RELATION BETWEEN SOCIAL AND ENVIRONMENTAL CONDITIONS IN COLOMBO, SRI LANKA AND THE URBAN INDEX ESTIMATED BY SATELLITE REMOTE SENSING DATA

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ABSTRACT:

In most developing nations authentic and continually updated information concerning the rapidly expanding urban areas does not exist. Therefore the planning of urban infrastructure for the needs of effective development has become difficult, because there is no adequate understanding of the existing urban system. This study shows how digital data from satellite images could replace costly and time consuming traditional data collection efforts and provide a relatively inexpensive and fast method of updating urban information and assessing conditions in urban areas. For this purpose the authors propose the Urban Index UI, using Landsat TM bands 7 and 4. As a case study the Colombo Metropolitan Region in Sri Lanka is selected and it is shown how UI is strongly related to socio-economic and environmental data of this region.

1. INTRODUCTION

The rapidly receding boundaries of population agglomerations in many regions of the world has given rise to many environmental problems demanding urgent attention. Each week over 1 million new urban inhabitants are added to the world. With this increase in urban population comes the need for building new urban infrastructure, providing more environmental and social services and creating new jobs. However in most developing nations the lack of sufficient continually updated spatial data has made the planning process difficult or if not practically impossible because of the inadequate understanding of the existing urban system. The high cost and time required for traditional data collection methods have made a systematically developed urban data base beyond the reach of many planning authorities. However, recent developments in the field of remote sensing technology in addition to the advancement in micro computers its related hardware and software components have made this technology more affordable and accessible to urban planners and engineers and is helping to overcome these problems effectively.

In this study Landsat TM data has been related with ground collected socio-economic and environmental information so that digital data from Landsat images could be used to update information and assess the conditions in urban areas. For this purpose the authors propose the Urban Index UI , using Landsat TM bands 7 and 4.

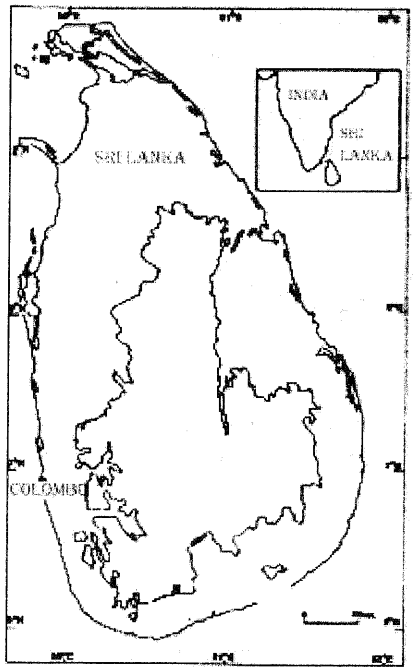

Figure 1. Location of Colombo City

As a case study, the Colombo Metropolitan Region in Sri Lanka has been selected. Colombo City is the commercial and industrial center of Sri Lanka. The location of the city is shown in Fig:1. Out of a total population of 17.7 million people living on the Island of Sri Lanka an estimated 2 million people live in the Colombo Urban Area which extends over 58 Sq.km. The population in the

most buit-up areas of Colombo are in the region of 160 persons to the hectare.

2. REMOTE SENSING DATA USED.

Digital data from a Landsat TM scene aquired on the 12th of February 1993 was used in the study.

2.1 The Proposed Index UI

The proposed index UI was computed as shown below using Landsat TM band7 (B7) and band 4 (B4), exploiting an observed inverse relationship between the brightness of urban areas in the near infra-red (0.76μm - 0.90μm) and mid infra-red (2.08μm - 2.35μm) portions of the spectrum.

$$UI=\left(\frac{B7-B4}{B7+B4}+1.0\right)\times 100 \qquad (1)$$

This index was verified by examining its relation with the Normalised Difference Vegetation Index (NDVI), land cover and building cover data of the Colombo City area.

2.1.1 Relation of UI with NDVI. In this study NDVI was defined as follows using Landsat TM band 4 (B4) and band 3 (B3).

$$NDVI=\left(\frac{B4-B3}{B4+B3}+1.0\right)\times 100 \qquad (2)$$

The UI - NDVI relation was examined in two ways. One was by seperating pixels into those of central and suburban areas and the other was by seperating them into those of different categories of land cover by using land cover information.

2.1.1.1 UI - NDVI Relation Based on Central and Suburban Areas. Average UI and NDVI values for pixels of 20X20 image pixels were computed, eliminating pixels from water areas by overlaying with a classified image. These pixels were picked up from an area of 1024X800 image pixels covering Colombo City and its suburbs. The central area of the city was seperated by selecting an area of 400X640 image pixels covering the central part of the city. The remaining pixels in the 1024X800 pixels image were considered to be of the suburban area. The scatter diagram of UI and NDVI for Colombo City is seen in Fig:2. From this figure it is seen that UI is high when NDVI is low in the central area of Colombo City.

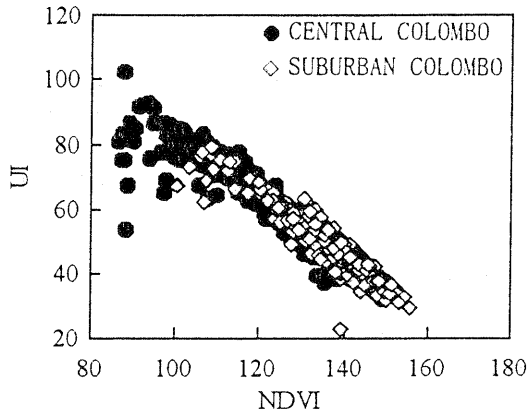

Figure 2. UI - NDVI Relation

2.1.1.2. UI - NDVI Relation Based on Land Cover Type. Digital land cover data of the Colombo City area was obtained by scanning a 1:50000 land use map of 1981. The UI and NDVI images were registered with images of digital land cover data by removing geometric distortions using ground control points and Afine Transformation Technique. Resamplng was done using Nearest Neighbour Method. Each pixel was assigned to a category if more than 80% of the original 20X20 image pixels within the considered pixel belonged to that category. The UI - NDVI relation based on land cover category is shown in figure 3. This figure shows that the UI value increases and NDVI value decreases with increased urbanisation.

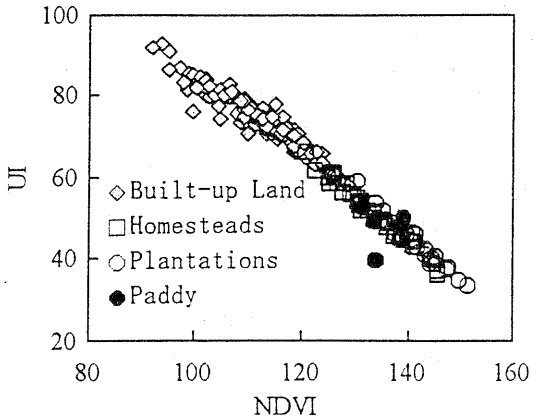

Figure 3 UI - NDVI Relation Based on Land Cover Category

2.1.2 Relation of UI with the Density of Building Cover.

Building cover data was obtained from a 1:12672 (16 chains to one inch) map of Colombo City and environs of 1970. This map was scanned and the percentage of building cover or urban density (UD) values were computed. UD was defined as the percentage of the total number of pixels representing buildings within a rastor grid cell of 650mX650m. The scanned image of building cover was registered with the Landsat TM image. The average UI values for the same rastor cells coresponding to the UD values were computed. Areas that have been urbanised after 1970 were identified using information from the Colombo City Development Plan of 1985 and new building cover maps which are under preperation. Then using UD values from the areas in which the building cover has not changed much during the past two decades the scatter diagram of UI with UD was obtained as shown in figure 4.

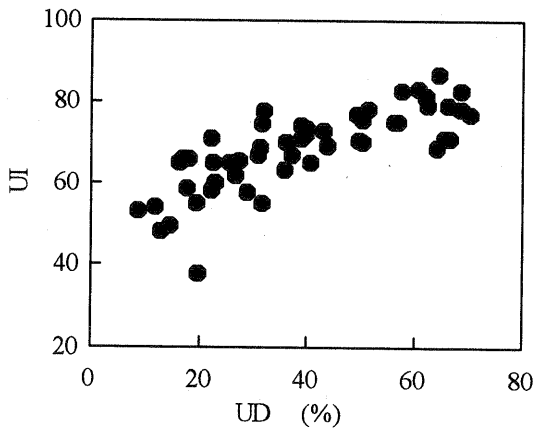

Figure 4. Relation Between UI and Urban Density

In concluding the verification of the index UI it could be said that UI is strongly related to the density of built-up land and therefore is an appropriate index that could be used to evaluate urbanisation.

3. SOCIO-ECONOMIC AND ENVIRONMENTAL DATA USED

Data of population, housing,labour force,water supply consumption, electrical energy consumption, land values and environmental related diseases relating to the administrative geographical units in the Colombo Metropolitan Region was used. The data relate to the period 1991 to 1994. The boundaries of the geographical units to which data of water supply consumption, land values and electrical energy consumption are related are different from the others because of different planning units adopted by the relevant administrative authorities. Hence, this data is shown in tables 2,3 and 4 respectively. The other data shown in table 1 relate to administrative areas (A.G.A Divisions) shown in figure 5, within the Colombo Metropolitan Region. They cover a land area of 1386 Sq.km and has a total population of approximately 3 million.

The environmental related diseases that have been considered are Dysentry, Entric Fever, Viral Hepatitis, Malaria, Diarrhoea, Leotos Pirosis and Wooping Cough. Data of reported cases of these diseases in the administrative areas of the Colombo Metropolitan Region for the period 1992 to 1994 has been obtained from the Epidemiological Unit of the Colombo General Hospital. From this data disease intensity in each area has been computed by considering an annual average of the total number of reported cases of all of the above mentioned diseases.

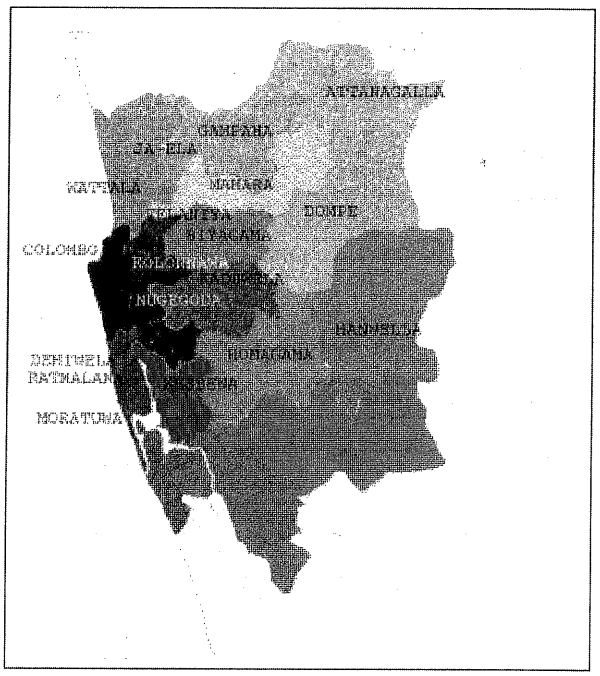

Figure 5. Administrative Units in the Colombo Metropolitan Region

4.0 RELATION BETWEEN UI AND SOCIO-ECONOMIC AND ENVIRONMENTAL DATA.

To compute UI values an image of 4000X2550 pixels was used. Average UI values for pixels of 2X2 Landsat TM pixels were computed and this image was registered with digitised maps showing the boundaries of the administrative units in the Colombo Metropolitan Region (CMR). The average UI value for each administrative area was then calculated. The relation between UI and the socio-economic and environmental data corresponding to the geographical units in the CMR is shown in the scatter diagrams of figures 6 to 12.

Table 1. Data of Administrative Units in the Colombo Metropoltan Region

A.G.A. DIVIION	AREA Sq.km	Population Density Persons/Sq.km	Housing Density Units/Sq.km	Labour Force Density Persons/Sq.km	Environmental Related Disease Intensity Perons/Sq.km	UI
Colombo	37. 7	16856	2823	14093	11	73. 36
Dehiwela	21. 0	9997	1986	8559	6	64. 28
Moratuwa	19. 8	9410	1867	7947	8	58. 77
Piliyandala	55. 0	2955	619	2547	3	45. 99
Nugegoda	32. 0	7178	1510	6335	5	54. 39
Kolonnawa	27. 3	6054	1114	512	6	50. 33
Kaduwela	87. 7	1657	356	1404	2	47. 71
Homagama	148. 2	950	216	804	1	44. 92
Avissawella	228. 0	580	123	492		36. 95
Dompe	178. 3	636	141	540		43. 92
Biyagama	61. 6	1769	364	1498	2	47. 10
Mahara	98. 8	1306	272	1083	2	44. 56
Attanagalla	154. 0	835	184	693	1	43. 77
Gampaha	95. 7	1483	318	1247	2	45. 94
Ja-Ela	64. 0	2188	465	1882	4	47. 88
Wattala	54. 68	2325	479	1939	2	49. 00
Kelaniya	21. 9	5864	1065	4963	6	51. 79

Table 2. Water Supply Consumption in the CMR

Planning Unit	Area Sq. km	Water Supply Consumption cu.m/d/sq.km	UI
Colombo	31.9	3598	72. 98
Dehiwela	18. 3	1675	62. 96
Kotte	8. 5	2142	56. 92
Moratuwa	11. 2	1247	55. 25
Panadura	7. 1	503	44. 91
Kolonnawa	2. 3	2345	59. 36
Mulleriyawa	16. 4	518	48. 77
Kelaniya	18. 4	693	51. 21

Table 3 Land Values in the CMR

Zone	Av.Land Value Ruppees/perch	UI
1	650000	74. 83
2	350000	66. 76
3	150000	59. 25
4	75000	52. 17
5	30000	47. 09

Table 4. Electrical Energy Consumption in the CMR

Planning Unit	Area Sq.km	Electrical Energy Consumption per year Gwh/Sq.km	UI
Colombo	46.5	12.94	68.26
Dehiwela	11.4	6.45	57.16
Ratmalana	62.8	3.88	50.26
Homagama	81.1	0.53	46.19
Sri Jayawardhanapura	118.8	1.99	49.29
Avissawella	241.1	0.13	37.61
Horana	443.2	0.07	42.41
Gampaha	338.0	0.18	44.21
Ja-Ela	166.7	0.64	44.77
Kelaniya	181.2	1.51	44.86

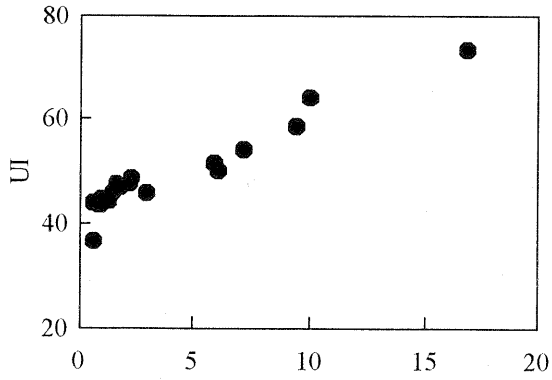

Figure 6 UI - Population Density

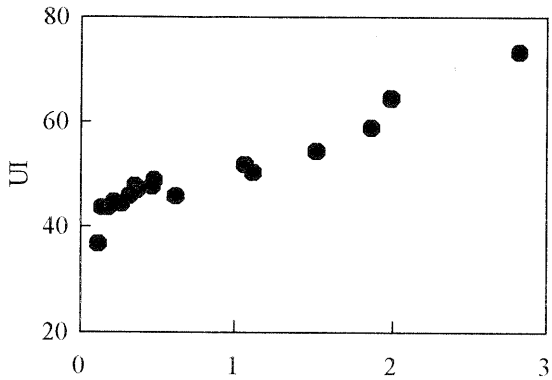

Figure 7 UI - Housing Density

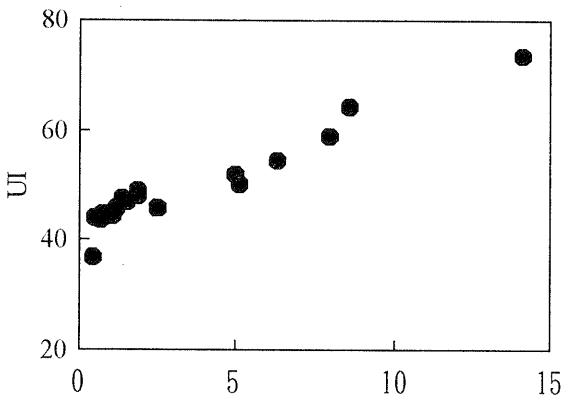

Figure 8. UI - Labour Force Density

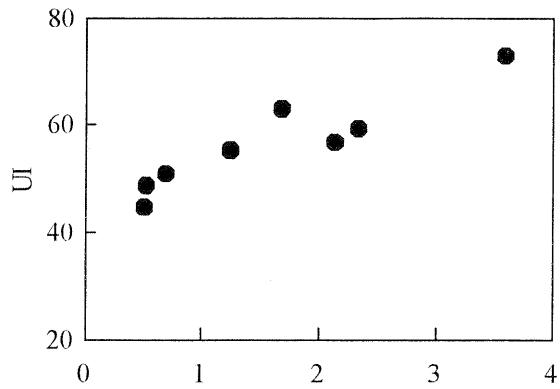

Figure 9. UI - Water Supply Consumption

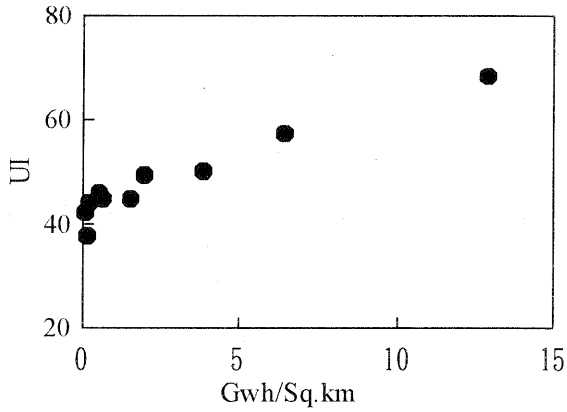

Figure 10. UI - Electrical Energy Consumption

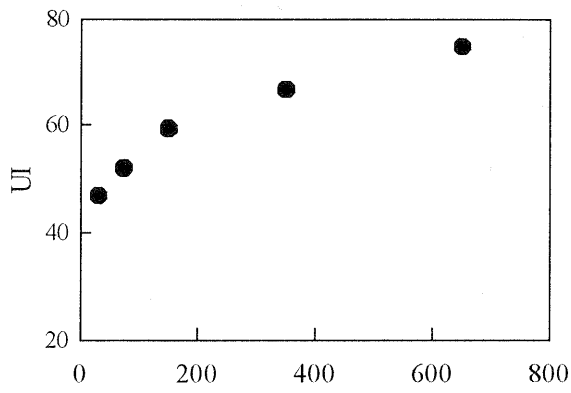

Figure 11. UI - Land Values

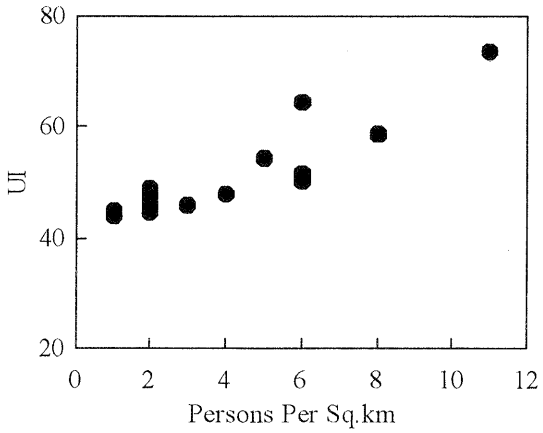

Figure 12. UI - Environmental Related Disease Intensity

5. CONCLUSION

From this study it could be seen that Landsat TM data could be used to update information and assess the conditions in urban areas. Hence satellite images could be used for effective urban and regional planning and could be particularly useful in rapidly changing urban areas.

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