REMOTE SENSING APPROACH TO DETECTION OF INITIAL STAGES OF URBAN INTRUSION INTO NATURAL LAND COVER

Amit Singh[1] and Saumitra Mukherjee[*2]

[1]Research Scholar, School of Environmental Sciences, Jawaharlal Nehru University,
New Delhi - 110067, INDIA; Tel: +919958610919; E-mail: amsingh5@gmail.com

[2]Professor, School of Environmental Sciences, Jawaharlal Nehru University,
New Delhi - 110067, INDIA; Telefax: +91-11-26704312; E-mail: saumitramukherjee3@gmail.com

* Corresponding Author

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ABSTRACT: As urban cover starts intruding into natural land cover, it is marked as isolated and scattered pixels in satellite images. Monitoring these initial stages can be very essential for proper planning as well as monitoring resource utilization (particularly, water resources). These pixels also need to be masked for doing any analysis of natural cover, but doing so on pixel-by-pixel basis becomes a difficult task prone to errors. In hyperspectral images, the added dimension of high spectral variability adds to the problem set. This work explored a methodology combining several spectral unmixing techniques to demarcate isolated spectrally unique pixels that are essentially attributed to inherent variability within urban spectra. Hyperspectral imagery from EO-1 Hyperion sensor acquired over a sub-urban area was used for this purpose. The area and its vicinity has seen vigorous growth in urban sector in past few years and due to rising land prices it is expected to intrude into the natural hard-rock terrain of the region. The whole exercise was carried out keeping in mind the pressures on ecology and water resources in the region due to this expansion. The outputs yielded desired results (with high accuracy) in a rather continuous approach with only surface water bodies identified by visual interpretation. Some interesting observations regarding the preferred orientation of urban intrusion was also made. The same technique can be applied for images from other sensors as well and for a range of applications particularly where spatial variability within isolated pixels is high. The resultants of this study will be of great aid for decision makers for urban growth monitoring and regulation purposes.

1. INTRODUCTION

Sub-urban areas round the world have constantly been facing the problem of escalated pressures on resources due to constant urban expansion. This has put the planners in compromising situations where the inability to predict or study the patterns or rates of urban intrusion becomes a great challenge.

Though it is possible to visually identify urban cover and map its extent using satellite imagery, but it becomes a problem when one is trying to identify or map early stages of urban intrusion. This is primarily because of its discontinuous and isolated behavior and lack of a clear pattern. It is very important to not only identify the intruding urban cover but map its preferred orientation. Hyperspectral imagery can be used to identify the land cover classes more accurately but there are various problems associated with the spectral response of materials. Naturally occurring materials occur as mixtures, where it may be difficult to resolve them spectrally among themselves or from the background (Adams et al., 1989; Sabol et al., 1992; Plaza et al., 2004; Hubbard and Crowley, 2005). Conversely, there can be high variability in spectral contrast between materials and their mixed backgrounds, which can reduce chances of their detection and complicate further analysis (Sabol et al., 1992). Moreover, urban areas if associated with geological cover can prove to be the biggest interference while finding endmembers as these urban targets include several spectrally unique as well as ambiguous targets (Herold et al., 2003).

This becomes a daunting task if it has to be done on a pixel-by-pixel basis. Also, the process itself may become highly erroneous. It is therefore imperative to look out for some methodology that can be used to ease the task and make it more accurate. This work explored a methodology combining several spectral techniques to demarcate isolated spectrally unique pixels that are essentially attributed to inherent variability within urban spectra and then analyze them on the basis of their spatial coverage.

2. METHODOLOGY

2.1 Study Area

Geographically, the area under study is a part of National Capital Region (NCR) of India and located at intersection of Gurgaon and Faridabad districts of Haryana state and Delhi, the national capital. The adjoining areas have high population density and a very high rate of urbanization. There land is a scarce resource in the region being subjected to agricultural, residential as well as industrial type of land use. The area is also having few lakes and reservoirs. Due to high demand of building materials for construction purposes, the area has also been subjected to stone quarrying. This alteration of natural landscape and increase in urban built up has put tremendous pressure on the ecosystem in the region and may continue to affect the water bodies in future as well.

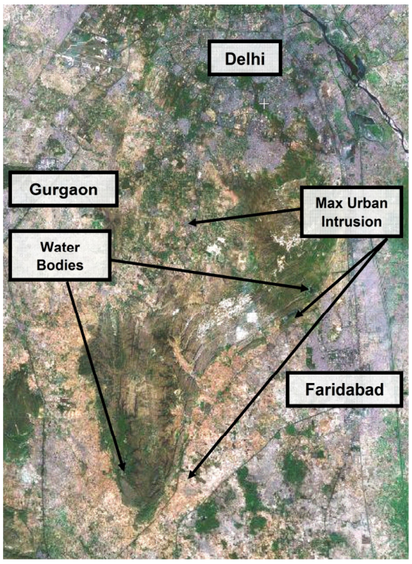

Figure 1 - Study Area

2.2 Satellite Data

Hyperion, a hyperspectral imaging spectrometer on-board EO-1 satellite, acquires 0.4 to 2.5 micrometer spectral radiation over 242 spectral bands with about 10nm spectral resolution and 30m spatial resolution (Pearlman et al., 1999; Barry et al., 2002; Cudahy et al., 2002; Beiso, 2002). The data has 196 calibrated unique bands and 2 overlapping bands. Hyperion L1GST scene used in this study was acquired on 20 February 2010 with 0-9% cloud cover in total over the scene. But most of the scene subset used in this study is virtually free from cloud cover (Figure 2).

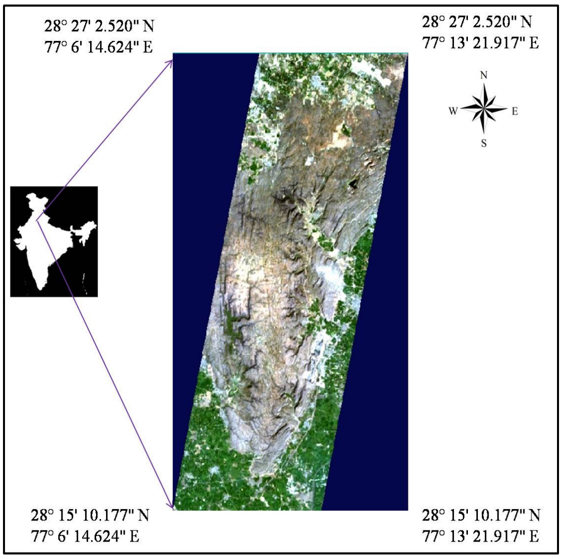

Figure 2 - Study Area Image Subset

2.3 Methodology

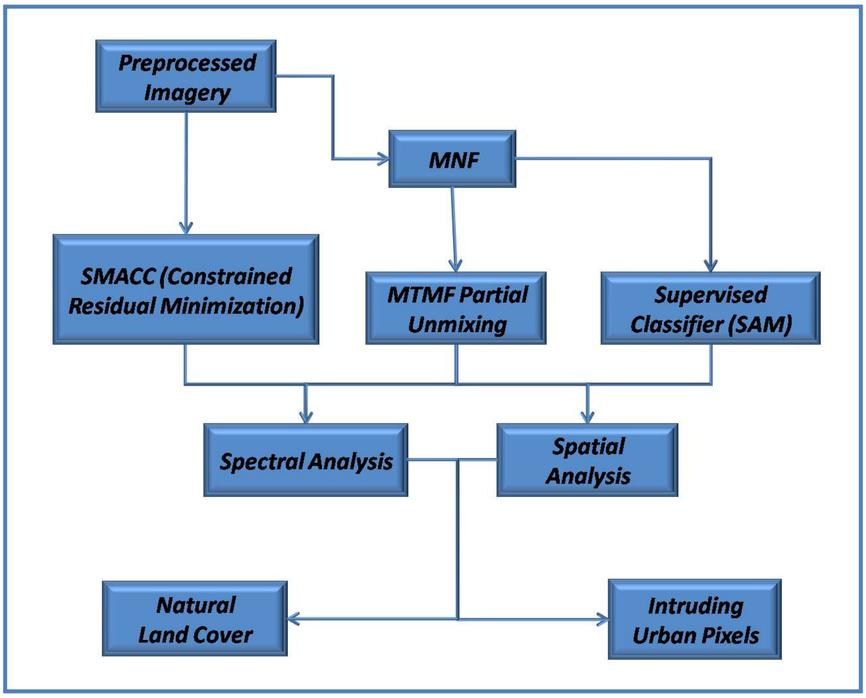

Figure 3 - Methodology

The Hyperion data was pre-processed and ultimately converted to surface reflectance values using FLAASH Atmospheric Correction algorithm of ENVI 4.7 software. The reflectance data was then analyzed for extraction of endmembers (Figure 3). Initially, SMACC (Sequential Maximum Angle Convex Cone) algorithm was used for extraction of endmember spectra and abundance images from the reflectance image using positivities only as the unmixing constrain (ENVI 4.7 User Guide). Afterwards, MNF (Minimum Noise Fraction) Transform was applied and the data was subset. The resulting MNF dataset was used for calculation of Pixel Purity Index (PPI) and analyzed in n-D Visualizer to obtain pixels associated with purest endmembers. Since it was not possible to determine all possible endmembers, MTMF (Mixture Tuned Matched Filtering) algorithm was used to account for the unknown spectral variability associated with urban pixels.

The endmember spectra were matched and the abundance images obtained were later used for verification. Supervised classification using SAM (Spectral Angle Mapper) algorithm was done to classify and map the spatial coverage of different classes. Post-Classification processing that included Sieving and Clumping was also performed to remove isolated heterogeneous unclassified pixels.

Spectra from ASTER Spectral Library v2.0 (Baldridge et al, 2009) were used to verify the endmembers obtained and find the nature of urban cover.

Water bodies were identified on image but primarily marked visually to avoid any errors.

3. RESULTS AND DISCUSSION

MNF bands were subset to minimize the noise and have an output with high spatial coherency and later used in n-D Visualizer to observe the data in three-dimensional space. But to limit the data for interpretation it was necessary to apply constrain and use only selective pixels for visualization. Using only the purest pixels selected using high PPI values made sure that the problem of mixed pixels was reduced to a great extent. This basically helped in establishing the natural land cover of the region. Urban pixels here were mostly eliminated while post-processing due to their mixed spectral nature and very low spatial coverage (at some places, clusters of even less than 0.1% of the total area) mostly as isolated pixels. Maximum cluster size of approximately 0.7% of study area was observed from the urban spectra obtained by SMACC algorithm.

Upon spectral analysis urban pixels were mainly found to be associated with asphalt and concrete

Mean MF score for intruding urban pixels was found to be about 0.72 (or 72% abundance). Also, minimum MF score for these pixels was found to be 0.53 (or 53% abundance). Margins of water bodies and urban cover were found to be region with least abundance and maximum sub-pixel variability. This is itself indicative of the intruding nature of the urban cover.

The SAM classified image was over-classified in margins of urban cover. This possibly could also be due to spectral similarity of the exposed bedrock with that of road material (asphalt). The problem here was successfully addressed by infeasibility images generated with MTMF classification.

Since the pixels associated with urban cover occupied discrete isolated pixels and could not be associated as a large class, a spatial analysis was done to account for the coverage and pixel purity. Also, the position or spread of intruding urban cover from the natural land cover was marked to ascertain the actual extent of intrusion. The resulting outputs clearly indicate that the Eastern and South-Eastern portions of the study area are dominated by intruding urban cover (Figure 4). These areas were verified on ground as extensions of Faridabad township. Some moderate intrusion was also observed visually as well as by image analysis in the Northern part of study area which could be mainly attributed to changing land use in Gurgaon district and spreading of farm houses in the Southern part of Delhi. These were also verified on field. The intrusion seemed to be having a preferential orientation along the fringe margins of the hard-rock terrain it surrounds. This could well be attributed to the presence of agricultural fields and availability of groundwater in the region. But this also presents an alarming situation of gradual land use changes from agricultural to urban built up in the near future. This will add up to the existing environmental pressures especially on the groundwater resources.

The total area covered by maximum intruding urban cover pixels was found to be about 4.126 Km^2.

Figure 4 – Pixels showing Urban Intrusion

4. CONCLUSIONS

Since the target area is in proximity of an urban setting there is a possibility of land use change and intrusion of urban built up into natural cover. At initial stages this may be difficult to detect, map, plan and manage as these intruding areas are observed in satellite imagery as isolated heterogeneous pixels. The approach followed helped in overcoming that problem and their classification in the subsequent output. Such methodology if followed in other areas will help in early detection of urban intrusion as well as its preferred orientation in other areas as well. This will aid policy makers for timely and accurate planning for developmental or regulatory purposes.

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