Temporal assessment on land use land cover of Somalia after the effect of the civil war using remote sensing

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Abstract. The aim of this study is to analyse land use and cover changes for the studied area during 1992-2015 and particularly evaluate the effect of civil war on these changes. Three Landsat images were used; Landsat 4 (1992), Landsat 7 (2000) and Landsat 8 (2015). Assessment of changes has been applied through three supervised classification algorithms, support vector machine, minimum classifier, and mahalanobis classifier. The result shows that SVM is providing highest overall accuracy of 98.5% for the years 2000 and 2015 with kappa coefficient of 0.9803 in year 2015. The change detection result show that the higher changes is between year 1992-2000 where vegetation land cover has dropped down to 11.1% and undeveloped area has increased to 11.4%. Whereas for year 2000-2015, higher changes belongs to build up area by 3.30% while undeveloped area and vegetation land cover keep decreasing by 2.64% and 1.93% respectively.

1 Introduction

Land use land cover (LULC) plays an important role in land management, natural recourse department, economic activities, and effect of war zone; it is also a necessary task for environmental monitoring and management [1]. It is essential for the authorities to have an up-to-date land use land cover map since the world is continuously reshaping and changing [2]. LULC maps provides the quantity of changes to the landscape, as well as where the changes took place. It also offers crucial information on the state environment, development trends, shift of vegetation areas and diversity of the desert and others [3]. Generally, this can be accomplished by utilizing the temporal ability of the earth observation satellite systems [4]. Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times [5].

Remote sensing (RS) is a tool that able to capture the earth system since the first earth orbiting satellite was launched into space. RS imageries have been used to detect and monitor land cover changes at various scales [6, 7]. A range of algorithms generated for change detection including, pre-classification and post-classification comparison, image geometric correction and etc. [8]. A variety of sensors can produce several images for the same area at different spectral, temporal and spatial resolutions. These capabilities help to solve various issues regarding agricultural, forestry, geology and environmental management. The digital change detection is effected by spatial, spectral, radiometric and temporal constraints since many change detection techniques are available. Selection of suitable method or algorithm is important for land use and cover changes for obtaining a better outcomes [5].

The objectives of this research are to assess the LULC changes of the study area in the period of 1992-2015, and identifying the difference between natural and the man-made changes especially occurred during civil war. The main target feature is the urban areas and the abrupt increase of population. Hence, the pattern changes to the city of Mogadishu can be found out. The land covers features for the study area has been divided into four types as follow:

i. Desert: A barren area which is covered with sand,
ii. Vegetation: The plant of a region,
iii. Built up area: Areas that has been developed by the human, and
iv. Undeveloped area: Bare soil or the land that has not been used.

The scope of this research is to compare three supervised classification method;1) Minimum Distance Classifier (MINDP), 2) Mahalanobis Distance Classifier (MAHADP) and 3) Support Vector Machine (SVM), in order to get better classification result and evaluate the overall accuracy for change detection in the study area. Landsat imagery has been utilized for this research with spatial resolution of 30m.

2 Study area and dataset

2.1 Study area

The study area, Mogadishu is in coastal Banaadir region on the Indian Ocean and the capital city of Somalia. It is the largest and the fastest growing city in the country with the area coverage approximately 91 km square (35 sq. mi). The city coordinates is 02°02′N 45°21′E and 2.033°′N 45.350°′E. The city has administered an important port for many centuries. The population of the city has been estimated 2.12 million at 2015 [9]. Figure 1 shows the geographical location of Mogadishu City, Somalia. Mogadishu has a relatively dry climate with the average temperature of 27°C and irregular rainfall. There are 47 wet days annually, which are associated with a 12% daily probability of rainfall. The city has an average of 3,066 hours of sunshine per year, with 8.4 hours of sunlight per day. Mean daylight hours and minutes per day are 8h 24'. The annual percentage of sunny versus cloudy daylight hours is 70% and 30%, respectively. Average sun altitude at solar noon on the 21st day of the month is 75.

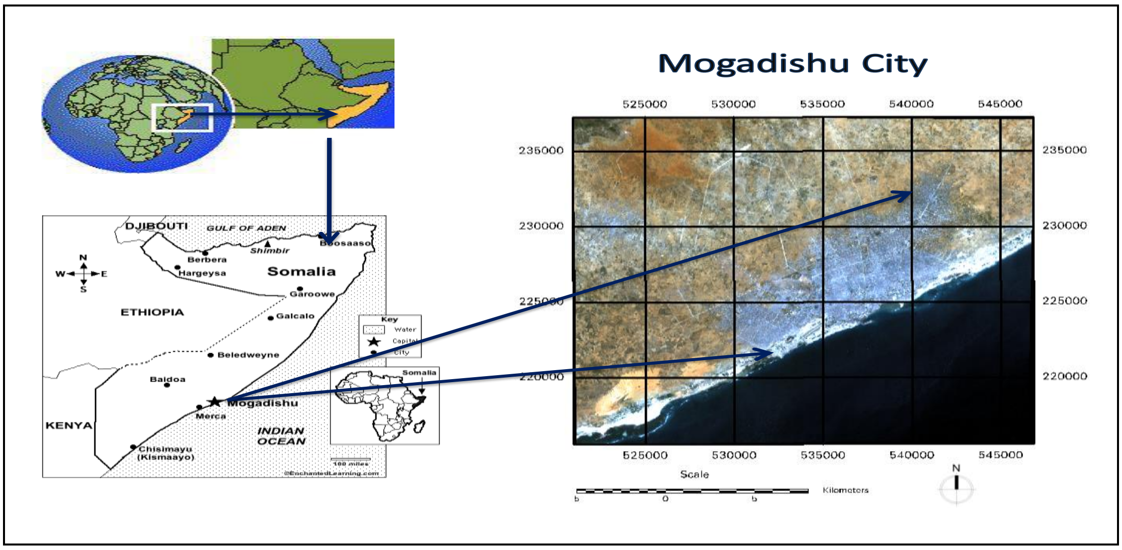

Figure 1. Map and the Landsat 8 image scene covering the study area.

2.2. Dataset

In this research, three Landsat images were used; Landsat 4 (1992), Landsat 7 (2000) and Landsat 8 (2015). Images of the study area were downloaded from the USGS Earth Explorer, especially the periods of 19 December 1992, 02 February 2000 and 18 January 2015. The details of the images are shown in Table 1. The selection of the dates of the datasets is based on the objectives of the research which to monitor the changes of the land cover during the period. Solid correlation of LULC is needed in a period of time in order to obtain these changes.

Landsat imagery is selected due to high quality images and multispectral band that allows extraction of valuable information. With the moderate spatial resolution (30 m), it has provided many layers of data across the visible and invisible light spectrum. These data can be manipulated to reveal what the Earth's surface looks like, including what types of vegetation are present or how a natural disaster has impacted an area [10].

Table 1. Properties of Landsat data for the research.

Details/Data	**Landsat 4 (TM)**	**Landsat 7 (ETM+)**	**Landsat 8 (OLI & TIRS)**
Acquisition date	12 December 1992	2 February 2000	18 January 2015
Source	USGS (Earth Explorer)	USGS (Earth Explorer)	USGS (Earth Explorer)
Spatial Resolution	30 m Band 1 to 5, 7 120 m (30 m) Band 6	15 m Band 8 (Pan) 30 m Band 1 to 5, 7 60m (30 m) Band 6	15 m Band 8 (Pan) 30 m Band 1 to 7, 9 60m (30 m) Band 10 and 11
Spectral Resolution	7 spectral bands	8 spectral bands	11 spectral bands

3 Methodology

3.1 Pre-processing phase

As shown in figure 2, the methodology for the research has been divided in to four phases. First is the pre-processing phase where the datasets has been gone through atmospheric and geometric correction due to atmospheric effect. Correction of the dataset in terms of the spectra information shall provide efficient input for the next step processing. Quick Atmosphere Correction (QUAC) is an atmospheric correction method for multispectral and hyperspectral imagery that works with the visible and near-infrared through shortwave infrared (VNIR-SWIR) wavelength range [11]. This followed by the geometric correction process. With this process, the images were rectified and able to be directly compared using the location wise. ROI has been established by subset the study area.

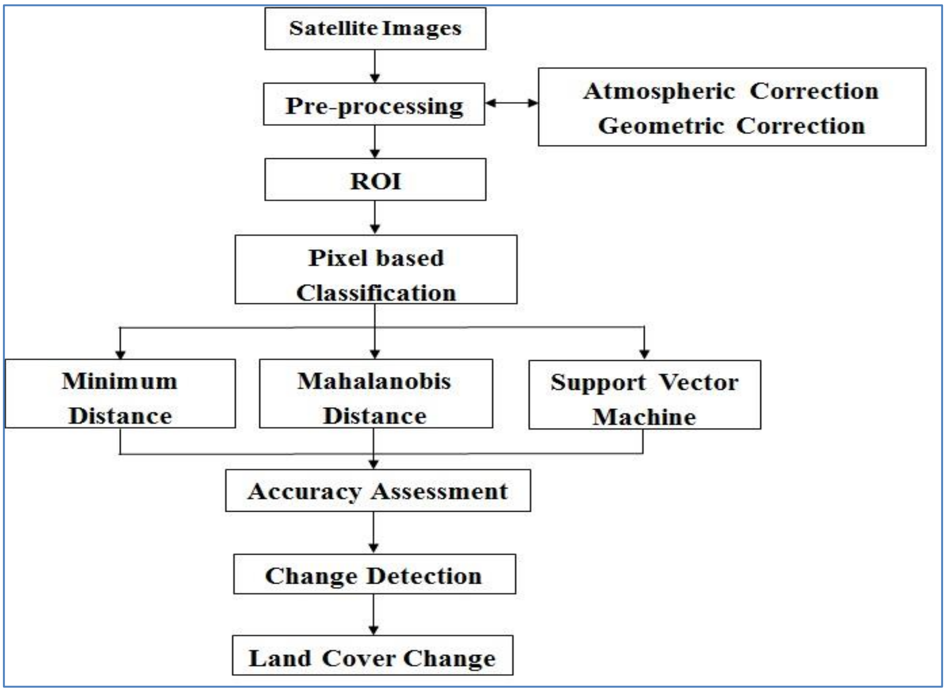

Figure 2. Methodological flowchart of the study.

3.2 Data classification phase
Next phase of methodology deals with image classification methods. Land cover features for the classification is desert, vegetation, built up area and undeveloped area. The supervised image classification based on the pixel information was selected in order to accomplish the classes. Samples of the features were collected from the images. In this case, the selection of the pixel based classification is due to the moderate resolution of the Landsat imagery.

Three different classification methods were applied; Minimum Distance Classifier (MINDP), Mahalanobis Distance Classifier (MAHADP) and Support Vector Machine (SVM). Based on the review papers, LULC usually have been classified by using SVM and Maximum Likelihood classifier (MLC) where its gives best result in terms of overall accuracy and kappa coefficient. This research focused on evaluation and comparison of these three methods to examine their aftermath. The result of the best classification will be used for the change detection analysis. This selection is based on the result of accuracy assessment.

3.3 Analysis
Research analysis phase is focusing on the accuracy assessment and the change detection findings. Accuracy assessment is the difference between the sample area and the training area. It is involves with the statistical estimation that obtained from the classification output and the independent references in the image for the probability error measurement of the classified map [12, 13]. This is to ensure the classification result is accurate and reliable. For each feature, sample areas and the training area need to be established in order to perform this assessment. Accuracy assessment has been applied for the classified map for year 1992, 2000 and 2015.

Change detection is based on the classification image differences between the initial state and the final state images [14-16]. The subtracted information from the initial and final image is the changes of the features properties. The result of changes detection will be deliberated in result section by comparing the each result based on the classification result. The first comparison is between years 1992 and 2000 and second is between 2000 and 2015. The main reason of the two comparisons is to know what is the trend or pattern of the changes. The total of the change detection will be reviewed in the discussion section.

4 Result

4.1 Image classification

Classification results were evaluated based on two main parameters. First is about the overall accuracy of the classification result; second is the Kappa coefficient for the measure of association between two categorical variables. Land cover maps based on the classification methods on the MINDP, MAHADP and SVM has been produced. Figure 3 shows that SVM method has producing high accuracy result for all images. For the year 2000 and 2015, the overall accuracy level is 98.5% while for year 1992 is 97.2%. For the MINDP classifier, the highest overall accuracy was recorded for year 2015 with 95.4%, followed by 93% for image of year 1992 and 92.4% for image of year 2000. Meanwhile for MAHADP, the highest overall accuracy is for year 2015 with 96.9%. Next is the image of year 2000 with 94.5% and 91.6% for image of year 1992.

Table 2 shows the overall accuracy and kappa coefficient of all image classification methods. The kappa coefficient ranking level is the same as the pattern in overall accuracy. From this phase, only the land cover map based on the SVM method remains for further details analysis. Figure 4 illustrates the SVM classification map for the year 1992, 2000 and 2015. It shows four main land cover classes; desert in grey, built up area in red, undeveloped area in yellow and vegetation in green. Table 3 represents classification results of the land cover features.

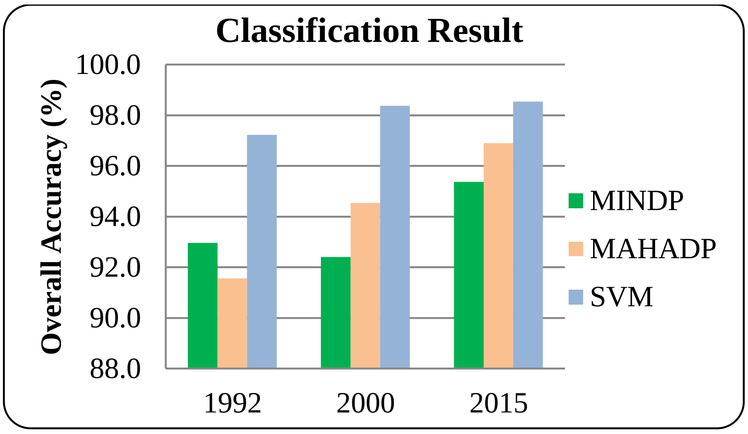

Figure 3. The overall accuracy classification result.

Table 2. Compilation of the overall accuracy result and kappa coefficient.

	1992		**2000**		**2015**	
	Overall Accuracy	**Kappa**	**Overall Accuracy**	**Kappa**	**Overall Accuracy**	**Kappa**
MINDP	93.0	0.9053	92.4	0.8957	95.4	0.9378
MAHADP	91.6	0.8868	94.5	0.9254	96.9	0.9583
SVM	97.2	0.9625	98.5	0.9798	98.5	0.9803

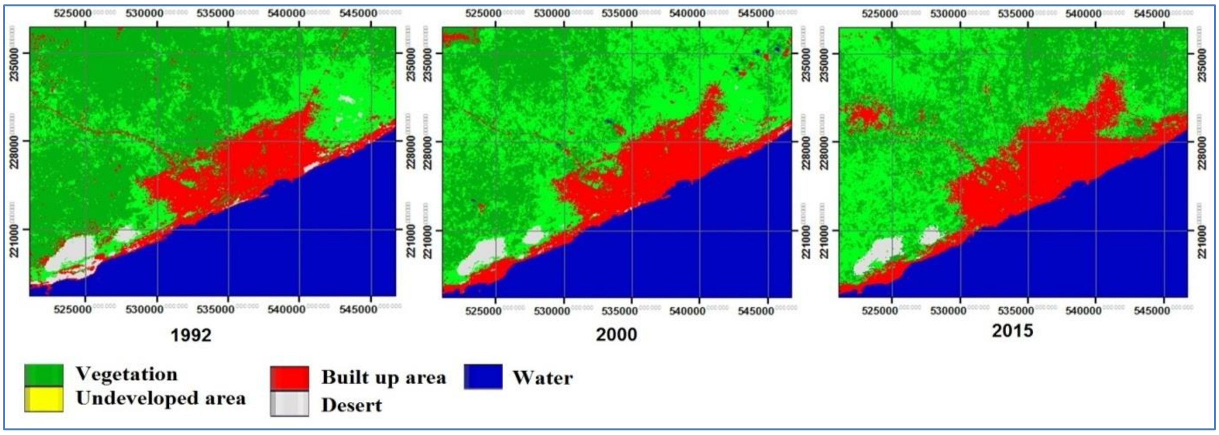

Figure 4. Land Cover Map based on SVM classification for year 1992, 2000 and 2015.

Table 3. Land Cover Features Classification Result.

	1992	2000	2015
Desert	2.27%	1.47%	1.25%
Undeveloped Area	17.20%	28.56%	25.91%
Built Up Area	12.75%	13.59%	16.89%
Vegetation	38.00%	26.88%	24.95%
Water	29.79%	29.51%	30.99%

4.2 Area of changes

Evaluation on the each feature area shows that there is lot of change happen to the Mogadishu city and its surrounding. Figure 5 illustrates the changes of the built up area that is expanding from 1992 to 2015. From the visual interpretation, the most growth of built up area is in east and north-east side of the city. In addition, in city centre also several new built up area can be observed. The vegetation land cover has displayed much of changes from a dense vegetation land cover to scatter vegetation area. The undeveloped area is rapidly spreading and desert area is reduced significantly. Water changes have been excluded due to insignificant analysis for this research. Further analysis on what caused the changes is explained in discussion section.

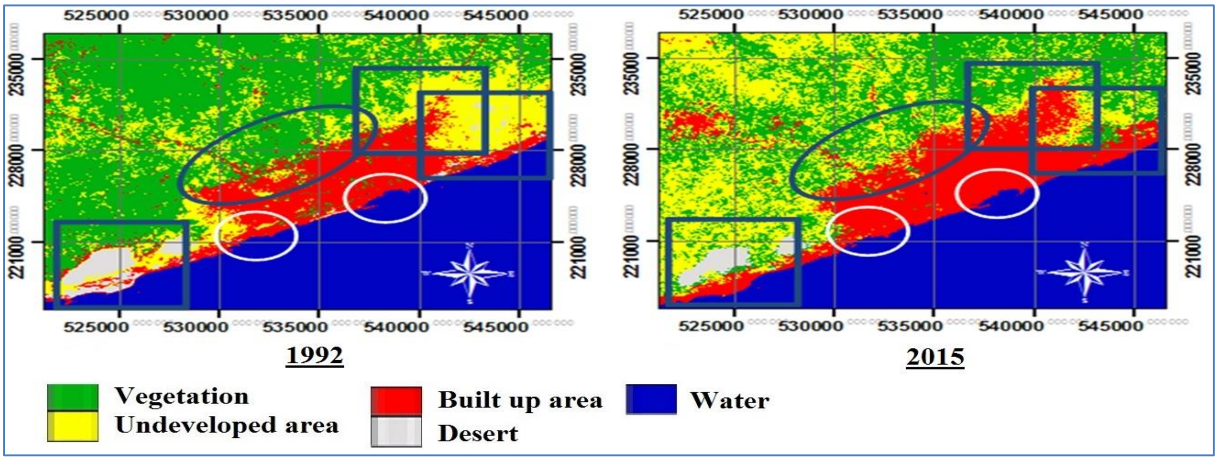

Figure 5. Land Cover changes for between year 1992 and 2015.

5 Discussion

In order to have better understanding to the changes, two comparisons has been implemented between year 1992 and 2000, and between year 2000 and 2015. Change detection for the first time period (1992-2000) has revealed that the most growth is for undeveloped area with increase of 11.36%. Vegetation land cover and desert were decreased 11.12% and 0.80% respectively. In contrast, built up area has increased 0.84%.

Meanwhile in 2000 to 2015 time period, the highest rate of change is for built up area with the growth rate of 3.30%. Other land cover areas had reduction of 2.64% for undeveloped area, 1.93% for vegetation and 0.22% for desert. In overall, desert area had slow and vegetation had high reduction rate during selected period of time. Undeveloped zones were expanded at the initial years, but then reduced in the subsequent years. The only land cover that keeps increasing was the built up area. Based on these two comparisons, the most changes rate happen to Mogadishu city is between years 1992 to 2000. Figure 6 depicts the change detection rate for both comparison years. Table 4 presents the rate of change detection for the comparison result and the overall changes between years 1992 to 2015.

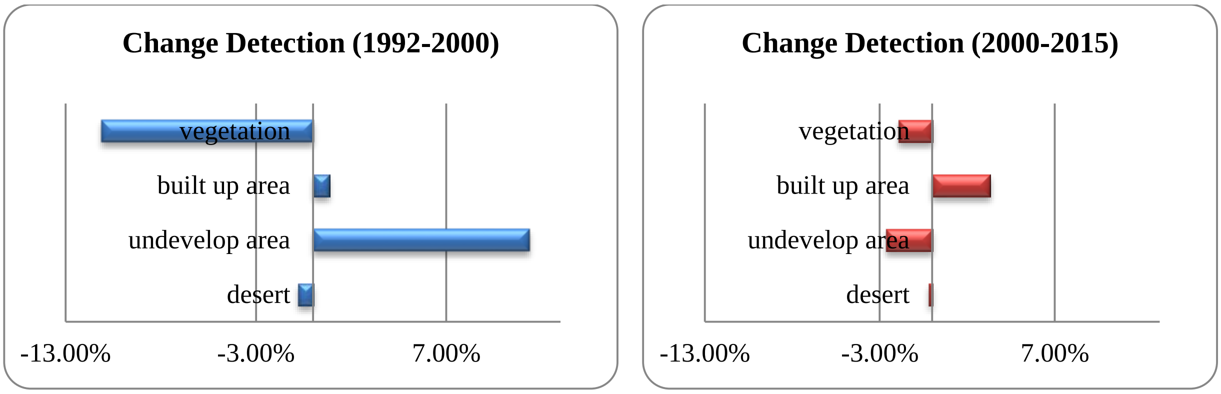

Figure 6. Change Detection rate for year 1992-2000 and 2000-2015.

Table 4. Changes rate based on the comparison result.

Changes	1992-2000	2000-2015	1992-2015
Desert	-0.80%	-0.22%	-1.01%
Undeveloped area	11.36%	-2.64%	8.71%
Built up area	0.84%	3.30%	4.14%
Vegetation	-11.12%	-1.93%	-13.04%

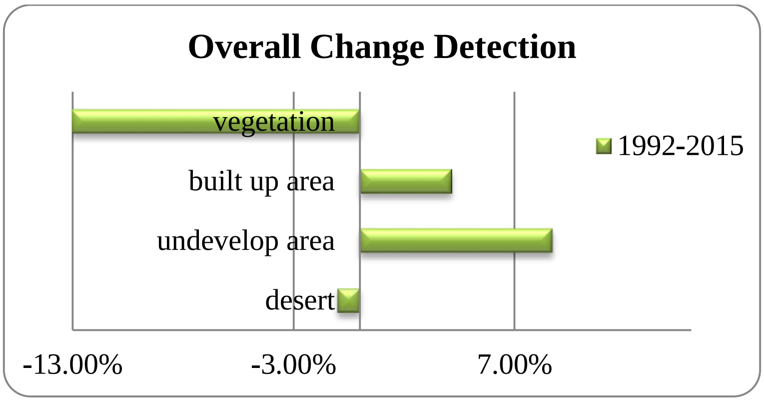

Figure 7. Overall Land Cover Changes for year 1992-2015.

The overall changes for each land cover type indicate that the built up area and undeveloped area has increased through the years. However, the land cover type for vegetation and desert is decreasing. Figure 7 displays the overall changes from year 1992 to 2015. Based on these findings, there are two types of changes that happen in the Mogadishu city; natural and man-made changes. Obviously the built up area growth is due to rapid growth of the settlement area after the war. The war incident has changed the topography of city where the location of the settlement area is moving out circuit from the city centre. The growth of the population over the years after the war has also increased the built up area. Figure 8 represents the change of the built up area for first (1992-2000) and second comparison (2000-2015). Figure 9 indicates reduction of desert area in both comparison stages. These finding show that the desert area is decreased because of the desert greening activities that has occurred at the north-east of the city. In addition, for the south-west desert, natural plant has over take some of the area.

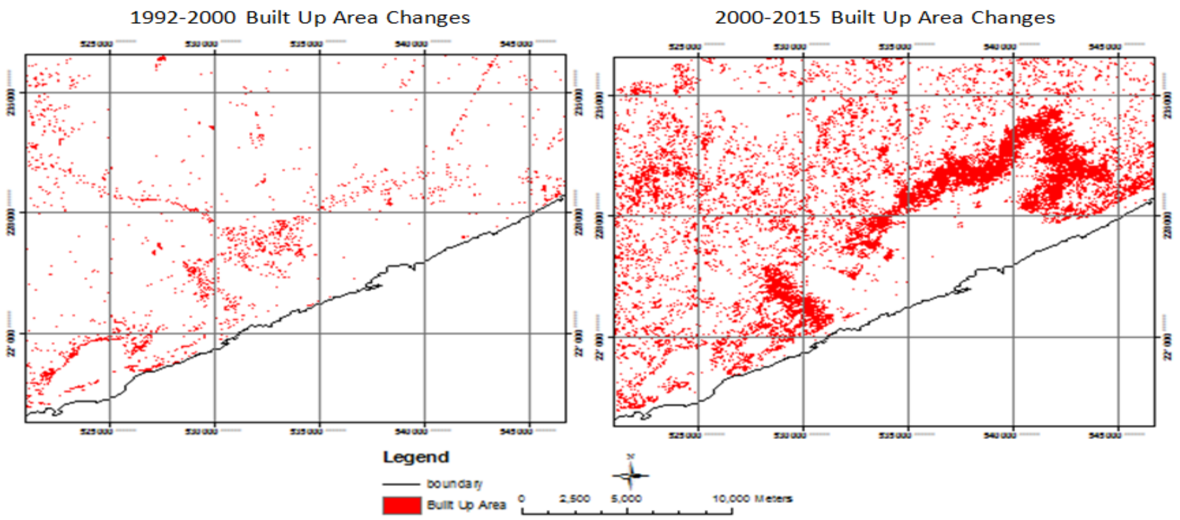

Figure 8. Growth of the Built up Area in Mogadishu City and surroundings.

The first comparison identified that a widening land cover has turn out to be undeveloped area. But in the second comparison, only small area has changed as built up and vegetation area. This change has been shown in Figure 10 where the proportional of undeveloped area changes in first comparison contrasted to second comparison. For the vegetation area, the land cover has reduced from year 1992 to 2015. Figure 11 shows the change details for the vegetation area. It is relevant to determine that the change between undeveloped area and the vegetation area is correlated. Back in year 1992, 1999, 2004, 2005, 2008, 2010 and 2012, historical data has shown that drought event has surged the Horn of Africa (Ethiopia, Somalia, and Kenya) [17]. Drought event has affected the vegetation area as it become dry and deforestation. This has the most signification contribution of land cover changes for the natural features.

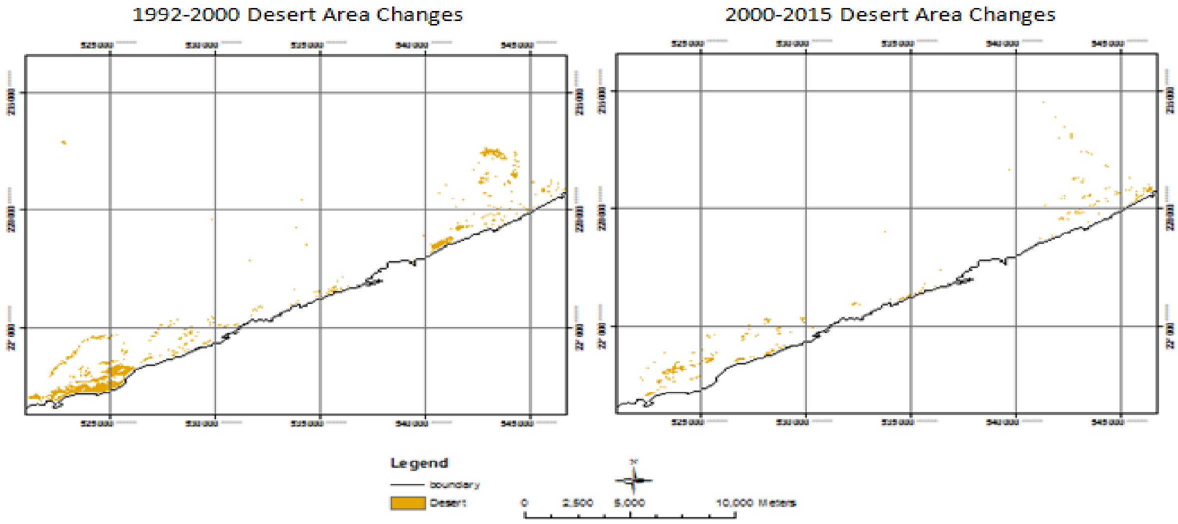

Figure 9. Decrease Desert Area over the period 1992-2015.

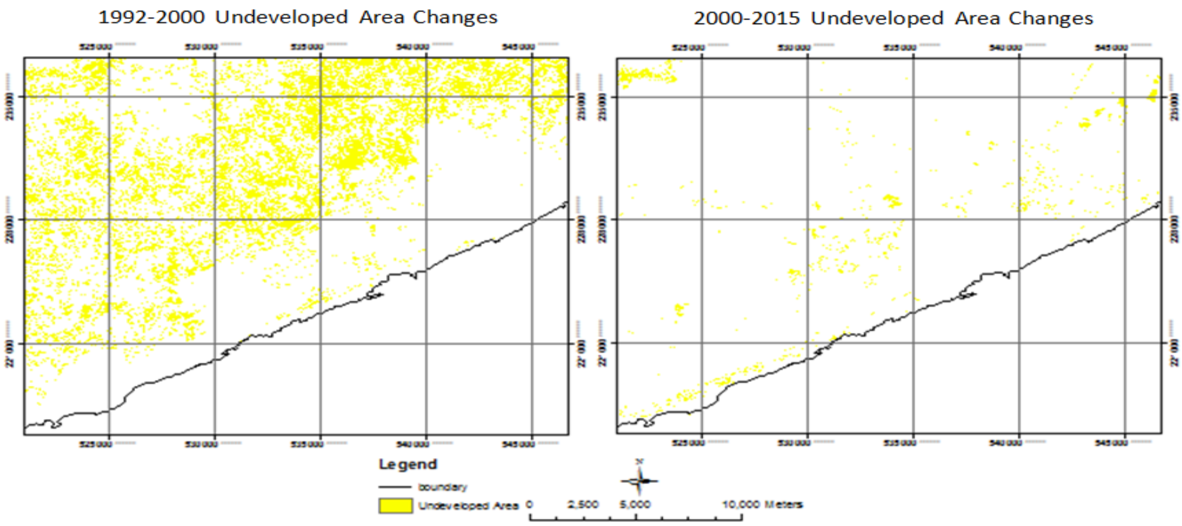

Figure 10. Increase of the Undeveloped Area over the period 1992-2015.

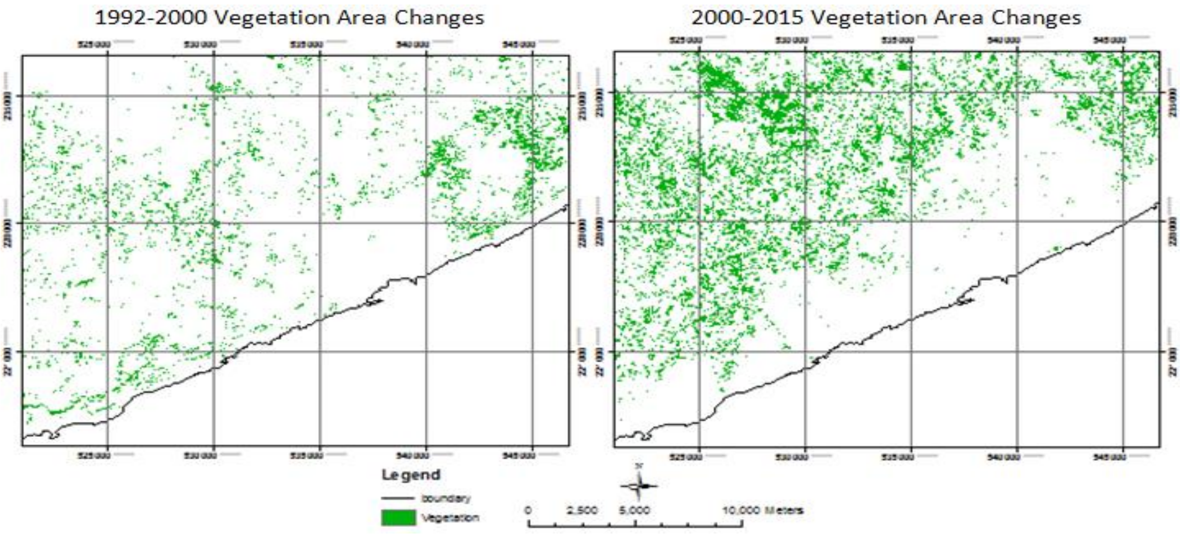

Figure 11. Vegetation Area shirking over the period 1992-2015.

Population Analysis: The study conducted above was to estimate the population of the city of Mogadishu, in order to better manage and supply sufficient care and need for the people of Mogadishu. Figure 12 represents the information about the population growth of the Mogadishu city. Based on the study Mogadishu population was estimated in 1990 around 779,000, while in 2015 it was estimated around 2,120,000 and it was concluded that Mogadishu remains the largest and the fastest growing city in the entire country. Population of year 2000 estimated at 1.2 million while in 2015 the population was doubled around 2.12 million.

Year	Population
1950	47,000
1955	66,000
1960	94,000
1965	134,000
1970	191,000
1975	271,000
1980	385,000
1985	548,000
1990	779,000
1995	965,000
2000	1,219,000
2005	1,552,000
2010	1,955,000
2015	2,120 ,000

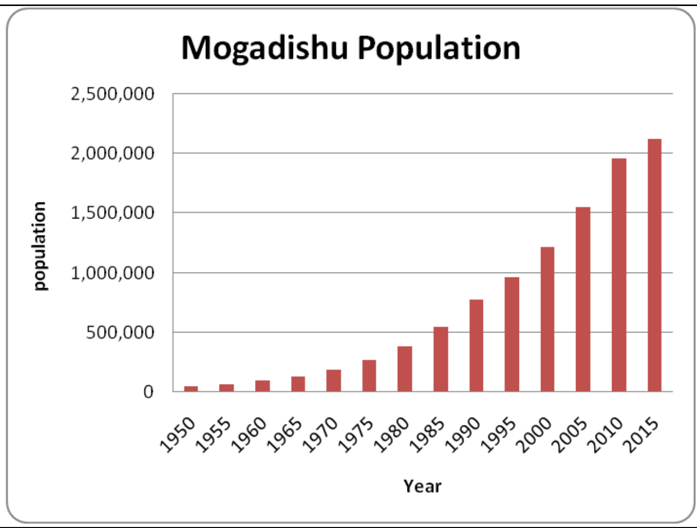

Figure 12. Mogadishu population over the period of time.

6 Conclusion

Land use land cover analysis is a unique method in describing the natural and man-made features over the area. This process has produced better fitting in locating the changes of the area and what is happening to the Mogadishu city in Somalia. Time series data and the image classification have indicated the changes that have occurred. SVM method has produced high accuracy result and high relationship correlation on the features for each image that have exploited.

The war incident has affected the city centre growth at the beginning. Major reconstruction area in the city centre and the abundant building has forced the people to migrate outside the area in order to start new life after the war. Major finding of the research shows that the growth of the downtown area at north-east of the city is due to space limitation in the city centre and the reconstruction.

The pattern of the comparison has revealed that the area of the natural and man-made changes is possible to distinguish. This is because most of the area that near to the city is unrelated to farming activities. The drought event has caused lots of changes to the vegetation area and the undeveloped area. If this situation is unable to be properly managed, deforestation rate will increased over the period of time.

For the future work, extension classification can be done through object based and reflectance (spectral) classification. Details analysis for the features can be prepared by using the data fusion, hyperspectral and high resolution data so that the characteristic of the urban is able to be carry out.

Acknowledgement
The Landsat data used in this study were downloaded from US Geological Surveyweb sites.

References

[1] Abdullahi S and B Pradhan 2015, Sustainable brownfields land use change modeling using GIS-Based weights-of-evidence approach. *Appl Spat Anal Polic*: p. 1-18.
[2] Abdullahi S, A R b Mahmud, and B Pradhan 2014, Spatial modelling of site suitability assessment for hospitals using geographical information system-based multicriteria approach at Qazvin city, Iran. *Geocarto International*. **29**(2): p. 164-184.
[3] Yao K, M O Idrees, B Pradhan, and S M Nabeel 2015, Detecting Land Use Land Cover Change Impacted by Civil Crisis in Ivory Coast using Remote Sensing and GIS. *Asian J Appl Sci*. **3**(05).
[4] Al-sharif A A, B Pradhan, H Z M Shafri, and S Mansor 2013, Spatio-temporal analysis of urban and population growths in Tripoli using remotely sensed data and GIS. *Indian J Sci Tech*. **6**(8): p. 5134-5142.
[5] Singh A 1989, Review article digital change detection techniques using remotely-sensed data. *Int J Remote Sens*. **10**(6): p. 989-1003.
[6] Treitz P and J Rogan 2004, Remote sensing for mapping and monitoring land-cover and land-use change—an introduction. *Prog Plann*. **61**(4): p. 269-279.
[7] Abdullahi S, B Pradhan, and M N Jebur 2015, GIS-based sustainable city compactness assessment using integration of MCDM, Bayes theorem and RADAR technology. *Geocarto Int*. **30**(4): p. 365-387.
[8] Hamedianfar A and H Z Shafri 2014, Development of fuzzy rule-based parameters for urban object-oriented classification using very high resolution imagery. *Geocarto Int*. **29**(3): p. 268-292.
[9] Cox W, *Demographia World Urban Areas*, in *10th Annual Edition (Belleville, IL: Demographia. com, 2014)*2012. p. 20.
[10] Miller H, N Sexton, and L Koontz, *Landsat imagery: a unique resource*, 2011, US Geological Survey.
[11] Guide E U s, *ENVI on-line software user's manual*, in *ITT Visual Information Solutions*2008.
[12] Foody G M 2002, Status of land cover classification accuracy assessment. *Remote Sens Envir*. **80**(1): p. 185-201.

[13] Tehrany M S, B Pradhan, and M N Jebuv 2014, A comparative assessment between object and pixel-based classification approaches for land use/land cover mapping using SPOT 5 imagery. *Geocarto Int*. **29**(4): p. 351-369.

[14] Al-Doski J, S B Mansor, and H Z M Shafri 2013, Image Classification in Remote Sensing. *Envir Earth Sci*. **3**(10): p. 141-147.

[15] Coppin P, I Jonckheere, K Nackaerts, B Muys, and E Lambin 2004, Review ArticleDigital change detection methods in ecosystem monitoring: a review. *Int J Remote Sens*. **25**(9): p. 1565-1596.

[16] Radke R J, S Andra, O Al-Kofahi, and B Roysam 2005, Image change detection algorithms: a systematic survey. *Image Process, IEEE Trans*. **14**(3): p. 294-307.

[17] Masih I, S Maskey, F Mussá, and P Trambauer 2014, A review of droughts on the African continent: a geospatial and long-term perspective. *Hydrol Earth Syst Sci*. **18**(9): p. 3635-3649.