Urban Development and Landuse change Patterns in Muscat City, Oman

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Abstract
Urban sprawl is a remarkable characteristic of cities of the Arabian Gulf region, including Muscat city, the capital of the Sultanate of Oman. The city has grown from discrete isolated settlements to a compact, dense urban metropolitan region across narrow coastal alluvial plain. This paper examines the specific implications and trends of urban landuse dynamic in Muscat city in the last five decades. Urban landuse patterns were traced and analyzed from different sources, including: Landsat, IRS, IKONOS, QuickBird, GeoEye, Aerial photos and Printed map. RS & GIS change detection techniques using Normalized Difference Building Index (NDBI) and Normalized Difference Vegetation Index (NDVI) were used. The categorization of landused classes was mainly based on high resolution images (IKONOS, QuickBird and GeoEye). The results indicated that, residential, commercial and industrial landuses have shown large increase, basically at the expense of vacant and agricultural areas. The trend of urban landuse patterns was largely filling the gap and empty areas, creating an urban structure of high density. The actual range of urban expansion might have been small, and the degree of change for the whole city region, might have been not remarkable because of the relatively new expansions of urbanization and industrial development in Muscat. However, the negative impacts of these changes might escalate in the future if a plan to regulate land development is not developed and implemented.

1. Introduction

Urbanization is well known as a worldwide phenomenon (Liu et el., 2014) particularly in the developing countries, as urban population has increased intensely in last decades. Urban growth rates have increased at a very fast in Africa, Asia and Latin America Continents by 3.9%, 2.9% and 4% respectively while in developed nations the rate of growth is 1.2% in Europe and 1.9% North America according to UN demographic statistics (UN, 2006). Urbanization has substantial impacts on human civilization (Bloom et al., 2008 and Wu, 2014), it has a profound influence on landuse change and dynamic (Zhou et al., 2004) and combined impacts on landscape patterns and ecosystem processes (Antrop, 2004 and Weng, 2007).

To investigate and assess the undesirable effects of this phenomenon research effort has been directed to explore the best ways for landuse policy and planning to deal with land resources (Tian et al., 2014), and (Long, 2014). Governments use Urban Planning as a mechanism to manage land development, particularly in cities. Urban plans are employed to direct and control urban environments (Balbo, 1993) as well as monitor urban expansions (Ramadan et al., 2004, Al-Awadhi, 2005, 2007 and 2008 and Al Gharibi, 2014).

Integrated sustainable landuse planning work to improve environmental quality, social equity and economic sustainability (Jim and Chen, 2003). Commonly, the conversion of land from its natural conditions to human use is in most instances long-lasting and often irreversible. Effects of human interaction with the natural environment include capital assets that take long time to change (Jolly and Torrey, 1995). Socio-economic drivers and other human-induced practices and manipulations are the major causes of d land-use change (Mitsuda and Ito, 2011). At the present time, the level of urbanization goes above 60% in developed countries (Brown et al., 2005). In the case of developing countries, the urbanization rate is lower than in developed countries; however, the rate of growth is five times faster (Brinkmann et al., 2012). As urbanization generates various socio-economic and cultural changes and challenges. In Oman, urbanization reached 84% in 2009 according to UN demographic statistics (UN, 2010). Muscat, the capital city, holds more than one third of the total population of Oman, according to Oman Census data of 2010 (NCSI, 2015). This trend makes the city grows both in demographic and physical expansion (Al-Awadhi, 2008 and Al Gharibi, 2014).

The urban growth is similar to the most Omani cities like Sohar (Al-Awadhi, 2017) or Al-Seeb (Al-Awadhi, 2005).

Urban growth in Muscat is characterized by sprawl form (Al Gharibi, 2014). Urban sprawl is an increasingly common feature of the built environment in Muscat. Urban sprawl notion has emerged as a result of debate among scholars, specifically urban planners, economists, environmentalists, sociologists, transportation professionals, policymakers, public officials and academics during the past two decades. Urban sprawl recently became an unique phenomenon due to several issues occurring in many countries. For example, vehicle invention, lead to increase urban sprawl and redirect urban growth to follow road network. It has also caused many socio-economic and environmental problems in contemporary urban areas. Urban growth and sprawl is a pertinent topic for analysis and assessment towards the sustainable development of a cities. Bhatta (2010), argued that 'sprawl as a process without considering the pattern cannot be identified. According to Bhatta (2010), 'sprawl refers to: (1) certain patterns of land-use, (2) processes of land development, (3) causes of particular land-use behaviors, and (4) consequences of land-use behaviors. Landuse patterns analysis and prediction provide a tool to assess landscape change and its socio economic implications at various temporal and spatial scales (Fukushima et al., 2007). Despite their relevance, quantitative data describing landuse change at various scales require more evidences from different places (Ramankutty and Foley, 1998).

The increasing rate of urbanization in Muscat metropolitan region and its impacts have created pressures on planning authorities to established sustainable urban development. The objectives of this study is to understand the dynamic of urbanization in Muscat city and explore the patterns and trends of landuse change as well as their spatial, socio-economic and environmental implications.

2. Material and Methods

2.1 The Study Area

Muscat governorate (Figure 1), contains the capital of the Sultanate of Oman. Muscat governorate extents approximately 1500 km² and includes 6 administrative divisions (Wilayats): Mutrah, Muscat, Bawshar, AS Seeb, Al-Amrat and Qurayyat. The total area of the Governorate is 3796 Km². However, the study area of the present investigations extent a cross the whole urban area of the Muscat Governorate excluding Qurayyat Wilayah which considered as rural hinterland and is quite distinguished from core urban fabric of the city. Accordingly, the study area will overs only 688.3 km².

Muscat is an important commercial, industrial and business center. The location contributed to the city being a junction of transport routes. It is the biggest metropolitan center in the country. It is also the chair of administration and the center of commercial and economic institutions. Its located in northeast part of the country, between 22° 53′ and 23° 47′ N and between 58° 02 and 59° 13′ E. It is bordered to its west by the coastal zone of the Al-Batinah North Governorates and to its east by Ash Sharqiyah North Governorates. The inner plains of the Ad Dakhiliyah Governorate border Muscat to the south, while the Sea of Oman forms the northern and western boundary of the city. The city is situated on a bay surrounded by volcanic mountains. The city plan and layout took the shape of a ribbon along the coast. Most urban areas and discrete settlements exits along the coast and between the two main roads that cross the city from west to east.

According to the 2010 census the population of Muscat is 775,878 (NCSI, 2010). In addition, and according to the same source the total population of the City is more than 1.488 million inhabitants in September 2017 (NCSI, 2017). At present, Muscat population is comprising third percentage of the total population of the county (Figure 2). The figure shows the influx of international immigration to the city. Which resulted in increasing the total number of expatriates living in the city. As indicated by (Figure 2) the total number of expatriates is become more than the citizens this issue is in fact, contributed to distorted development in urban areas in Oman.

2.2 Materials and Preprocessing

In recent decades Remote Sensing (RS) and Geographical Information Systems (GIS) techniques for urban areas are becoming an important tool for quantifying urban landuse growth and expansion and have been used frequently in recent studies. It has turn out to be an integral part of information technology and provides solutions to issues of sustainable development of natural resources and conservation of environment. The RS and GIS applications oriented research in land development fields has led to improve the operational and commercial use of this technology in addressing environmental and planning related issues. It has the ability to include a variety of data sources and delivers response to key questions of sustainable development.

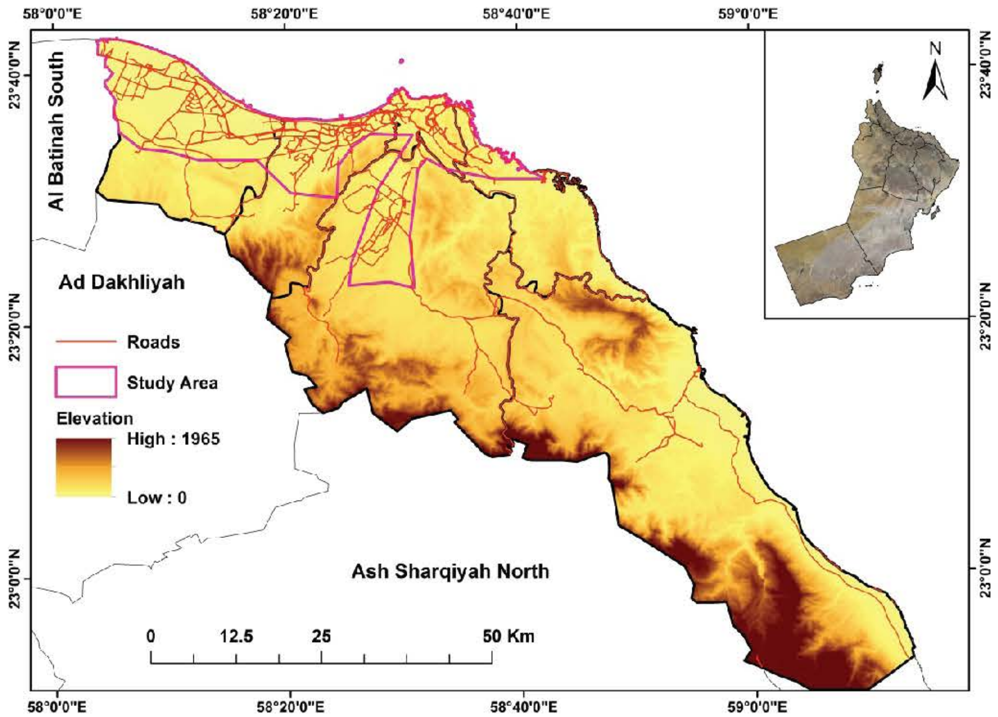
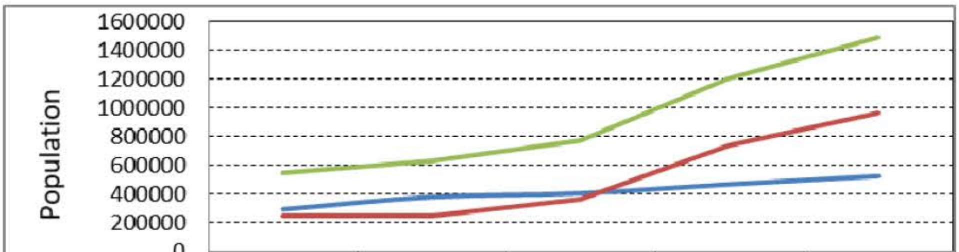


Figure 1: The study area



	1993	2003	2010	2014	2017
Omani	295641	381612	407006	470085	526707
Expatriate	253509	250461	368872	740395	961323
Total	549150	632073	775878	1210480	1488030

Figure 2: Population growth in Muscat (1993 - 2017)

Table 1: Data sources description used for tracking changes in the study area

Satellite	Date	Bands	Spatial Resolution	Format
GeoEye	2012	4	0.46 m	GeoTIFF
QuikBird	2004	3	0.63 m	GeoTIFF
IKONS	2000, 2003 & 2008	3	1 m	GeoTIFF
IRS	2000	3	5.8 m	GeoTIFF
Landsat-4 (TM)	1982	7	30 m	GeoTIFF
Landsat-5 (TM)	1990	7	30 m	GeoTIFF
Landsat-7 (ETM)	1999	8	30 m	GeoTIFF
Road Network	2003	-	20 cm accuracy	Shapefile
Census District	2010	-	5 m accuracy	Shapefile
Aerial Photos	1980, 1970, 1966 & 1960	-	Different scales	Paper
Topographic Maps	1984	-	1:100000 and 1:50000	Paper
Tourist Maps	1982 & 1992	-	1:10000 and 1:20000	Paper

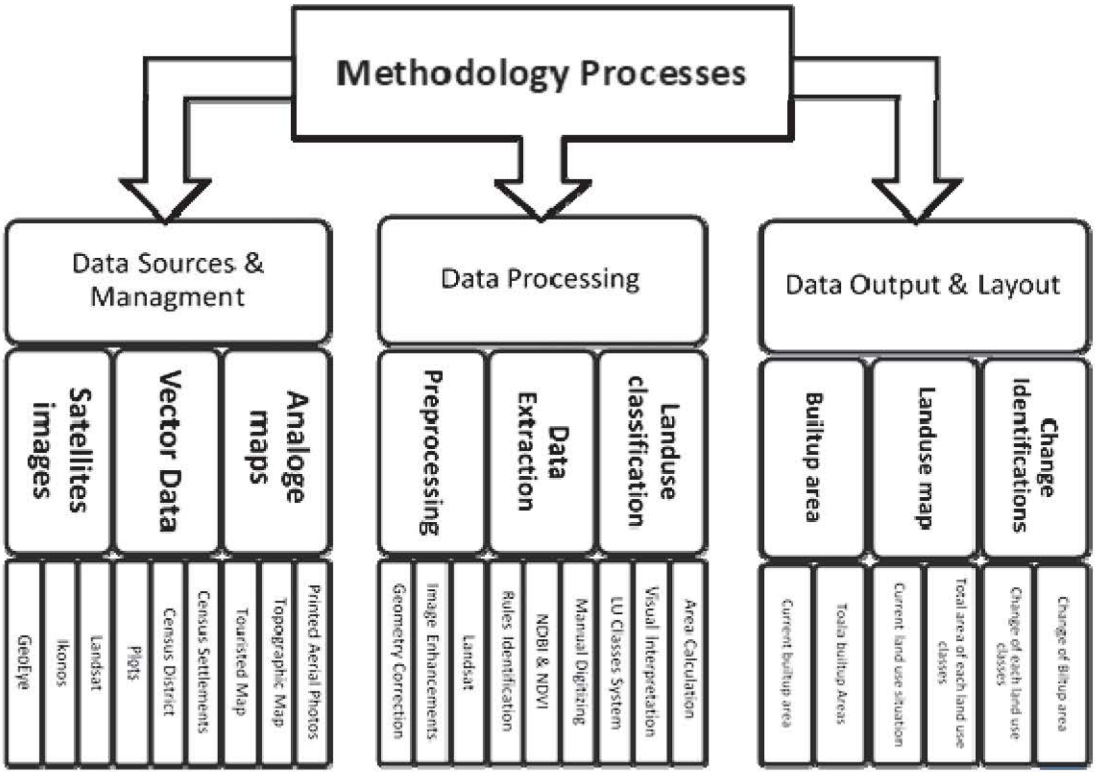


Figure 3: Methodology flowchart

In the case of present investigation, these technologies have been widely used to investigate both qualitative and quantitative extents of urban growth and landuse change trends at local level.

The data sourness used in this study is shown in Table 1, it includes multi temporal Landsat TM and ETM images for the years 1990, 1999, 2003 and 2011. High resolution images were also used such as IRS panchromatic image acquired for 2000. Multi spectral IKONOS images with 1-meter resolution for 2003 and 2008 were used as well as QuickBird image (0.64 M resolutions) for 2004 and GeoEye (50 cm resolutions) for 2012. Other analogues sources such as: (1) paper maps like topographic map (1:100000 and 1:50000) also used for the future analysis. (2) paper aerial photos were main data sources for tracking urban and landuse change before 1980. (3) paper tourist and topographic maps, and very accurate vector data from census district data were also used to support final results validations.

Figure 3 illustrated general methodology adopted in this research. Urban landuse classes were generated with an interval of 10 years to analyze the nature, rate and location of urban landuse trend for last 50 years. To cover the whole Muscat region a composite of various data resources was used for preparations of landuse maps (Al-Awadhi, 2007 and 2008).

To achieve the main objective of this study a comprehensive temporal landuse database has been developed. The database has a common and detailed and flexible classification systems. This classification has been used to trace the landuse patterns from both high spatial resolution images to lower resolution images. Several landuse classification systems such as CORINE system and Land Based Classification Standards (LBCS) and Anderson's classification were adapted. Muscat has its own urban identity, yet the classification system developed has two levels: the first level was divided into two general classes (built up area class & Vegetation class). The second class was subdivided into further landuse classes which include: residential, commercial, industrial, public building, transportation, agricultural, recreational, vacant and water uses.

2.3 Classification and Information Extraction

All images and vector data were georeferenced using UTM WGS 1984 projection zone 40. The first GeoEye Image for 2012 was georeferenced using road networks from Muscat Municipality with less than 20 cm error shifting. This image then used to georeferenced other all images through image to image processing. All images were pre-processed to remove radiometric, atmospheric and geometric distortions. Some guidelines have been identified to trace and detect the landuse classes such as: (1) the size of the landuse polygon which should not be less than 900 m^2, (2) when the mix landuse occur in the tracing polygon, majority of the use will be applied and (3) when no details data resources available, others supported ancillaries would be used especially for older periods.

The most recent image which was GeoEye 2012 has been considered as starting point for 2010 period. Others supported ancillaries has been overlaid to the image for easily identification. Numerous scales were also used to verify the classification accuracy. Due to the characteristics of different landuses and it dynamic nature it is difficult to identify the classes. Thus the visual interpretation was used to digitize the landuse classes according to rules of the classification system. The second IKONOS image for 2003 and 2000 was placed in separate layer. The last version of the digitized landuse layer was placed at the top of the IKONOS images. Then, landuse changes were traced by removing any landuse classes which cannot be identified in the image. In the same time, new landuse classes are added to the layer after confirmation from other sources. This processes have been repeated for all other periods consequently with less resolutions data sources.

Since high resolution images were not available for older periods, the estimates of urban landuse trends in this study area have been attained by using multiple-date classification maps of Muscat city extracted from Landsat images of 1990, and 1982. The built-up land image was produced using the NDBI (Normalized Difference Built-up Index) as shown in Equation 1 (Zha et al., 2003, Hanqiu, 2007and Rajendran et al., 2016).

$$NDBI = (TM5 - TM4)/(TM5 + TM4)$$

Equation 1

While the vegetation areas were extracted using the NDVI (Normalized Difference Vegetation Index) (Di and Hasting, 1995, Krishnaswamy et al., 2004 and Rajendran et al., 2016). NDVI is realistic approaches to define vegetation in a single image using an Equation 2.

$$NDVI = (\text{band } 4 - \text{band } 3)/(\text{band } 4 + \text{band } 3)$$

Equation 2

The output from the last processes for images for 1990s and 1980s have only built-up areas and vegetation which then are combined and converted to vector data format. 1990 layers were compared with other data source such as land plots, census data to define each landuse cases in that period.

The same processes were done for 1990. For 1970s and 1960s aerial photos were used to extract landuse map by using visual interpretation. Several sets of aerial photos scale 1:10000 were used as well as ground check up and verification of expert people to identify each classes of landuse in the area at that time.

3. Results and Discussion

Table 2 shows the actual areas of different classes in six different periods of time between 1960 to 2010. The table also showed the identification of changes in landuse categories. For instance, substantial change in urban landuse has occurred between 1970 to 1980 which constitute more than 3.5 times the extension that took place before. Simultaneously, a major increase in residential land has occurred with the same time. These results are consistent with the results of Antrop, (2004), Sarvestani et al., (2011) and Al-Awadhi (2017) studies.

In comparison, the agricultural land barely changed during the same period of time. Further explanations can be made with regard to different landuse classes within the general frame of the study data. For example, public building class has constituted the big portion of the built-up area particularly for the period before 1980 representing about 29.8% in 1980 and increased to 30.2% in 2003.

To examine the driving factors, supplementary data were used. Census information from 1960 to 2010 was used to describe the amount of new urbanization, the population totals for each of the six divisions of the city (Wilayah) was sorted for the different study periods and used as an indicator to validate urban landuse change delineated from the air photo and imagery data. The changes in urban area and urban population density have been found to be good indicators of the processes of urbanization and urban expansion as shown in Figure 4. To trace and identify the trends of urban landuse change in Muscat historical review of urbanization the city is carried out. The causes and consequences of urbanization were analyzed based on urban forms. To analyze the patterns and dynamic of landuse expansions and their consequences in the study area, a landscape-scale investigation was made based on existing ecosystems and landuse patches throughout the landscape. The indicators were used to find the effect of urbanization on land assets. The increase of newly urbanized areas, decrease of vacant land, and loss of ecologically important natural land were observed.

Table 2: The actual areas of different classes in different time zones (1960 - 2010)

Classes	1960	1970	1980	1990	2000	2010
Residential	5.37	5.472	12.531	31.566	57.21	73.824
Commercial	0.28	0.301	5.722	9.302	10.725	12.414
Industry	0.1	0.102	4.945	12.906	17.203	21.566
Public Building	0.45	0.446	22.485	37.666	59.218	69.767
Transportation	0.03	0.121	13.297	22.147	28.329	42.354
Agriculture	17.97	17.915	18.289	18	17.136	18.156
Recreation area	0.04	0.044	0.126	3.46	5.393	8.096
Lake	0.1	0.097	1.327	1.378	1.378	1.373

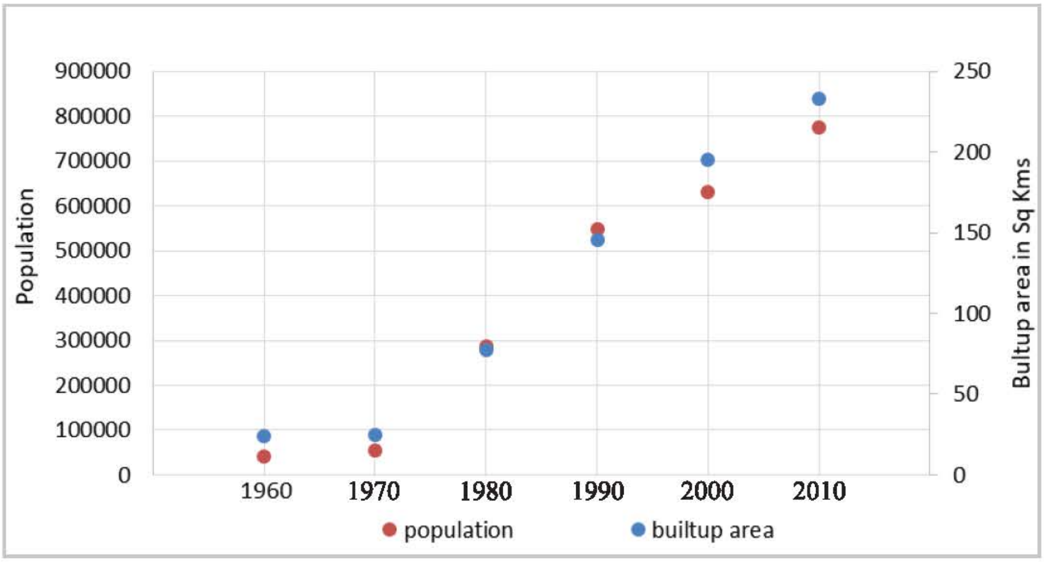


Figure 4: Year wise population vs. built up area (data has been constructed from different data sources)

3.1 Analysis of Historic Landuse changes

For the analysis of historic landuse change it is noticed that considerable development in the city have occurred between early 1970s and up to the mid of 1980s. During this period Muscat has witnessed fast social, economic, and environmental change drawn by the huge population influxes motivated by the economic prosperity and infrastructures development. The landuse categories that were analyzed for the period 1960-2010 are illustrated by Figures 5 and 6 and Table 3, which include the following:

1. Residential area
2. Commercial districts and streets
3. Industrial areas
4. Public building
5. Streets and transport infrastructure
6. Agricultural land
7. Recreational land
8. Vacant land
9. Water (lake)

For an in-depth analysis of the driving causes, additional data were gathered, such as census data obtained from National center for statistics and information (NCSI, 2015) The built-up area is the major landuse category that witnessed a considerable change which represent the major landuse change. Among these driving factors, demographic and economic factors as Xindong et al., (2014) mentioned in their study. Table 4 showed the most change happened between 1960 – 2010 in two Wilayats which are AS Seeb and Bawshar, 770% and 1600% respectively. These two Wilayats also contains the most total built-up area in Muscat Governorate, 121.15 Km^2 and 75.57 Km^2.

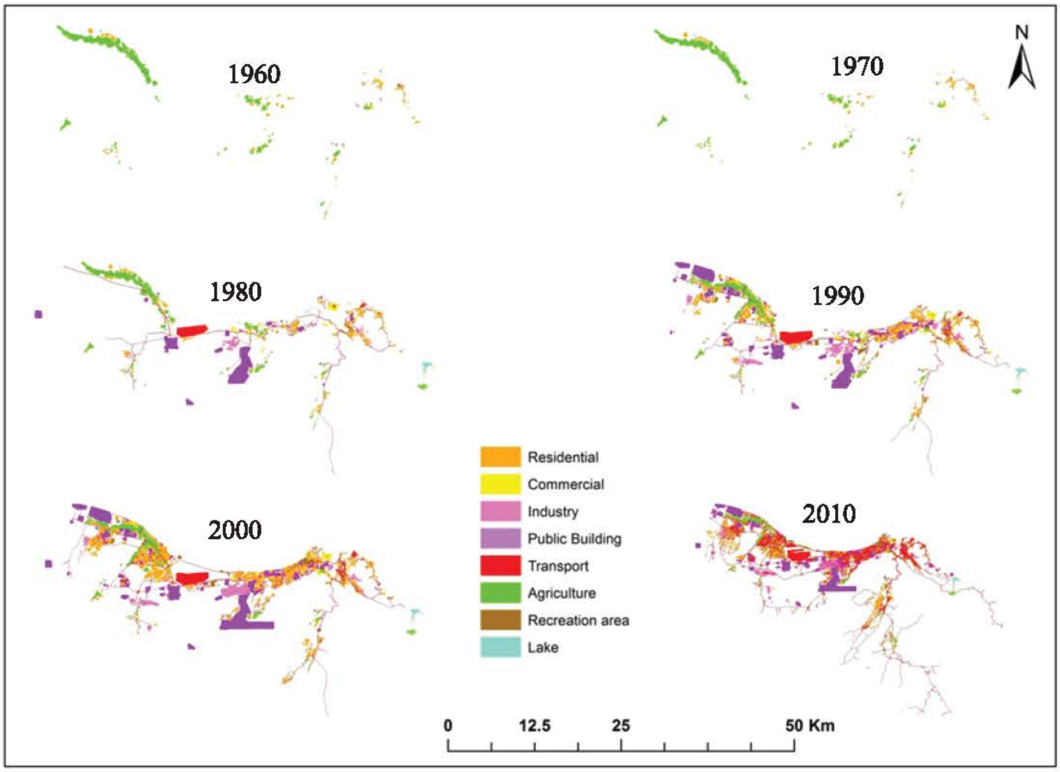


Figure 5: Urban landuse development in Muscat (1960-2010)

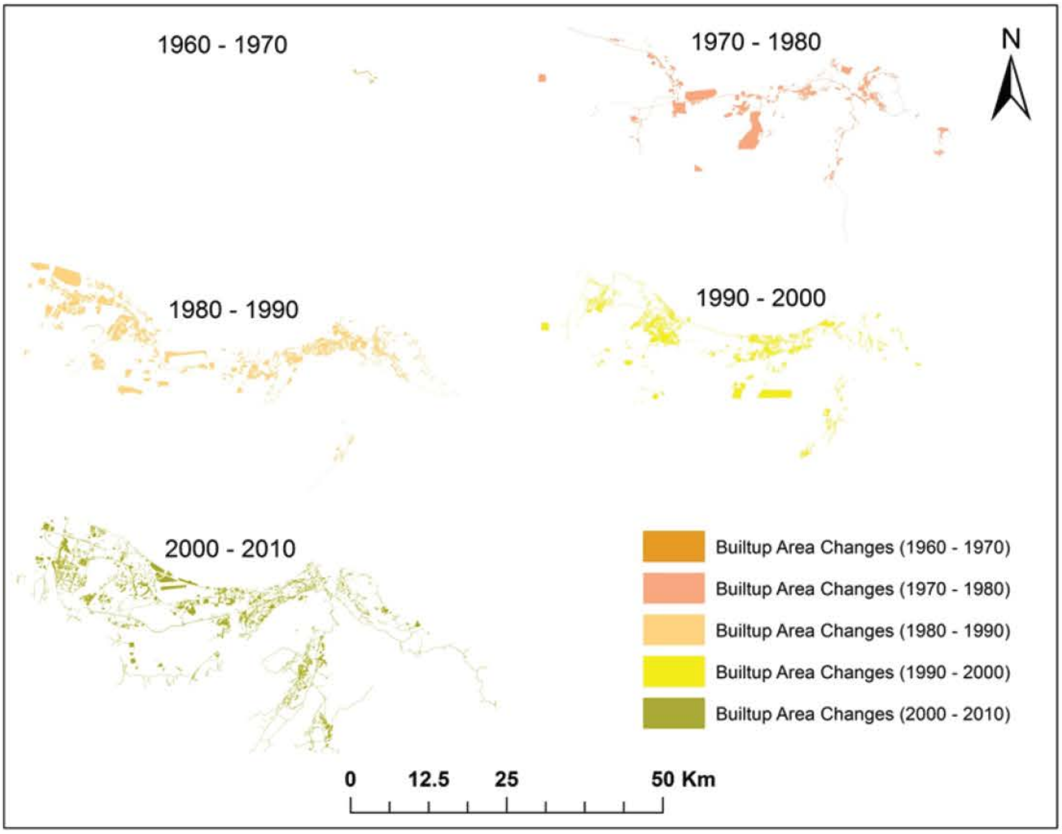


Figure 6: Built up area changes in Muscat (1960 - 2010)

Table 4: The historical built up area in Km^2 in all Wilayats in Muscat Governorate (1960 - 2010)

Year	Wilayat Name					
	AS Seeb	Bawshar	Mutrah	Muscat	Al-Amrat	Total
1960	15.74	4.51	1.71	1.00	1.31	24.27
1970	15.74	4.52	1.76	1.08	1.32	24.42
1980	32.50	27.62	10.49	3.44	3.10	77.15
1990	76.44	41.73	20.38	4.23	3.10	145.88
2000	96.99	62.59	23.62	4.54	7.25	194.99
2010	121.15	72.57	25.83	6.46	7.25	233.25

Understanding landuse change and dynamic is more than merely looking at the total area of certain landuses that increased or decreased. Observing the change in structure and the underlying reasons of this change are equally important. It is the complete picture of different elements that provides insight in landuse changes. For this reason, we have focused earlier on ways to measure the change as well as connect that to demographic aspect and population growth.

To extend the analysis to further level an overview of observed changes in area in the 9 classes were mentioned above. Results from this analysis indicated that urban landuse patterns in Muscat are described by discrete settlement structures in the beginning of the Omani renaissance in early 1970s. These settlements represent the present six divisions of the governorate they are spread throughout the coastal area. The initial impetus behind the urban explosion was the creation of the nucleus of a modern government. The growing number of Omanis returning from abroad at this stage tended to relocate to their own villages and regions throughout the countryside. The total population of the Sultanate has redoubled nearly six times from 500,000 in 1950 to 2,775,878 in 2010. Although Muscat and Batinah represent merely 5.3% of the total area of the Sultanate, they accommodate about 56% of the total population. This urban growth and dynamic meet limited land resources due to the morphological setting of the region. The fact that made most of the vacant area not fit for permanent settlement. Thus the remaining land has to be shared for different uses. While land consumption by residential use, services and transport infrastructure is increasing steadily, suitable land for agriculture is decreasing.

Government development plans have catered for the development of Muscat Governorate. As example is the sixth five years' development plans (2001-2005) Muscat Governorate received a total amount of 300 Million Omani Riyals (about 770$ Million) which is 50% of total budget of investment in the country in order to develop the infrastructure and services.

The city is need for more comprehensive strategy to guide and control sustainable development that should include strategies, programs, and action plans. Implementation frameworks to manage future balanced development in the city include indicators for sustainable landuse planning.

Urban development is essentially transforming and adjusting land utilization by different human activities. Land utilization happens from a variety of choices made by different socio-economic and demographic drivers. These alterations are somewhat unpredictable and needs understanding by urban practitioners. This basically the case of Muscat city. Where urban polices enhances city development and expansion. Land tenure systems encourage citizens to develop their own houses. Muscat city scores very high among the world cites where inhabitants own their houses. This trend of fast city development within the last two decades put pressures on urban planners to cope with the fast rate of urban growth. Oman national spatial strategy developed between 2012 and 2015 is an effort to institutionalize planning activities to deal with the escalating urban sprawl.

4. Conclusions

Research investigation of landuse dynamic and change is quite essential for urban planning and management. The present study examined the landuse dynamics and trends resulted from urbanization. This study examined the spatial pattern of landuse dynamics in Muscat city. The study outcomes have revealed that the study area was predominantly occupied by built-up land which represents the following uses residential area, commercial districts and streets, industrial areas, public building and streets and transport infrastructure which composed of over 95.7% of the entire land, and the inquiry also revealed that the total landuse increase rate was substantial and denotes ever-ending expansion, the vacant and agricultural land decline was mostly a result of increase of built-up land.

Furthermore, the trend was enhanced by following developments. Investigation of urban landuse dynamic in Muscat City through a landscape development approach provided a whole explanation of the landuse patterns incorporated in these changes. The frequent internal migration to the city has influenced the landuse arrangements in Muscat metropolitan region. International migration as well played an important part in the growth of the study area by changing the social and economic structures and transforming the spatial patterns. Infrastructure and roods uses are also undergoing the substantial rise. Followed by commercial and recreational uses. The changes were triggered by many motives, part of that may be linked to the mutual interaction of these factors and causes. Accordingly, it become very hard to accurately measure the contribution of each factor. Thus, relating these changes to the above mentioned driven factors is equally important. The results indicated that demographic change and economic development had always played important roles in landuse change. Yet, the weight of each driven factor is changing with changing circumstances. The intensification of economic activities places more pressures on planning institution to present counter plans. Development policies generally had indirect impacts, particularly economic development policies, which promote the economic development to cause landuse change, while land management strategies had direct impacts.

Urban development and population growth have triggered rapid changes to landuse patterns in Muscat city as a result of urbanization & industrialization. Urban growth assessment and prediction are essential components of urban development and planning, which helps in better landuse planning and sustainable use of resources. Based of RS and GIS the study analyzed the quantitative and qualitative characteristics of landuse patterns in the city. The framework of GIS/RS application is described by the work flow chart as shown in Figure 3. Both spatial and temporal changes were considered in the analysis. Results were shown in analysis maps, statistical tables and statistical charts .The Aspect of urban changes and its dynamics have been achieved with RS/GIS analysis in temporal, spatial and planning dimensions. Urban dynamism could be investigated in depth in future research.

Acknowledgment

The authors are grateful to all support provided by department of geography at SQU.

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