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RESEARCH ARTICLE

ANALYSIS OF URBAN GROWTH AND SPRAWL AND BUILT UP DENSITY USING REMOTE SENSING DATA: CASE OF CASABLANCA, MOROCCO.

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Abstract

In Casablanca, the rate of population growth has been spectacular in recent years according to the 2014 National population census. The city has a population of 3.35 million in the urban area and over 4.27million on the outskirts. However, the unprecedented fast urban and demographic growth of Casablanca in the last decades, compiled with chronic lack of integrative urban strategies, has led to an urban and environmental crisis in the city. Remote sensing and GIS have become essential tools for urban planners to ensure better living quality and sustainable development. This study is the first of its kind in Morocco. In this paper, we have analyzed the city's transformation in terms of built-up density, urban growth and sprawl and the relationship between urbanization and land use changes and their impact on the city space of Casablanca. Urban growth and sprawl in Casablanca have been assessed over a period of 32 years (1986-2018).Satellite imageries and census data have been used to accomplish this study, using classification methods and analysis of satellite imageries.

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Introduction:-

The urbanization is a major issue facing many metropolitan areas (Coisson et al. 2014; Estoque et al. 2015; Halleux et al. 2012; Haregeweyn et al. 2012; He et al. 2006; Lund, 2013.), and although it may seem straightforward, urbanization is a complex concept upon closer examination. The complexity stems mainly from the multitude of definitions of the term in different disciplines and under different contexts. Altogether, the urbanization is a gradual increase in the proportion of people living in urban areas as a consequence of socioeconomic development under specific circumstances ("Urbanization". *MeSH browser. National Library of Medicine*. Retrieved 5 November 2014). It refers also to the gradual increase in the proportion of people living in urban areas.

The Urban sprawl is an important characteristic of regional urbanization that stands for an uncontrolled spread of urban development into neighboring regions. (Belanche et al. 2016; Deal et al. 2004; Gennaio et al. 2009). The urban land-use structure evolution is sharply related to urban socio-economic development and ecological environment (Angel et al. 2011; Lichtenberg et al. 2009; Puertas et al. 2014). Setting an appropriate urban structure is related to the powerful allocation of land resources as well as to healthy and orderly socio-economic development (Angel et al. 2015; Hassan et al. 2015). Current studies cover urban sprawls from multiple angles of approach and large range of topics (Jaeger et al. 2010; Alnsour 2016; Jaeger, Bertiller et al. 2010; Alnsour 2016) including the form (Altieri et al. 2014; Jacobson, 2011), extent and path of sprawl (Vaz et al. 2015; Hamidi et al. 2014) and influence assessment (Bhatta et al. 2010; Disperati et al. 2015; Kang et al. 2013; Mendiola et al. 2015; Wu et al. 2009). The morphology

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of the urban areas has an intricate relationship with built-up density (Bae et al. 2015; Dorning et al. 2015; Jat et al. 2008) that plays a major role in the shaping of urban form. The urban development exhibits very different urban forms in the face of rapid urbanization. The relationship between building density and urban form has attracted wide interest. The growing pressure on the peri-urban land as a consequence of increasing urban population has initiated extensive investigation on the spatial benefit of multi-storey buildings (Gropius, 1935; Beckett, 1942; Segal, 1964; Martin et al. 1972; Evans, 1973; Davidovich, 1968).

The recent accelerated rate of urbanization in all forms and the population growth in Morocco generates serious urban planning and environmental problems (Lehzam, 2012), particularly in Casablanca, the economical capital and symbol of urbanization in Morocco. Spatial information on land use and land cover types and their change detection in time series are important means for city planning and new development activities (Ewing et al.2002). The Geographic Information Systems (GIS) and remote sensing (RS) have long been accepted as the most appropriate solution to use spatially referenced data and have become the two most common methods of demonstrating the dynamics of urban sprawl (Calkins 1972).

Urbanization is a major cause of land use changes and land conversions. It makes unpredictable and long lasting changes on the landscape. An important aspect of change detection is determining what is actually changes to. Analyzing the spatial and temporal changes in land use and land cover is one of the effective ways to understand the current environmental status of an area and ongoing changes (Arvind, 2006, Yuan et al. 2005 and Zubair,2006).

The current research will analyze the transformation of the city of Casablanca in terms of urban growth and sprawl and built-up density, the relationship between urban growth and land use changes and their impact on the city space. We calculated the urban sprawl index (USI) in order to analyze the relationship between urban sprawl and the population growth. Urban growth and sprawl in Casablanca have been assessed over 32 years (1986-2018). Satellite imageries and census data were used to accomplish this study, using classification methods and analysis of satellite imageries.

Study Area:-

Casablanca, the study site, is a coastal metropolis, located near the capital city of Rabat, is the main business, commercial and financial hub of the Moroccan Kingdom generating 30% of GDP (**Figure 1**).

Country's largest city, Casablanca has a busy history going back to the 11th century (Cohen 2008). After serving as a strategic port during the Second World War, the city gained independence along with the rest of Morocco in 1955 with a then population of 682,388 (Statistical office of the United Nations).

In the 2014 census, Casablanca's population was 3,359,818 inhabitants, and its population agglomeration amounted to 4,270,750 inhabitants, representing 46% of labor force and making it the most populated city in the country.

Over the last decades, there were many problems and challenges caused by the rapid growth and sprawl of Casablanca that lead to an increase in the demand of infrastructure and in basic services and housing in expanding urban area, moreover, the provision of education, health, transportation, water and sanitation services should be improved.



Figure 1:-Location of study area

Spatial Data

To accomplish the objectives of the present study, four available satellite images were used. Landsat Thematic Mapper (TM) and Operational Land Imager-Thermal Infrared Sensor (OLI_TIRS) data have several advantages for this application: synoptic view, digital, GIS compatible data. Sentinel-2A is a European optical imaging satellite launched in 2015. The satellite carries a wide swath high-resolution multispectral imager with 13 spectral bands. It performs terrestrial observations in support of services such as forest monitoring, land cover changes detection, and natural disaster management.

Data used in this research include the multi-temporal dataset and topographic maps:

1. Landsat TM and OLI-TIRS images (1986/1996/2007).
2. Sentinel-2A (2018).
3. Aerial photographs - Topographic maps.
4. Demographics and census data (1982, 1994, 2004 and 2014).
5. Urban development plan of Casablanca - Field observations.

Before analysis, the images were geometrically corrected. During geometric correction, control points are detected on the topographic maps and the satellite images with RMS errors that are estimated below 0.5 pixels. After that, the images for 1986, 1996, 2007 and 2018 were registered on Lambert Conform Conic Projection, datum Merchich, zone I (North Morocco).

A subset image was created from each Landsat and Sentinel images for subsequent treatment and classification

Figure 2

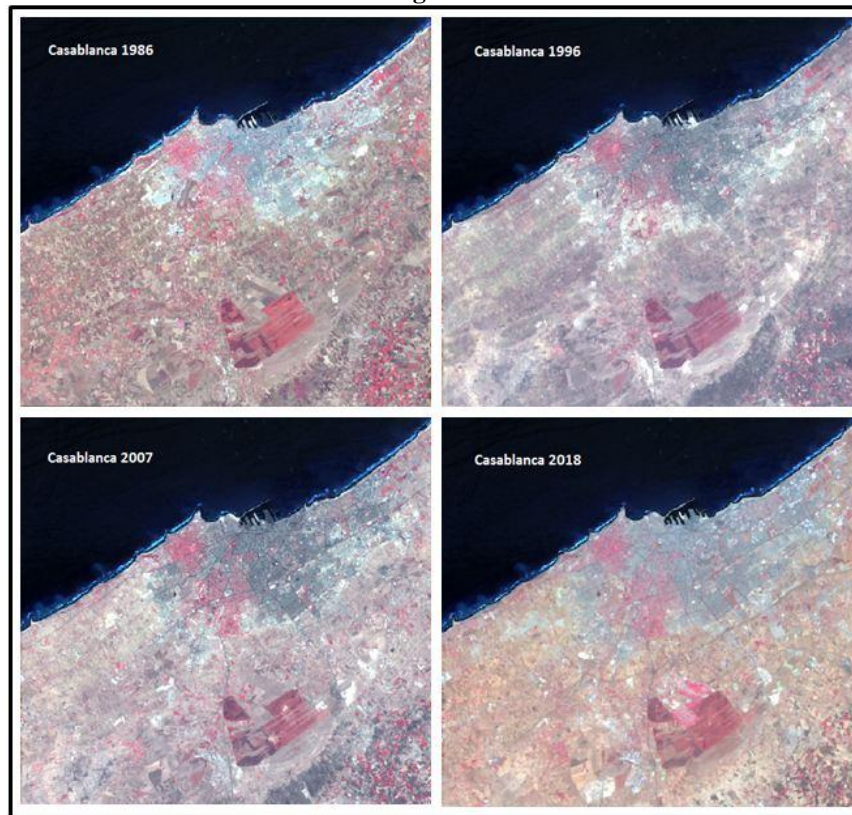


Figure 2:-False color composites of the Landsat and Sentinel-2A images showing Casablanca in 1986, 1996, 2007 and 2018.

Methodology:-

Image classification:-

A fairly common objective of remote sensing in connection with earth resources is to attempt to establish the type of ground cover on the basis of the observed spectral radiance.

Image classification is a conventional change detection method. The advantage of image classification is the ability to create a series of land cover maps. We applied the Minimum Distance Supervised Classification (MDC) method for time series of Landsat bands and Sentinel-2A bands.

Minimum distance classifiers belong to a family of classifiers referred to as sample classifiers. In such classifiers the items that are classified are groups of measurement vectors rather than individual vectors as in more conventional vector classifiers.

Specifically, in minimum distance classification, a sample (i.e. group of vectors) is classified into the class whose known or estimated distribution most closely resembles the estimated distribution of the sample to be classified. The measure of resemblance is a distance measure in the space of distribution functions.

Kappa coefficient formula is given by the following formula:

$$\kappa = \frac{N \sum_{i=1}^r x_{ii} - \sum_{i=1}^r (x_{i+} * x_{+i})}{N^2 - \sum_{i=1}^r (x_{i+} * x_{+i})}$$

Data processing workflow:-

The present study is based on spatial remote sensing data as well as non-spatial data available from various sources for different periods. Urban development has led to expansion of the cityscape of Casablanca, leading to changes in land use. The study specifically focuses on interpreting the city’s land use change patterns and growth based on satellite and demographic data.

Our approach used images from different years(1986-1996-2007-2018)in order to visualize the transformation of the city space for each decade and the changes in the built-up density and the peri-urban land.

The data used in this study were based on remote sensing images. A total of 4 satellite images: 3 Landsat images (1986-1996-2007) and 1 Sentinel image (2018). The reason of this choice is the high resolution of the data which allows us to distinguish the different levels of urban density (highly dense, dense, and moderately dense). In order to calculate and analyze the urban growth and sprawl, the images were classified.

Table 1 presents the classification units of land use identified in the study area. **Figure 3** presents the methodology elaborated to produce maps of land use change and urban expansion.

Table 1:-Land cover classification scheme

Level I	Level II
Building	Highly dense, dense, low dense
Green space	Green space
Forest	Forest
Peri-urban land	Bare soil

Procedure Overview

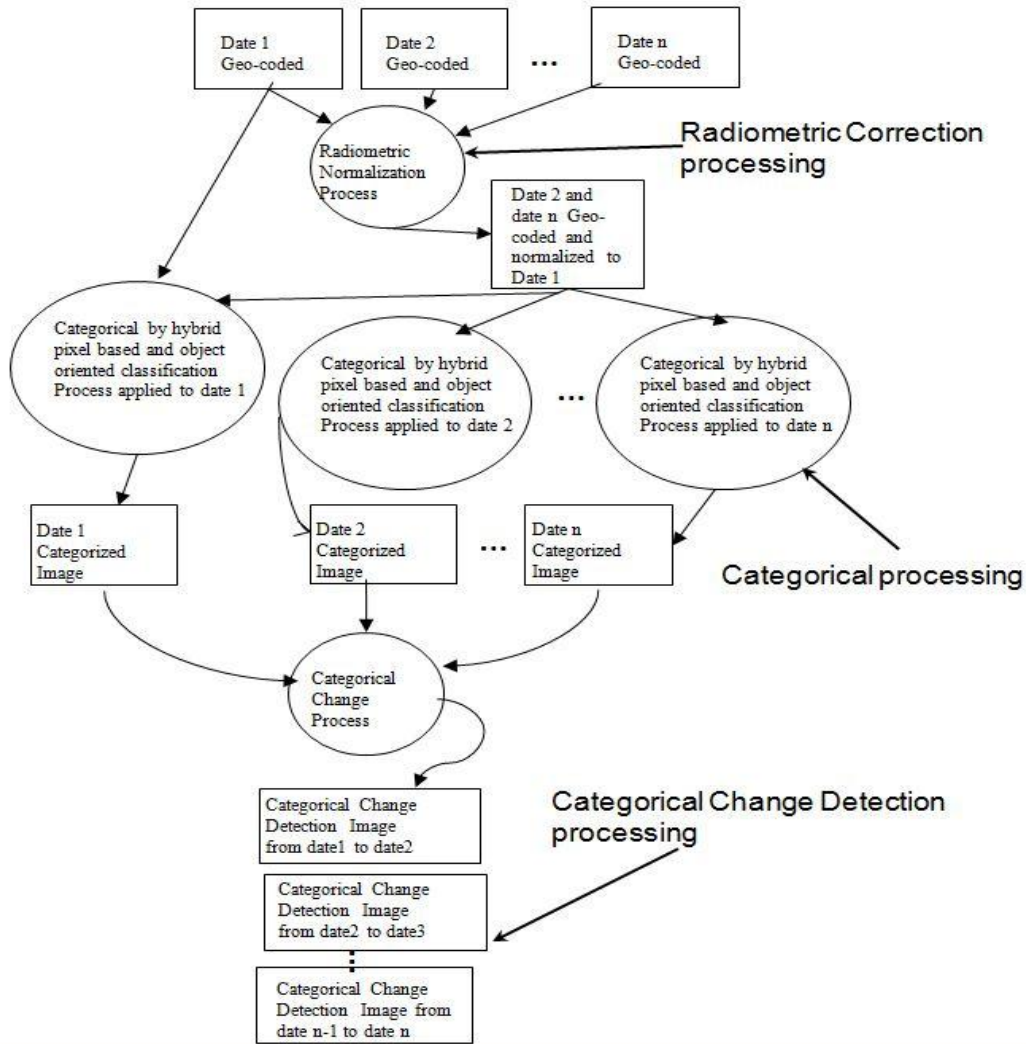


Figure 3:-Flowchart of spatial and temporal changes

Results And Discussion:-

Land use maps

The images were processed according to the methodology presented in the flowchart in figure 3 to acquire the land use maps at four points in time (1986, 1996, 2007 and 2018). The results shows 6 land use categories: high dense built-up, dense built-up, low dense built-up, bare soil, green space and forest (**Figure 4**). The growth of urban area is dominant. An independent sample of polygons was randomly selected from each class to assess classification. For overall accuracy, error matrixes and the Kappa coefficient were calculated (Table 2 to Table 5).

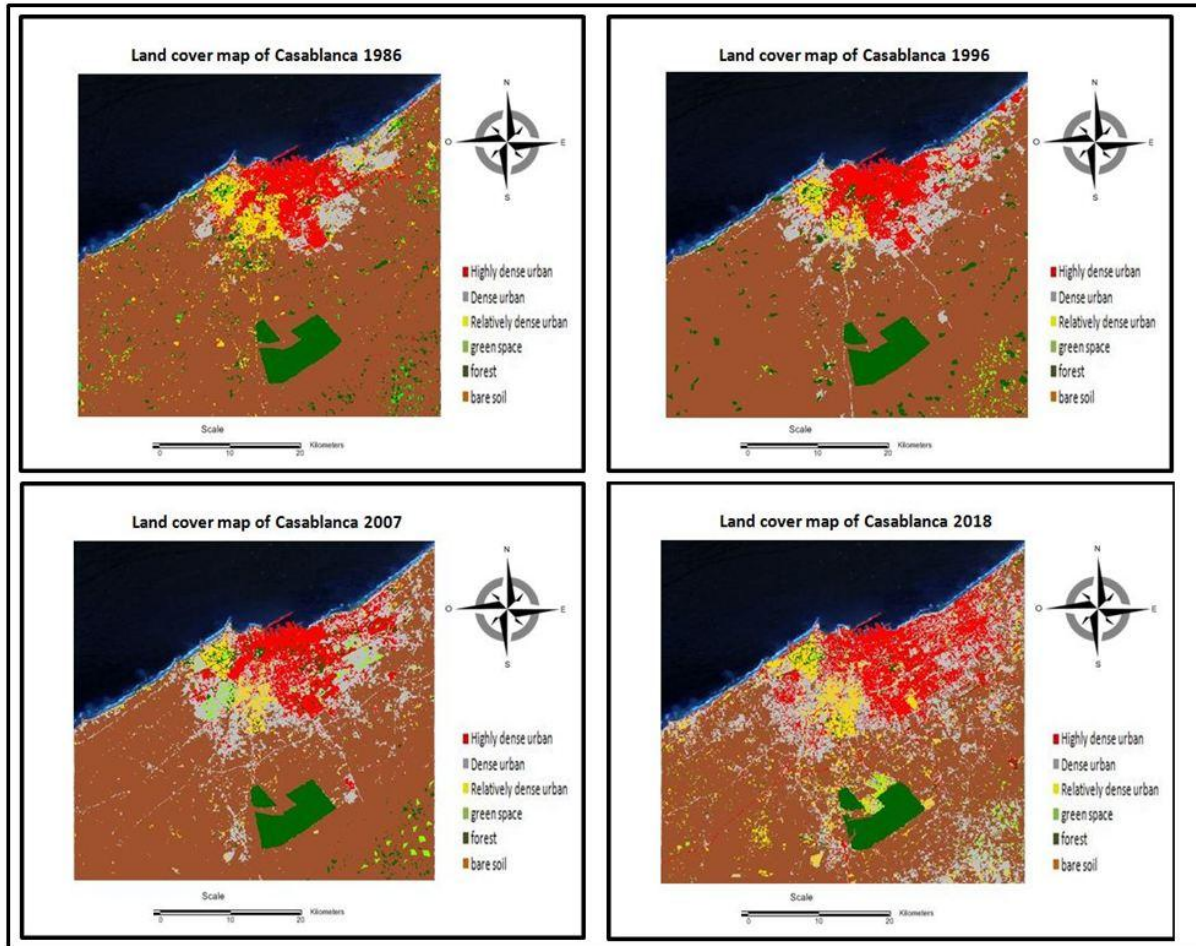


Figure 4:-The land covers maps of Casablanca in 1986, 1996, 2007 and 2018.

Table 2:-Error Matrix Analysis of field sites (columns) against Landsat classification (rows) (year: 1986)

		1	2	3	4	5	6	Somme	Ratio	errorC
high density built-up	1	67	9	0	0	0	9	85	79%	21%
dense built-up	2	1	27	0	0	0	10	38	71%	29%
low density built-up	3	0	3	47	5	0	0	55	85%	15%
green space	4	0	0	5	19	0	1	25	76%	24%
forest	5	0	0	0	0	38	7	45	84%	16%
bare soil	6		1	0	1	9	176	187	94%	6%
	Somme	68	40	52	25	47	203	N		435
	accuracy	99%	68%	90%	76%	81%	87%	Overall accuracy		86%
	errorO	1%	33%	10%	24%	19%	13%	Kappa coefficient		81%

Table 3:-Error Matrix Analysis of field sites (columns) against Landsat classification (rows) (year :1996)

		1	2	3	4	5	6	Somme	Ratio	errorC
high density built-up	1	75	13	0	0	0	5	93	81%	19%
dense built-up	2	0	53	0	0	0	12	65	82%	18%
low density built-up	3	0	0	38	5	0	5	48	79%	21%
green space	4	0	0	5	25	0	0	30	83%	17%
forest	5	0	0	0	0	34	3	37	92%	8%
bare soil	6	3	0	0	0	8	157	168	93%	7%
	Somme	78	66	43	30	42	182	N		441
	accuracy	96%	80%	88%	83%	81%	86%	Overall accuracy		87%
	errorO	4%	20%	12%	17%	19%	14%	Kappa coefficient		82%

Table 4:-Error Matrix Analysis of field sites (columns) against Landsat classification (rows) (year :2007)

		1	2	3	4	5	6	Somme	Ratio	errorC
high density built-up	1	78	10	0	0	0	5	93	84%	16%
dense built-up	2	0	51	0	0	0	12	63	81%	19%
low density built-up	3	0	0	37	5	0	4	46	80%	20%
green space	4	0	0	5	27	0	0	32	84%	16%
forest	5	0	0	0	0	36	0	36	100%	0%
bare soil	6	4	0	0	0	8	160	172	93%	7%
Somme		82	61	42	32	44	181	N		442
accuracy		95%	84%	88%	84%	82%	88%	Overall accuracy		88%
errorO		5%	16%	12%	16%	18%	12%	Kappa coefficient		84%

Table 5:-Error Matrix Analysis of field sites (columns) against Landsat classification (rows) (year :2018)

		1	2	3	4	5	6	Somme	Ratio	errorC
high density built-up	1	76	12	0	0	0	5	93	82%	18%
dense built-up	2	0	55	0	0	0	10	65	85%	15%
low density built-up	3	0	0	40	5	0	7	52	77%	23%
green space	4	0	0	3	30	0	0	33	91%	9%
forest	5	0	0	0	0	30	4	34	88%	12%
bare soil	6	2	0	0	0	9	150	161	93%	7%
Somme		78	67	43	35	39	176	N		438
accuracy		97%	82%	93%	86%	77%	85%	Overall accuracy		87%
errorO		3%	18%	7%	14%	23%	15%	Kappa coefficient		83%

Error matrixes and Kappa coefficient were used to assess classification accuracy and are summarized in Table 2 to Table 5. The overall accuracies for 1986, 1996, 2007 and 2018 were, respectively, 86%, 87%, 88% and 87% and the Kappa coefficient for 1986, 1996, 2007 and 2018 were, respectively, 81%, 82%, 84% and 83%. The field observation and the results of overall accuracy and coefficient Kappa validate the land use maps obtained by the classification. According to the land use maps, the city of Casablanca experienced during the period 1986-2018 a major growth in urban area and change in built-up density. The urban growth and sprawl have been evolving progressively and could be easily distinguished by the crown shape of the built-up area.

Change detection:-

According to the results for the period starting from 1986 to 2018, the urban change was large, built-up areas increased by 144.8 % from 1986 (11093.49 ha) to 2018 (27154.61 ha), the highly dense built-up increased by 100.62 % from 1986 (4227.12 ha) to 2018 (8480.59 ha), the dense built-up increased by 337.65 % from 1986 (3384.27 ha) to 2018 (14811.3 ha) and the low dense built-up increased by 10.93 % from 1986 (3482.1 ha) to 2018 (3862.72 ha) (Table 5). The bare soil decreased by 27.56% (14668.01 ha) while green space decreased by 4.55% (29.8 ha) and forest decreased by 31.04% (1363.31 ha) (Table 6).

Table 6:-Classes area and percentage along the study period.

	1986		1996		2007		2018	
	ha	%	ha	%	ha	%	ha	%
High dense built-up	4227,12	6	4688.55	7	5983.2	9	8480.59	12
Dense built-up	3384,27	5	6334.47	9	10183.1	15	14811.3	21
Low dense built-up	3482,1	5	1229.85	2	1548.54	2	3862.72	6
Green spaces	653.58	1	651.6	1	626.67	1	623.78	1
Forest	4392.09	6	4196.88	6	3694.86	5	3028.78	4
Bare soil	53205.8	77	52243.61	75	47308.59	68	38537.79	56
Studied area surface	69344.96	100	69344.96	100	69344.96	100	69344.96	100

We noticed that the highly dense and dense built-up was increasing during the whole period of study while the low dense built-up decreased from 1986 (3482.1 ha) to 2007 (1548.54 ha) and increased in the last decade to 3862.72 ha. This is due to the transformation of low dense built-up in the main city to the dense and highly dense built-up during

the two first decades of the study period. The high increase of urban area is due to the population growth in the city of Casablanca, the economical capital of Morocco (table 7), therefore the demand for new housing is high. We calculated for the period of study, the urbanization and population annual growth that are respectively 4.52 % and 1.75 % in order to determine the urban sprawl index ($USI = \text{Urbanization annual growth} / \text{Population annual growth}$).

Table 7:-Comparison of urban area estimates from images classifications and the demographics and census data.

Year	1982	1994	2004	2014	1982-2014	change (%)	Annual Growth(%)
Population	2151602	2717125	2949125	3359818	1208216	56,15	1,75
Year	1986	1996	2007	2018	1986-2018	change (%)	Annual Growth(%)
Urbanisation (ha)	11093,49	12252,87	17714,84	27154,61	16061,12	144,77	4,52

The value of USI is equal to 2.58 which means that the urban expansion is much higher than the population growth. This index provides a way to assess the degree and nature of sprawl for the city of Casablanca.

Table 6 and Figure 5 indicate that increases in urban areas mainly came from conversion of peri-urban land (bare soil and agriculture land) to urban uses during this period. The urban land has grown by 16061.12 ha, 14668.01 ha of which was converted from bare soil land. Forest and green space, respectively, contributed by 1363.31 ha and 29.8 ha.

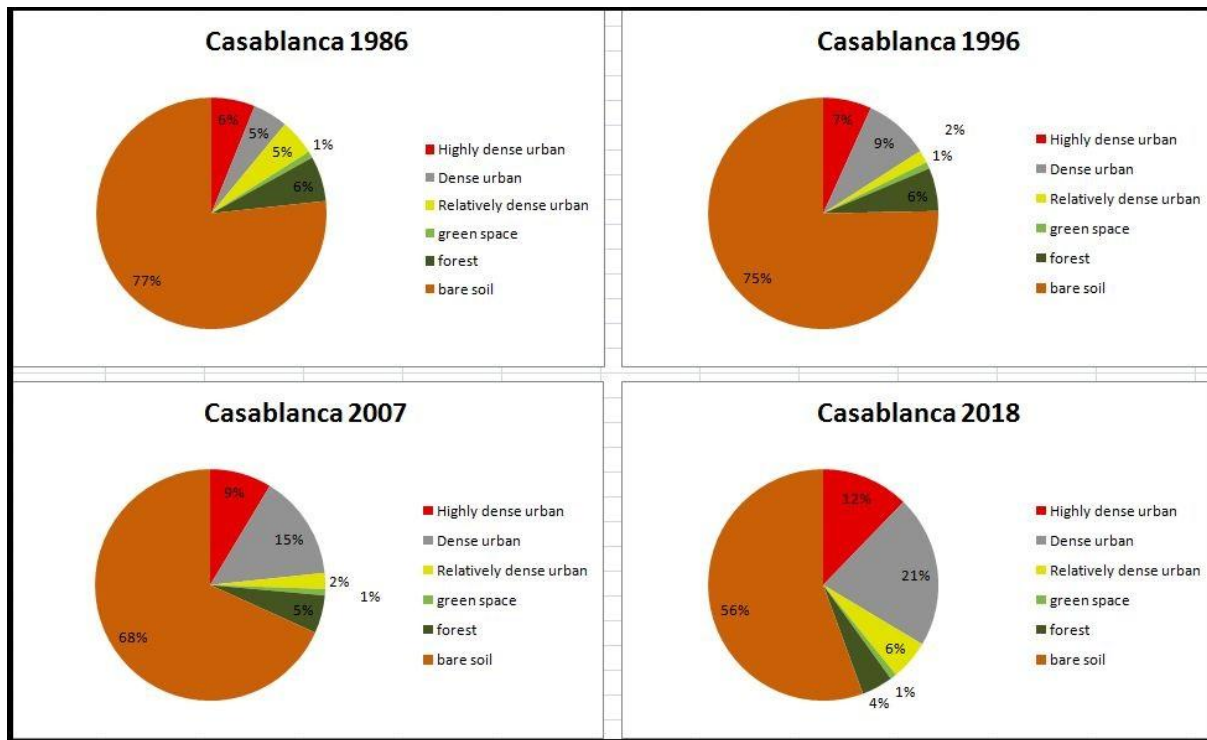


Figure 5:-The percentage of each class in the study area surface.

This approach has demonstrated how landscape changes have been evolving during the period of study. Analyzing these data allows a deeper understanding of growth in order to assess the impact and to plan the urbanization in an efficient way.

According to this study, the urban sprawl has a negative impact on forest and green space. Casablanca lacks vegetation cover and green space as the urban area has been doubled in the period of 1986-2018 whereas the green space slightly decreased. Hence a vigorous focus needs to be given to environmental issues of the city of Casablanca

and to its sustainability. The information on land use change should be used as a tool in policy decision making by local authority.

As the city grows in size and population, harmony among the spatial, social and environmental aspects of a city and between its inhabitants becomes of paramount importance. Urban development should be guided by a sustainable planning that creates a balance between buildings and green space and protects cultural aspects. We recommend policymakers, regulators and developers that are working on the urbanization of the city of Casablanca to use the analysis and data presented in this work for a better future of the city.

Conclusion:-

Through this research, the analysis of the built-up density and the urban growth and sprawl of Casablanca during the study period using multi-temporal satellite images was achieved. The classification was able to delineate different type of built-up density, bare soil, forest and green space. Once the city space was saturated, the urban growth and sprawl in Casablanca started to propagate in the peri-urban land in form of a crown. Information from remote sensing data and GIS can play a significant role in quantifying and understanding the nature of changes in land cover and where they are occurring. Such information is essential to a sustainable urban planning and development and better life quality.

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