NDVI Derived Sugarcane Area Identification and Crop Condition Assessment

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ABSTRACT

Remote sensing offers an efficient and reliable means of collecting the information required, in order to map crop type and acreage. Besides providing a synoptic view, remote sensing can provide structure information about the health of the vegetation. The spectral reflectance of a field will vary with respect to changes in the phenology (growth), stage type, and crop health, and thus can be measured and monitored by multispectral sensors. In the present study IRS LISS II digital data and NDVI (Normalized difference vegetation index) has been used to identify the sugarcane area and its condition assessment. Ratio image are often useful for discriminating subtle differences in spectral variation in a scene that is masked by brightness variations. For identifying the area and condition of dense crop like sugarcane, NDVI image is often useful because of its canopy cover, crop biomass and vigour. The accuracy achieved was 85.25% for NDVI image of IRS LISS II digital data.

Key Words: Remote sensing, Spectral vegetation indices, NDVI, band ratio, NIR and RED band, Chlorophyll, Crop condition assessment.

Introduction:

Remote sensing techniques can play quite an important role in land cover survey and as a source of information relating to land resource condition. Besides, remote sensing techniques of the satellite imageries are also useful whenever there are rapid changes of landscape due to introduction of large scale development specially in the field of agriculture. Remote sensing data are capable of capturing changes in plant phenology (growth) throughout the growing season, whether relating to changes in chlorophyll content or structural changes. Satellite and airborne images are used as mapping tools to classify crops, examine their health and viability, and monitor farming practices. Identifying and mapping crop is important for a number of reasons. The main objective is to prepare an inventory of what was grown in certain areas and when. Key activities include identifying the crop types and delineating their extent (often measured in acres). Traditional methods of obtaining this information are census and ground surveying. In order to standardize measurements however, particularly for multinational agencies and consortia, remote sensing can provide common data collection and information extraction strategies. From these points of view, present study has been selected for identification the area of sugarcane and condition of crop in the floodplain area of Charghat thana by using IRS LISS II digital data.

Study Area - An Overview:

An area of agricultural potential varies in response to local and regional differences of its constituents of physical setting (Hassan, 1991). Therefore, a proper consideration of physical environment is essential for any assessment of agricultural research study. However, Charghat thana has been selected as the area of study whose

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total area is about 15373 hectares. Geographically Charghat thana is located between 24°14' and 24°22' north latitude and between 88°40' and 88°52' east longitudes (Fig-1). Physiographically the area lies in the floodplain of the Padma river and is characterized by a flat low-lying terrain with no appreciable difference in relief. There are some marshes in the study area and Gangetic flood plain is the only physiographic unit in Charghat thana (SRDI, 1989). The soil of the thana belongs to the old alluvial groups. However, on the basis of soil texture, four types of soil exists in the thana (Fig-2). Loamy soil occupies the largest portion of the total land of Charghat thana and this types covers 13079 hectares or 79.4 %. It may be mentioned that this type of soil is suitable especially for sugarcane and rice cultivation.

**Sugarcane – Physiological Aspect:**

Sugarcane is one of the most important cash crops in Bangladesh. It is an annual crop with solid jointed stems and its mode of photosynthesis is very efficient and growth is quick. Generally sugarcane is planted in January-February and harvested in November-December. The cane plant usually requires 10-12 months to reach maturity. In general, maximum leaf area index (LAI) is achieved about six months from planting and then slowly declines, but this may be affected by both variety of sugarcane and condition of growth. Most of the light (solar radiation) in a closed-in canopy is intercepted by the top six fully expanded leaves in the crop. The number of green leaves on a stalk varies between 6 and 12, with fewer leaves being maintained during dry or cold conditions. The top three fully opened leaves of nearly all cultivators tend to be erect, but droop more or less at the tips. The older leaves may be erect or droopy (planophile) depending on variety and environmental conditions (Evans, 1975).

Sugarcane is one of the extreme types of crop and in that it has extraordinarily high rates of photosynthesis. Leaves of mature plants give maximum rate of photosynthesis. The high crop growth rates attributed to sugarcane are at least partially due to an extended growing season, rather than to an inherently superior photosynthetic pathway. Hesketh and Moss (1963) shows that photosynthesis by leaves of maize, sugarcane and related tropical grasses could reach much higher rates, with less marked light saturation, than leaves of other plants. On the other hand, leaf area index (LAI) provided a more meaningful way of analysing growth in crops and stimulated renewed interest in crop physiology.

**Spectral Reflectance, Vegetation and Normalized Difference Vegetation Index (NDVI):**

Spectral vegetation index measurement derived from remotely sensed observations shows great promise as a means to improve knowledge of vegetation pattern. Different band ratios are possible given the number of spectral bands of the satellite image. Various mathematical combinations of satellite bands have been found to be sensitive indicators of the presence and condition of green vegetation. These band combinations are thus referred to as vegetation indices. The dominant method for vegetation area identification and change detection using remotely sensed data is through vegetation indices (Deering & Hass, 1980). Vegetation indices are algorithms aimed at simplifying data from multiple reflectance bands to a single value correlating to physical vegetation parameters (such as biomass, productivity, leaf area index, or percent vegetation ground cover) (Tucker, 1979). These vegetation indices are based on the well-documented unique spectral characteristics of healthy green vegetation over the visible to infrared wavelengths.
A green healthy leaf has typical spectral features, which differ in function of the three main optical spectral domains (Fig.-3). In the visible bands (400-700 nm), light absorption by pigments dominates the reflectance spectrum of the leaf and leads to generally lower reflectances (15% maximum). There are two main absorption bands, in blue (450nm) and in red (670nm), due to the absorption of the two main leaf pigments: the chlorophyll a and b, which account for 65% of the total leaf pigments of superior plants. These strong absorption bands induce a reflectance peak in the yellow-green (550 nm) band. For this reason, chlorophyll is called the green pigment. Other leaf pigments also have an important effect of the visible spectrum. For example, the yellow to orange-red pigment, the carotene, has a strong absorption in the 350-500 nm range and is responsible for the color of some flowers and fruits as well as of leaves without chlorophyll. The red and blue pigment, the xanthophylls, has a strong absorption in the 350-500 nm range and is responsible for the leaf color in fall. In the near infrared spectrum domain (700-1300 nm), leaf structure explains the optical properties. Leaf pigment and cellulose are transparent to near-infrared wavelengths and therefore leaf absorption is very small (10% maximum), but not the leaf reflectance and transmittance, which can reach 50%. In this region, there is typically a reflectance plateau in the leaf spectrum. The level of this plateau is dependent on the internal leaf structure as well as on the space amount in the mesophyll that determines interfaces with different reflection indices (air or water-cells). Leaf reflectance increases for more heterogeneous cell shapes and contents as well as with increasing number of cell layers, number of inter cell spaces and cell size. This reflectance is therefore depending on the relative thickness of the mesophyll. In order to minimize the effect, on the canopy radiometric response of factors like optical properties of the soil background, illumination and view geometric as well as meteorological factors (wind, cloud), single band reflectances are combined into a vegetation index. An ideal vegetation index must be sensitive to the plant canopy (the green part) and not to the soil. Most of the ratio-based vegetation indices use, as spectral band, the red one, which is related to the chlorophyll light absorption (Fig.-3) and the near infrared one, which is related to the green vegetation density, because this band contain more than 90% of the information on a plant canopy. So, Photosynthetically active plant components, primarily leaves, produce a stepped reflectance pattern with low reflectance in the visible and high reflectance in the near infrared. This green vegetation spectral reflectance pattern results from strong absorption of visible light by chlorophylls and related pigments and scattering, because of leaf structural properties, but minimal absorption of light in the near infrared. A number of spectral vegetation indices premised on the contrasts in spectral reflectance between green vegetation and background materials (Rouse et al. 1974; Kauth & Thomas, 1976; Richardson & Wiegand, 1977; Tucker, 1979; Jackson, 1983). The normalized difference vegetation index (NDVI) is representative of the various spectral vegetation indices (Rouse et al., 1974). NDVI is the traditional vegetation index used by researchers for extracting vegetation abundance from remotely sensed data (Tucker, 1979). It divides the difference between reflectance values in the visible red and near-infrared wavelengths by the overall reflectance in those wavelengths to give an estimate of green vegetation abundance (Tucker, 1979). In essence, the algorithm isolates the dramatic increase in reflectance over the visible red to near infrared wavelengths, and normalizes it by dividing by the overall brightness of each pixel in those wavelengths. It is computed:

$$\text{NDVI} = \frac{(\text{NIR}-\text{VIS})}{(\text{NIR} + \text{VIS})}$$

where  \(\text{NIR} = \) reflectance in the near infrared band (Band4)  
\(\text{VIS} = \) reflectance in the red (visible) band (Band3)
In theory NDVI measurements range between -1.0 and +1.0. However, in practice the measurements generally range between -0.1 and +0.7. Clouds, water, snow and ice give negative NDVI values. Bare soils and other background materials produce NDVI values between -0.1 and + 0.1. Larger NDVI values occur as the amount of green vegetation in the observed area increases.

NDVI has been used extensively to measure vegetation cover characteristics, crop assessment studies (Peterson et al., 1987; Asrar et al., 1984; Bausch, 1993; Benedetti & Rossini, 1993; Hatfield et al., 1985; Wanjura & Hatfield, 1987), used to provide weekly vegetation maps, monitor crops over large regions, monitor vegetation change in much of the tropics, and estimate biomass. Specifically, for example, Shih (1994) used it to monitor agricultural areas in the Everglades, Dejong (1994) used it in a model of soil erosion, Wood (1993) used NDVI to help monitor water and energy fluxes for a climate model, and Dymond et al. (1992) used NDVI to estimate rangeland degradation. As therefore, in this study NDVI image was generated and its value has been used for crop feature recognition and condition assessment.

![Typical spectral response characteristics of green vegetation (after Hoffer, 1978)](image)

**Objectives:**

(i) The main objective of the study is to identify the extent of sugarcane area and mapping using remotely sensed data and NDVI algorithm; and

(ii) To assess the condition of crop health from NDVI value.
Materials:

Remote Sensing Data:
- Satellite digital data: IRS LISS II
- Bands: 3, 4
- Data acquisition: August 25, 1999
- Spatial resolution: 36.25m

Ancillary Data:
- Survey of Bangladesh Toposheet, scale 1:50,000
- Thana and Soil map of Charghat.

Methodology:

In accordance with the objectives of the study satellite image of IRS LISS II (4 Bands) has been collected for August 25, 1999 and field observation has been completed after two weeks of digital data acquisition. It was mentioned earlier that for sugarcane, maximum leaf area index (LAI) is achieved about six months from planting. On the other hand, for digital data processing, analysis and integration of spatial and non-spatial data PC based raster GIS package ILWIS version 2.2 has been used in this study. Two bands (NIR and RED) of the IRS LISS II have been geo-referenced using sufficient number of ground control points and pixel size defined as 36.25m. Then, using NDVI algorithm NDVI image has been generated and the study area extracted from the NDVI image. For feature recognition especially for crop mapping, NDVI value of band 4 (infrared) and band 3 (red) of IRS LISS II digital data have been used. For classifying the NDVI image cluster and knowledge based classification methods have been applied. According to the signature, pattern and color of NDVI image and ground truth and observation, range of NDVI values has been selected for each of the classes (Fig-4). For ground truth/observation some training sample/site have been selected in the NDVI image and verified those sample site in the respective ground or field.

FIG-4: Histogram of NDVI Image and Range of NDVI Value for each of the Classes

It may be mentioned here that after field observation, it has been seen in the NDVI image the orchard area and some sugarcane areas have same NDVI value. So, to separate out the orchard area from the sugarcane area, orchard areas have been identified from the
toposheet map firstly and then traced and scanned. The scanned orchard map was digitized, geo-referenced, resampled and then made a raster by polygonization and rasterization and replaced in the classified image/map. From the classified image, sugarcane area has been extracted and a map has been generated for sugarcane (Flow diagram-1). On the other hand, for assessing the sugarcane crop condition, sugarcane area map has been used as a ‘mask’ over the NDVI value map to generate respective NDVI mask for sugarcane. NDVI value is very much sensitive to crop canopy, biomass and vigour i.e. health condition of the crop. So, NDVI mask map was then classified and given the class names as ‘very good’, ‘good’, ‘moderate’ and ‘poor’ for sugarcane health condition according to verified crop condition by field observation and farmers knowledge (Fig-5).

**Results and Discussion:**

It was mentioned earlier that NDVI image was created with the help of spectral vegetation index (Fig.-6). In the NDVI map, the bright areas are vegetated while the non-vegetated areas (river, ponds, sandy area, building) are generally dark. Using NDVI value, image of the study area has been classified for the identification of different crop areas (Fig.-7). Table-1 shows the spatial extent of different landuse/landcover in the study area. From this table it is clear that sugarcane was the dominant crop in the study area and was occupied 33.97% of the total area. The area distribution of sugarcane acreage is given in Fig.-8. On the other hand, to assess the condition of crop health, NDVI value for sugarcane has been analyzed. In referring healthy crops, reflectance in the blue and red parts of the spectrum is low since chlorophyll absorbs this energy. In contrast, reflectance in the green and near-infrared spectral regions is high. Stressed or damage crop experience a decrease in chlorophyll content and changes in the internal leaf structure. So examining the ratio of reflected infrared to red wavelengths is an excellent measure of vegetation health. Healthy plants have a high NDVI value because of their high reflectance of infrared light, and relatively low reflectance of red light. Phenology and vigour are the main factors in affecting NDVI. That’s why in the study area, for other crops (rice and minor crops) NDVI value is lower than sugarcane. Not only that, in the sugarcane area NDVI value also differs (0.23 to 0.56). Table-2 shows the conditions of
sugarcane in the study area. From the table and Fig.-9 it may be said that overall sugarcane condition was good in the area, because more than 57% of the total sugarcane area was under ‘good’ and ‘very good’ conditions. Only 15% of the total sugarcane area falls under ‘poor’ condition. In this area spectral reflectance was comparatively low and it is mainly because of crop stress and damage. So, from the above result it may be concluded that in the study area sugarcane productivity is in satisfactory level assessing the health of crop, as well as early detection of crop infestations. This is critical in ensuring good agricultural productivity.

### Table-1: Spatial Extent of Different Land cover/use

<table>
<thead>
<tr>
<th>Category</th>
<th>No. of Pixels</th>
<th>Area</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minor Crops</td>
<td>13060</td>
<td>1692.58</td>
<td>11.01</td>
</tr>
<tr>
<td>Others (Bare soil, Settlement etc.)</td>
<td>20149</td>
<td>2611.31</td>
<td>16.99</td>
</tr>
<tr>
<td>Roads</td>
<td>1092</td>
<td>141.52</td>
<td>0.92</td>
</tr>
<tr>
<td>Rice</td>
<td>27311</td>
<td>3539.51</td>
<td>23.02</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>39919</td>
<td>5173.50</td>
<td>33.65</td>
</tr>
<tr>
<td>Orchard</td>
<td>528</td>
<td>68.43</td>
<td>0.45</td>
</tr>
<tr>
<td>Water Bodies</td>
<td>16556</td>
<td>2145.66</td>
<td>13.96</td>
</tr>
<tr>
<td>Total</td>
<td>118615</td>
<td>15372.51</td>
<td>100.00</td>
</tr>
</tbody>
</table>

### Table-2: Crop Condition of Sugarcane in the Study Area

<table>
<thead>
<tr>
<th>Conditions</th>
<th>No. of Pixels</th>
<th>Area</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>6019</td>
<td>779.74</td>
<td>15.07</td>
</tr>
<tr>
<td>Moderate</td>
<td>11008</td>
<td>1427.64</td>
<td>27.60</td>
</tr>
<tr>
<td>Good</td>
<td>19404</td>
<td>2515.62</td>
<td>48.63</td>
</tr>
<tr>
<td>Very Good</td>
<td>3488</td>
<td>450.5</td>
<td>8.71</td>
</tr>
<tr>
<td>Total</td>
<td>39919</td>
<td>5173.5</td>
<td>100.00</td>
</tr>
</tbody>
</table>

### Conclusion:

The result of the study leads to the following conclusions:

(i) It is easy to distinguish sugarcane areas from the other cropped area using NDVI image referring sugarcane crop canopy, structure and LAI.

(ii) IRS LISS II digital data is suitable for large area crop mapping especially sugarcane and identification of their extent.

(iii) Normalized Difference Vegetation Index (NDVI) is a most successful and commonly used vegetation index and in this study, it was also successfully used for sugarcane condition assessment and area identification.

In conclusion it may be said that there is a need for consistent, timely and reliable information sources to facilitate analysis of crop vegetation pattern. Remotely sensed spectral measurements of reflected solar radiation may contribute such an information source. Areas of consistently healthy and vigorous crop would appear uniformly bright. Stressed vegetation would appear dark amongst the brighter, healthier crop areas. If the data is geo referenced, with the help of GPS (global positioning system) early detection of crop stress is possible by matching the coordinates of the location to that on the image. Finally, it may be concluded that using this approach and technique it is quite possible to improve productivity and reduces costs of farm input and minimizes environmental impacts.
References:


SRDI (1989): Soil Report, Charghat Thana Soil Resource Development Institute, Rajshahi


FLOW DIAGRAM-1: SHOWING METHODOLOGY FOR SUGARCANE AREA IDENTIFICATION AND CONDITION ASSESSMENT

Digitized Thana Map (Charghat Thana)

Satellite Digital Data (IRS LISS II, Band 3,4)

Band4 (NIR)

Geo referencing

Band3 (RED)

Algorithm

NDVI Image

NDVI Mask Image

Cluster Method

Ground Truth

Digital classified Image

Extract

SUGARCANE AREA DISTRIBUTION MAP

Crop Mask over NDVI

NDVI of Sugarcane

Threshold based classification (Field observation/Farmers knowledge)

SUGARCANE CONDITION ASSESSMENT MAP

Digitized Orchard Areas (From Toposheet)