AN ASSESSMENT OF LAND COVER CHANGES AND ASSOCIATED URBANIZATION IMPACTS ON AIR QUALITY IN NAWABSHAH, PAKISTAN: A REMOTE SENSING PERSPECTIVE

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ABSTRACT:

In recent years, urban development has expanded rapidly in Nawabshah City of Pakistan. A major effect associated with this population trend is transformation of the landscape from natural cover types to increasingly impervious urban land. The core objective of this study are to provide time-series information to define and measure the urban land cover changes of Nawabshah, Pakistan between the years 1992 and 2002, and to examine related urbanization impacts on air quality of the study area. Two multi-temporal Landsat images acquired in 1992 and 2002 together with standard topographical maps to measure land cover changes were used in this study. The image processing and data manipulation were conducted using algorithms supplied with the ERDAS Imagine software. An unsupervised classification approach, which uses a minimum spectral distance to assign pixels to clusters, was used with the overall accuracy ranging from 84 percent to 92 percent. Land cover statistics demonstrate that during the study period (1992-2002) extensive transformation of barren and vegetated lands into urban land have taken place in Nawabshah City. Results revealed that land cover changes due to urbanization has not only contaminated the air quality of the study area but also raised the health concerns for the local residents.

KEY WORDS: Satellite Remote Sensing, Urbanization, Land cover changes, Air quality, Environmental degradation

1. INTRODUCTION

To ensure a sustainable development and a better environment, it is necessary to understand and quantify the processes of landscape change. Remote sensing has emerged as the most useful data source for quantitatively measuring land cover changes. It provides cost-effective multi-spectral and multi-temporal data and converts them to information valuable for understanding and monitoring land development patterns.

Nawabshah is one of the fastest growing cities in the country. Over few decades, Nawabshah has experienced rapid growth in terms of population. The population has increased from 45651 people in 1961 to the current 236473 people (Figure 1). The process of urbanization has been characterized not only by population growth, but also by industrial expansion. Rapidly growing industrial sector in Nawabshah is highly responsible for degrading the air quality of the study area. The continued emission of pollutants by the growing industries has mostly contributed to the present status of air atmospheric pollution problems in Nawabshah.

The aim of this study is to analyze dynamic land cover changes in Nawabshah between the years 1992 and 2002 and discovers the related urbanization effects to the air degradation in the study area.

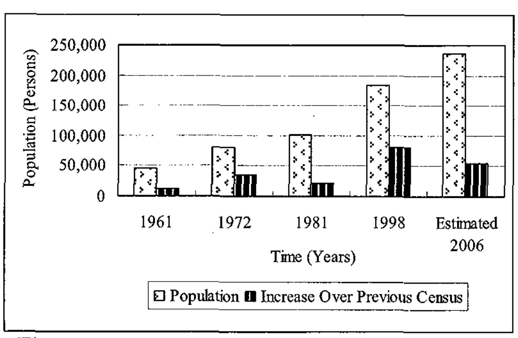


Figure 1. Average annual growth of population in Nawabshah, Pakistan

2. STUDY AREA

The study area, Nawabshah, is situated in the center of Sindh province of Pakistan and located between latitudes 25°

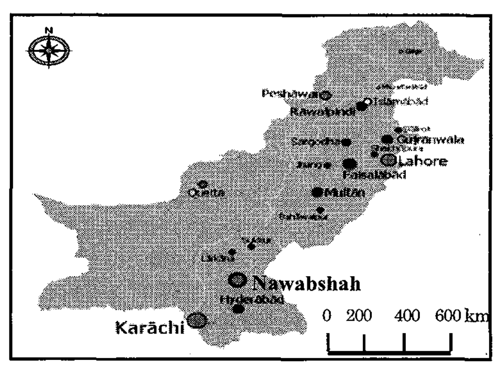


Figure 2. Location of Nawabshah, Pakistan

59′ N and 27° 15′ N, and longitudes 67° 52′ E and 68° 54′ E (Figure 2). Nawabshah is bounded on the east by Sanghar district, on the west by Dadu district, on the north by Khairpur Mirus and Noushero districts, and on the south by Hyderabad and Sanghar districts. With the exception of northeastern part of Nawabshah, the rest of the area is a fertile plain.

The climate of Nawabshah is not uniform. It is divided very sharply into northern and southern portions. The desert affects the northern portion of the city and hence climatic conditions are extreme. The southern portion enjoys the advantage of Sea Breeze. The average altitude is approximately 50 meters above sea-level with a mean annual rainfall of about 180 mm.

Regressive succession stages of evergreen forests have taken place due to drastic human-induced disturbances for rapid urban development. Increasing industrialization and rapidly growing population in the study area have made environmental problems more acute in Nawabshah. At present, there are 7 cotton grinning factories, 3 sugar factories, 1 textile factory, 4 flour factories, 1 oil factory and 1 Chemical plant in Nawabshah. All these industries are emitting waste materials, which as a result pollute the air and danger the health concerns for the residents in Nawabshah.

3. METHODOLOGY

3.1 Data Used

Predominantly cloud-free subset of each of the Landsat TM digital image acquired in September 1992, and Landsat ETM + image acquired in October 2002 covering Nawabshah city were used in this study (WRS2 path 152, row 42). Standard 1:50000 scale topographic maps of Nawabshah, compiled in 2001 and prepared under the direction of Department of Survey of Pakistan were also used as reference data to determine the accuracy assessment analysis. These maps are the latest and most authenticated source of information available for the study area. The image processing and data manipulation were conducted using algorithms supplied with the ERDAS Imagine image processing software.

3.2 Geometric Rectification and Radiometric Calibration

The intent of geometric correction is to compensate for the distortions introduced by Earth's curvature, relief displacement, and the acquisition geometry of the satellites so that the corrected image will have the geometric integrity of a map (Lillesand and Kiefer, 2000).

The 1992 Landsat TM image, which was supplied by United State Geological Survey (USGS), had already been rectified and geo-referenced to UTM map projection (Zone 42) and WGS84. Then, this image was therefore employed as the reference image to which the second image (ETM + of 2002) was registered. Using the image-to-image registration, the first-degree polynomial equation was used in image transformation. 35 well-distributed ground control points (GCPs) were used for the registration and the resultant root mean square error (RMSE) was less than 0.5 pixels (15m).

Table 1. Land cover classification scheme

Land cover class	Description
Urban land	Residential, commercial services, industrial, transportation, communications, construction materials and mixed urban or build-up land
Barren land	Bare rock areas, gravels, stones and boulder areas, hardpan areas and bare soil areas
Vegetated land	Crop fields, pasture, vegetation, plowed areas, golf courses and parks
Water	Permanent open water, lakes, reservoirs, streams, bays and estuaries

The images were re-sampled to 30m by 30m pixels using a nearest neighbor-sampling algorithm to avoid altering the original pixel values of the image data.

Without radiometric calibration of multi-temporal images, atmospheric factors can make it difficult to quantify and interpret change (Chavez and Mc Kinnon, 1994). A method developed by Hall (Hall *et al.*, 1992), which uses dark objects (e.g. burned area, water) and bright objects (e.g. bare soil, rock) as targets for radiometric adjustments, was used in this study. After this correction, image statistics and histograms of two periods were found to be similar and comparable.

3.3 Image Classification

Certain classification schemes that can readily incorporate land cover data obtained by the interpretation of remotely sensed data have been developed. In this study, common and popular unsupervised, ISODATA classification algorithm (Tou and Gonazales, 1974), provided by ERDAS Imagine software had been used for classifying Landsat images. The classes were determined in accordance with the land cover and land use classification system developed by Anderson (Anderson *et al.*, 1976). In total, four land cover classes were included in the scheme: (1) Urban land, (2) Barren land, (3) Vegetated land, and (4) Water. Detailed description for the four level 1 classes of land cover is summarized in Table 1.

3.4 Accuracy Assessment

Accuracy assessment is necessary for testing the accuracy of the resultant classes from the classification image. There are several methods for performing an accuracy assessment, such as the overall accuracy and the Kappa coefficient (Congalton, 1991). The confusion (or error) matrix, which can be used as a starting point for a series of descriptive and analytical statistical analysis, was used to represent the accuracy assessment for this study. The columns of the matrix represent the reference data, while the rows indicate the classes generated from the classification process.

Tables 2 and 3 show the error matrix resulting from the classifying digital data. For the 1992 land cover map, a total of 495 randomly generated pixels were selected, which were then checked with reference to topographic maps of the study area. Reference maps of Nawabshah are relatively older to the remote sensing data applied in this study, but are the latest source data. The result indicated an overall classification accuracy of 84.04% and a Kappa index of agreement of 0.75 (Table 2).

Table 2. Error matrix of the classification map derived from Landsat TM data of Nawabshah in 1992

Classification	Urban	Barren	Vegetated	Water	Row total	Producer's accuracy (%)	User's accuracy (%)
	Reference data						
Urban	61	8	11	0	80	70.11	76.25
Barren	6	124	14	1	145	84.35	85.52
Vegetated	20	15	218	3	256	89.34	85.16
Water	0	0	1	13	14	76.47	92.86
Column total	87	147	244	17	495		

Overall accuracy **84.04%**, Kappa coefficient **0.75**

Table 3. Error matrix of the classification map derived from Landsat ETM+ data of Nawabshah in 2002

Classification	Urban	Barren	Vegetated	Water	Row total	Producer's accuracy (%)	User's accuracy (%)
	Reference data						
Urban	97	8	4	0	109	90.65	88.99
Barren	3	114	6	0	123	87.03	92.68
Vegetated	6	9	234	2	251	95.9	93.23
Water	1	0	0	22	23	91.67	95.65
Column total	107	131	244	24	506		

Overall accuracy **92.29%**, Kappa coefficient **0.88**

For the 2002 land cover map, a total of 506 randomly generated pixels were selected. These were also checked with reference to 1:50000 topographic maps of the study area. The result showed an overall classification accuracy of 92.29% and a Kappa index of agreement of 0.88 (Table 3).

A contrast of Table 2 and Table 3 discloses that the 1992 land cover map yielded inferior accuracy than that of the 2002 land cover map. This may possibly be the effect of comparing older reference data, which is taken in 2001. Overall accuracy for both the maps shows that the image processing approach applied in this study has been effective in generating compatible land cover maps over time.

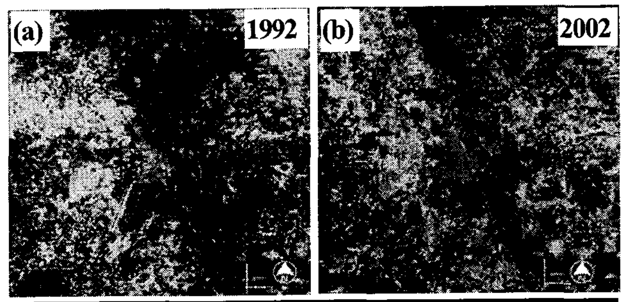
4. RESULTS AND DISCUSSION

Land cover classification maps of Nawabshah in the years 1992 and 2002 were generated. Figure 3 shows the land cover classification map for the selected years and Table 4 summarizes the related land cover distribution and overall change statistics. From 1992 to 2002, urban and barren lands have increased by 27.69 km^2 and 3.53 km^2, respectively. However, the vegetated land and water have decreased by 26.96 km^2 and 4.26 km^2, respectively.

From the results mentioned above, it is observable that vegetated land has mostly given way to the urban land for expansion of urban sprawl in the study area. Spatial patterns of urban sprawl in Nawabshah show temporal variations where the growth has changed expansion directions in different time periods.

To further assess the consequence of land cover changes, we examined, exclusively, two significant developing areas within the study area. Figure 4 shows the locations of these areas. Figures 5 and 6 display the land cover classification maps of these typical areas.

Figure 5 shows the temporal land cover changes in main city area of Nawabshah. Urban land in this area has increased from 2.58 km^2 in 1992 to 5.01 km^2 in 2002, resulting in an addition of 2.43 km^2. Vegetated land, in contrast, has decreased from 6 km^2 in 1992 to 4.92 km^2 in 2002, indicating an overall loss of 1.08 km^2. After analyzing A, and A' in



Color Scheme			
Color	Class	Color	Class
	Urban land		Vegetated land
	Barren land		Water

Figure 3. Land cover classification map of Nawabshah, Pakistan in 1992 and 2002

Table 4. Land cover distribution and overall change statistics for Nawabshah in 1992 and 2002

Area in km^2	1992/9/18	2002/10/18	Overall Change
Urban land	23.07	50.76	27.69
Barren land	60.69	64.22	3.53
Vegetated land	145.69	118.73	-26.96
Water	10.91	6.65	-4.26

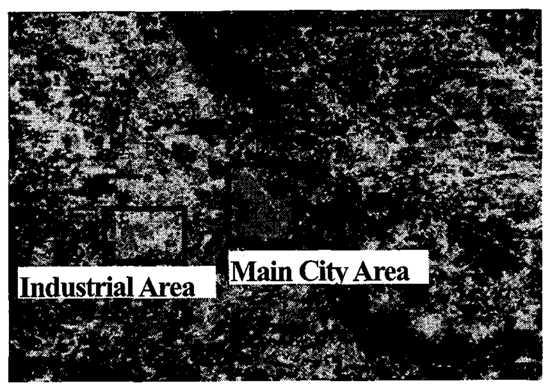


Figure 4. Location of two significant locations in Nawabshah, Pakistan

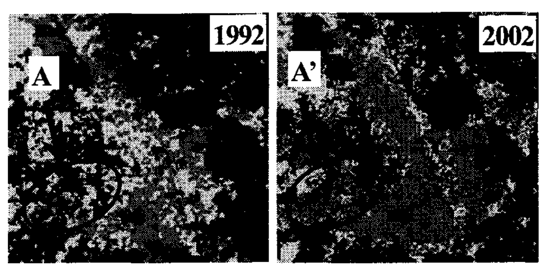


Figure 5. Land cover classification maps of Main City Area in 1992 and 2002

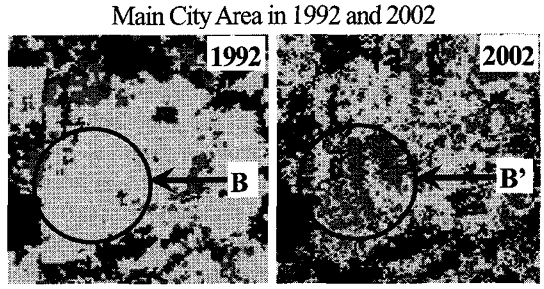


Figure 6. Land cover classification maps of Industrial Area in 1992 and 2002

Figure 5 it is apparent that a large portion of vegetated land has converted to the urban land between 1992 and 2002.

Figure 6 shows the dramatic land cover change in the newly developed industrial area of Nawabshah. In this area, urban land has increased from 0.93 km^2 in 1992 to 2.46 km^2 in 2002, a net gain of 1.53 km^2 within the study period. On the other hand, barren land has decreased from 4.82 km^2 in 1992 to 3.57 km^2 in 2002. It shows a total decrease of 1.25 km^2 in barren land. By evaluating B and B' in Figure 6, the rapid development of industrial area and dramatic conversion of Barren land into urban land are easily noticeable.

The assessment of Figures 5 and 6 indicates that major land cover changes have taken place in both significantly developed areas within Nawabshah.

5. URBANIZATION EFFECTS ON AIR QUALITY

Rapid urbanization is the area that has received substantial public attention over the past several decades. Air pollution is one of the diversities of man-made environmental degradation that are currently taking place in all over the world. The intensified process of urbanization, coupled with industrialization has resulted in a profound deterioration of Nawabshah's air quality. Over the past several years, industrial emissions have been a major source of pollution in Nawabshah.

Figure 6 evidently shows the significant land cover changes from 1992 to 2002 (barren land to urban land) in the industrial area of Nawabshah. Sugar, chemical, and other factories that are established in industrial area (close to main city area) are chiefly creating serious environmental pollution. The smoke releasing from the steel factories is full of carbon particles and toxic gases, while the waste material of the sugar factories is thrown into a drain, which is creating alarming environmental hazards and health ailments in the area.

Figure 7 shows the trends of the average concentrations of major air pollutants in Nawabshah from 1994 to 2003. The average concentration of TSP climbed throughout the years showing its continuous increasing tendency. CO pollution has dropped in the year 1994, but showing significant increase since 1997. It possibly is the reason of sugar factories developed in the industrial area. SO_2 pollution and NO_x concentration have fluctuated over the years but almost at the same level. The air quality monitoring data show that the annual average PM_{10} in Nawabshah has increased from 177μg/m^3 in 1994 to 219μg/m^3 in 2003[2)]. Hence, it is evident that current level of air pollutants is quite high and all the three indicators exceed much more of the standards of WHO recommend guidelines (e.g. 50μg/m^3 for SO_2, 10ppm for CO and 260μg/m^3 for TSP).

Comparison of Figures 6 and 7 show that with the increased urban growth and industrialization, the air quality deteriorates rapidly in Nawabshah. Finally, it suggests that growing industrialization due to population growth is directly influencing the environmental degradation by accelerating the air pollution in the study area. It clearly indicates that if the rapid urbanization and industrialization are not controlled properly, then within the next few years the environmental degradation in shape of highly polluted air is inevitable which may not only affect the health conditions of local inhabitants but also put adverse affects on the agriculture in Nawabshah.

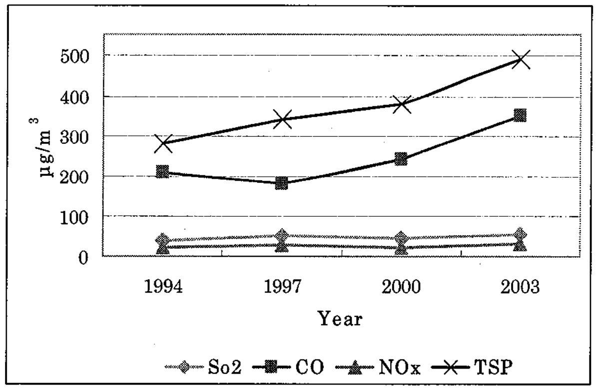


Figure 7. Annual average major air pollutants concentrations in Nawabshah

6. CONCLUSION

Air pollution caused by industrial pollutants is a grave environmental concern in Nawabshah. It has not only degraded the local environment but also threatened the human health of local population. However, the data on air quality collected in Nawabshah is not sufficient to develop a comprehensive picture of the state of the air quality and its effects. Therefore, it is imperative that air quality monitoring networks be established more efficiently in and around the study area. On the whole, the government needs to make a serious commitment to improve Nawabshah's air quality by drawing up a comprehensive action plan with the involvement of all stakeholders and then take bold steps to implement the action plan.

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