction Using (QGIS) Plugin Model in Wukro, Tigray Region, Northern Ethiopia." *J Civil Environ Eng* 15 (2025): 585.