APPROACHES FOR EXTRACTION OF SLUM AREA FROM HIGH RESOLUTION SATELLITE DATA

Case Study: Dehra Dun, India

by

Dr. Sadhana Jain
Scientist, Human Settlement Analysis Division, Indian Institute of Remote Sensing, Dehradun, India
Slums are darker side of urbanisation and termed as cancer to the city.

It has become a common phenomenon not only in mega cities but also emerging rapidly in small and medium towns of developing countries.

Target 11 of Millennium Development Goal 7 – to ‘significantly improve’ the lives of at least 100 million slum dwellers by the year 2020

The purpose of the study is to discusses different approaches to capture the information about slum areas from high spatial resolution satellite imagery.
Issues highlighted in Peer Review Meeting on Slum Mapping -

- Slum definition and estimates
- Determining the current number of slum dwellers
  - Lack of access to improved water supply
  - Lack of access to improved sanitation
  - Overcrowding (3 or more persons per room)
  - Dwellings made of non durable materials
  - Secure tenure
- Issues related to the definition and concepts
  - Shelter deprivation
  - Spatial dimension of slum dwellers
According to Cowie (1974), the process of planning will involve a five-step paradigm of data use to-

• indicate and define a problem
• be used to analyse the problem
• be used to generate alternative courses of action
• be used to implement a paradigm to alleviate the problem as suggested by item (iii)
• provide feedback for monitoring.
Absence of information about rapid changing slum areas is a challenge.

Urban local bodies are facing following problems-

- Absence of spatial database,
- Non-uniformity of database,
- Accuracy of database,
- Difference in attribute,
- Integration of information

**Solutions: Remote Sensing and GIS**
It is essential to know more in detail about the characteristics and capabilities of these remote sensing data products available to handle slum problem.

<table>
<thead>
<tr>
<th>What Remote Sensing Can do???</th>
<th>What GIS can do??</th>
</tr>
</thead>
<tbody>
<tr>
<td>It provides ...................</td>
<td>It facilitates ............</td>
</tr>
<tr>
<td>• Position</td>
<td>• Integration of data</td>
</tr>
<tr>
<td>• Size</td>
<td>• Analysis of data</td>
</tr>
<tr>
<td>• Inter-relationship between</td>
<td>• Modeling… alternate scenarios</td>
</tr>
<tr>
<td>objects</td>
<td></td>
</tr>
</tbody>
</table>
DEHRA DUN: capital of Uttrakhand is selected for this study because-

- It is fastest growing city in the region,
- facing new challenges due to pressure of capital of state,
- remote sensing data of different sensors is available over a period,
- field survey can be conducted frequently.
INFORMATION EXTRACTION

- Characteristics of the imagery
- Characteristics of the slum areas
- Characteristics of the user
Characteristics of the imagery

Resolution and scale, contrast, sharpness, waveband(s) used, photographic or digital format
Ikonos PAN and MS Data, acquired on April 19th, 2001, and May 5th, 2005, with UTM projection and datum WGS 84 have been used.

<table>
<thead>
<tr>
<th>SENSOR</th>
<th>BAND</th>
<th>SPECTRAL RANGE</th>
<th>SPATIAL RESOLUTION</th>
<th>RADIOMETRIC RESOLUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>IKONO (PAN)</td>
<td>Band 1</td>
<td>0.45 - 0.90  ( \mu m )</td>
<td>1 meter</td>
<td>11 bits</td>
</tr>
<tr>
<td>IKONOS (MS)</td>
<td>Band 1</td>
<td>0.445 – 0.516 ( \mu m ) (Blue)</td>
<td>4 meter</td>
<td>11 bits</td>
</tr>
<tr>
<td></td>
<td>Band 2</td>
<td>0.506 – 0.595 ( \mu m ) (Green)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Band 3</td>
<td>0.632 – 0.698 ( \mu m ) (Red)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Band 4</td>
<td>0.757 – 0.853 ( \mu m ) (NIR)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Another factor, which controls the quality of the image, is the position of the sun. Sun elevation and azimuth angle play an important role in the information content of satellite imagery.

Sun angle azimuth means that the position of the sun with respect to north of the earth is towards south-east direction,

Ikonos data (2001) : 134.79 degree
Ikonos data (2005) : 135.46 degree
causes considerable small shadows of objects towards north-west direction.

Elevation angle is an indicator of sun position with respect to horizon of earth

Ikonos data (2001) : 64.74 degree
Ikonos data (2005) : 71.27 degree
Characteristics of the slum areas

Spatial arrangement, orientation, relationship between form and function, the amount of ground control, change since imagery was obtained.
INFORMATION EXTRACTION

Characteristics of the user:
- background knowledge,
- interpretation skill,
- use of stereoscopic techniques,
- familiarity with study area,
- accuracy check.
Satellite imagery provides certain key data sets pertinent to slum detection and monitoring in urban areas -

- Location/spatial distribution and/or extent of slum areas
- Temporary/ permanent dwellings
- Socio-economic indicators
- Monitor changes in these features over time
APPROACHES FOR SLUM EXTRACTION

- Basic image processing
- Advanced image processing
- Visual interpretation
The majority of the highest resolution images are presently recorded in panchromatic mode only (Donnay et al., 2001b).

Generally, multi-spectral imagery provides more land cover information than panchromatic imagery, since each spectral waveband provides specific information about land cover features (Ben-Dor et al., 2001; Roessner et al., 2001; Aplin, 2003).

Thus, fusion of panchromatic and multi-spectral imagery of different spatial and spectral resolution has been carried out to enhance the interpretation capabilities for the preparation of base map.

A number of methods are used to fuse the data set in this research out of which, fused image output obtained through Brovey transformation is used to study the different aspects of urban scenario.
Image fusion using Brovey Transform, which visually increases contrast in the low and high ends of an image's histogram (i.e., to provide contrast in shadows, water, and high reflectance areas such as urban features) results in improved interpretation (ERDAS, field guide, 1999).

In this method, a new image is created according to the following formula:

\[
\frac{DNB1}{DNB1 + DNB2 + DNBn} \times [DN_{\text{high res. image}}] = DNB1_{\text{new}}
\]

\[
\frac{DNB2}{DNB1 + DNB2 + DNBn} \times [DN_{\text{high res. image}}] = DNB2_{\text{new}}
\]

etc.

where \(B = \text{band}\)

It is observed that the combination of band 4, band 3, and band 2 of MSS imagery provides better results than any other combination used for fusion using Brovery Transform.
BASIC IMAGE PROCESSING
Slums associated with planned residential area.
QUANTITATIVE ASSESSMENT

VECTOR MAP: 1.19
CLASSIFIED MAP: 1.33

AREA IN HECTARE
Vector map: 1.19
Classified map: 1.33
BASIC IMAGE PROCESSING: Limitation
ADVANCED IMAGE PROCESSING

A: Multi spectral image

B: Panchromatic image

C: Brovey transformed merged image

D: Advanced processed merged image displayed in e-cognition

Ikonos (2001)

A: Multi spectral image

B: Panchromatic image
Advanced processed merged image displayed in e-cognition helps to delineate RCC and MUD roof cover.
ADVANCED IMAGE PROCESSING
ADVANCED IMAGE PROCESSING

Advanced processed Ikonos 2005 merged image
ADVANCED IMAGE PROCESSING

Advanced processed Ikonos 2001 merged image
SCALE PARAMETER
SCALE PARAMETER
SCALE PARAMETER
FEATURE CLASS RANGE
FEATURE CLASS RANGE

```
 Mean dlblayer1D2.img (1) (NI)
 [325.1 - 397.8] StdDev.: 10.50
 [363.2 - 460.0] StdDev.: 27.06

 Mean dlblayer1D2.img (2) (NI)
 [338.0 - 445.2] StdDev.: 27.91
 [347.0 - 499.8] StdDev.: 40.07

 Mean dlblayer1D2.img (3) (NI)
 [250.9 - 338.3] StdDev.: 20.97
 [274.0 - 390.1] StdDev.: 34.89

 Mean dlblayer1D2.img (4) (NI)
 [95.8 - 977.2] StdDev.: 139.91
 [253.1 - 389.1] StdDev.: 40.24

 Mean dlblayer1D2.img (5) (NI)
 [303.3 - 602.1] StdDev.: 51.06
 [264.9 - 337.2] StdDev.: 16.02

 Mean dlblayer1D2.img (6) (NI)
 [56.0 - 114.0] StdDev.: 9.86
 [91.0 - 109.0] StdDev.: 2.28

 Mean dlblayer1D2.img (7) (NI)
 [100.0 - 235.0] StdDev.: 42.23
 [5.0 - 47.0] StdDev.: 10.98

 Mean dlblayer1D2.img (8) (NI)
 [48.0 - 95.0] StdDev.: 4.95
 [56.0 - 72.0] StdDev.: 5.93

 Mean dlblayer1D2.img (9) (NI)
 [149.0 - 174.0] StdDev.: 18.57
 [120.0 - 192.0] StdDev.: 19.54
```
Area under temporary structures: 1.39 hectare
Because remote sensing is a process of physical detection, the inference of physical conditions of developments is a lot more straightforward than socio-economic.

The social and economic conditions are directly related with physical conditions and can be interlinked easily with the results derived from the high-resolution satellite imagery.

**Elements of Visual Interpretation**

- **Shape**: usually square or rectangle structures,
- **Size**: small sized dwelling units with plastic/ tin/ mud roof,
- **Pattern**: irregular pattern of streets and mostly governed by the topography of the area.
- **Tone**: temporary structures with plastic roof cover reveal dark gray tone.
- **Location and Association**: mostly located in marginal areas such as along railway line, drainage network etc.
As per Ikonos merged data (2001)

Total built up area of Dehradun = 4072 hectare

Source: Amit K. (2005)
As per Ikonos merged data (2001)

Total slum area of Dehradun = 85 hectare

VISUAL INTERPRETATION: SLUM 2001

As per Ikonos merged data (2005)

Total built up area of

Dehradun = 5174 hectare

Source: Amit K. (2005)
As per Ikonos merged data (2005)

Total slum area of Dehradun = 99 hectare
IMPACT OF TOPOGRAPHY

Slum pattern governed by topography of the area within planned residential area in ward no 23- Devsuman Nagar.
ACCESSIBILITY TO SLUMS

A: Paved street, & A’: its presentation in satellite imagery

B: Unpaved street, & B’: its presentation in satellite imagery
ACCESSIBILITY TO SLUMS
MONITORING OF SLUMS
Strategic location resulted in the densification of existing slum area.

Dwellings near to river is more deprived in comparison to dwellings away from the river.
MONITORING OF SLUMS

Cluster of temporary structure in the periphery

2001

2005
Slum development in periphery also follows topographical pattern.
Improvement in the slum condition
### Housing Type Area (in hectare) %

<table>
<thead>
<tr>
<th>Housing Type</th>
<th>Area (in hectare)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIG</td>
<td>3.36</td>
<td>15.84%</td>
</tr>
<tr>
<td>MIG</td>
<td>13.39</td>
<td>63.24%</td>
</tr>
<tr>
<td>LIG</td>
<td>4.39</td>
<td>20.73%</td>
</tr>
<tr>
<td>Squatter</td>
<td>0.04</td>
<td>0.18%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>21.18</strong></td>
<td><strong>100.00%</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Road</th>
<th>4.23</th>
</tr>
</thead>
</table>

**Total ward area** 25.41

---

### DYNAMICS OF SLUMS

<table>
<thead>
<tr>
<th>Housing Type</th>
<th>Area (in hectare)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIG</td>
<td>5.27</td>
<td>39.79%</td>
</tr>
<tr>
<td>MIG</td>
<td>5.44</td>
<td>41.12%</td>
</tr>
<tr>
<td>LIG</td>
<td>2.14</td>
<td>16.19%</td>
</tr>
<tr>
<td>Squatter</td>
<td>0.38</td>
<td>2.90%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>13.24</strong></td>
<td><strong>100.00%</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Road</th>
<th>2.9</th>
</tr>
</thead>
</table>

**Total ward area** 16.16
### Dynamics of Slums

**HOUSING TYPE: Ward No. 23- Devsuman Nagar**

<table>
<thead>
<tr>
<th>Housing Type</th>
<th>Area (in hectare)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>HiG</td>
<td>11.02</td>
<td>34.92%</td>
</tr>
<tr>
<td>MIG</td>
<td>14.99</td>
<td>47.49%</td>
</tr>
<tr>
<td>LIG</td>
<td>4.99</td>
<td>15.81%</td>
</tr>
<tr>
<td>Squater</td>
<td>0.56</td>
<td>1.78%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>31.56</strong></td>
<td><strong>100.00%</strong></td>
</tr>
</tbody>
</table>

Road: 9.35

Drainage: 1.13

**Total ward area**: 42.04

---

**HOUSING TYPE: Ward No. 4- D.L. Road**

<table>
<thead>
<tr>
<th>Housing Type</th>
<th>Area (in hectare)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>HiG</td>
<td>1.83</td>
<td>8.49%</td>
</tr>
<tr>
<td>MIG</td>
<td>11.20</td>
<td>51.97%</td>
</tr>
<tr>
<td>LIG</td>
<td>6.96</td>
<td>32.30%</td>
</tr>
<tr>
<td>Squater</td>
<td>1.56</td>
<td>7.24%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>21.55</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

Road: 4.81

Drainage: 3.12

**Total ward area**: 29.48
DETAILED STUDY OF SLUMS

INTERPRETATION KEY: Pattern (Layout), Shape (Roof Types etc), Size of Houses, Tone, Association, Road Pattern


CONDITION OF HOUSES

ARYANAGAR-1
CHIRIYA MANDI
KONDOLI

ARYANAGAR-2
ARYANAGAR D.L ROAD
NALAPANI NAI BASTI

LEGEND

CHIRIYA MANDI: Condition & Infrastructure

**COMPOSITION OF WALL MATERIAL**
- Brick: 0%
- Asbestos Concrete: 0%
- Concrete: 100%
- Concrete and Tin: 0%
- Tin: 0%
- Wood and Plastic: 0%

**COMPOSITION OF ROOF MATERIAL**
- Asbestos: 0%
- Concrete: 0%
- Concrete and Tin: 0%
- Tin: 0%
- Wood and Plastic: 100%

**PROVISION FOR DRAINAGE**
- Without Drainage: 25%
- With Drainage (Open Drain): 75%

**PROVISION FOR SANITATION**
- Without Sanitation: 30%
- With Sanitation: 70%

**AVAILABILITY OF WATER IN HOUSES**
- Water Available: 51%
- Water Not Available: 49%

**PROVISION FOR ELECTRICITY**
- Electricity Available: 72%
- Electricity Not Available: 28%

**AVAILABILITY OF STREET LIGHTING**
- Lighting Available: 43%
- Lighting Not Available: 76%

**ACCESS TO HOUSES**
- Easily Accessible: 0%
- Accessible: 20%
- Poorly Accessible: 100%
- Very Poorly Accessible: 0%

**OBSERVATIONS**
- Condition is overall better
- Mostly permanet and semi-permanent houses

*Source: Sur (2003)*
NEW SLUM DEVELOPMENT

New slum development in Periphery of Dehradun
CONCLUSIONS

- High resolution satellite imagery shows tremendous potential to cater the information on slum area mapping and monitoring.
- Basic image processing i.e. image fusion is indispensable to extract information about slum area.
- Advanced image processing is helpful to differentiate the roof material in slum area and further research is required.
- Visual interpretation of the processed image is helpful for detailed mapping and monitoring of these shanty areas.
Thank You