

Study of Bangladesh Soil Nutrient over Satellite Images

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Abstract: *In the Asian, African and Latin American countries, well over 500 million [1] people are living in what the World Bank has called "absolute poverty". Nearly one in four people, 1.3 billion - a majority of humanity - live on less than \$1 per day [2] – not even enough to feed themselves well. Suffering from hunger many of them die gradually. A solution to this problem could be letting them able to produce enough amount of foods. Using satellite imagery, it is possible to analyze the amount of nutrient available in soil. If soil properties is known, it's possible to determine which crop will grow best and what amount of fertilizer is needed. Obviously it will reduce the cost and maximize the food production.*

Keywords: Remote sensing, Hyper spectral, ETM+, Digital Number (DN), Radiance, Reflectance, Soil Nutrient.

1. Introduction

The whole world has been suffering from many problems, most probably, from the first day of its formation. Among all, one of the major problems is hunger. Researchers, scholars, scientists have been trying to solve this problem from many days. And significant goals have also been achieved in this sector. As the time passed on, the solutions have become more efficient and productive. However, hunger is still one of the major problems because of the continuous growth of population and also the natural or human made disasters. It is not humanly possible to reduce this massive growth of population, or predict and avoid the disasters, or increase the size of the cultivating land. So the only way out of this is to use the available resources and make them more productive.

The conventional agricultural system in Bangladesh and also most of the world does not consider the spatial variability of soil and crops. In spite of that, fertilizers, pesticides and irrigation are applied uniformly on the field. As a result, there is a greater possibility that, the field would suffer from excessive usage of chemicals, which is harmful to the crops. To increase production, one needs to know all the factors that can affect the growth of crops in both good and bad way. For example, the type of soil, the amount of soil nutrients, the height of the cultivating land, the season, flood, drought and many more factors influence it severely. And also not to forget that, the amount of soil nutrients present in a region can change in a certain period of time. It is a must to have an accurate knowledge on the region of cultivation. However, it is very hard to cope-up with these variations, because the traditional procedure of soil sampling that is used in most of the countries including Bangladesh is time consuming, labor intensive and expensive. Remote sensing process can

In the remote sensing process, the data captured by remote sensing systems is analyzed by interpretive and measurement techniques in order to provide useful information. These

techniques are diverse, ranging from traditional methods of visual interpretation to methods using sophisticated computer processing. Remote sensing is a technique of obtaining information about objects by analyzing data - collected using tools that are not physically in contact with the objects. An example of remote sensing device is satellite. Satellites capture images of the surface while rotating in its orbit. The images captured by the satellites consist of several monochrome images of the same object. As example, LANDSAT5 [3] produces 7 band images with the wavelength of the bands being between 450nm and 1250nm [4]. LANDSAT7 [5] generates 8band images.

This paper exhibits an analysis on the variability of soil throughout a region and also an argument - if it is possible to determine the amount of specific soil nutrients that is present in that region. It is focused on examining the soil using hyper spectral reflectance data and predicting the soil nutrients.

2. Literature Review

Remote sensing technique is being used widely in agriculture filed. An example could be precision farming [9]. Many researchers researched on determining factors of cultivation using remote sensing and satellite imagery.

J.G.P.W. Clevers, L. Kooistra and M.E. Schaepman showed in their research [6] that it is possible to detect canopy water using remote sensing. They used PROSAIL to measure canopy water.

Fouad Al-Khaier [7] described and compared two methods of determining soil salinity using remote sensing. Fouad Al-Khaier, in his research, used biophysical [7] method for Landsat 7 image. Biophysical method is mainly built on the concept of surface resistance. He showed the relation between surface resistance and soil salinity.

In this paper we will use satellite image of bare soil. And we will try to find if there is any relation between reflectance and available soil nutrient. Using the relation, we will try to predict amount of nutrient available in soil.

3. Proposed Approach

3.1 Theoretical Information

Satellite images are available from various sources. The following process uses images collected from GLOVIS: The USGS Global Visualization Viewer [8]. GLOVIS distributes images captured by various satellites for free to use in educational purposes.

Landsat Enhanced Thematic Mapper Plus (ETM+) [9] images use in total 8 bands of two different resolutions. Band 1 to band 7 acquire at 30-meter resolution (30 square meter per pixel) and band 8 acquire at 15-meter resolution. In addition band 6 also acquire at a resolution of 60-meter.

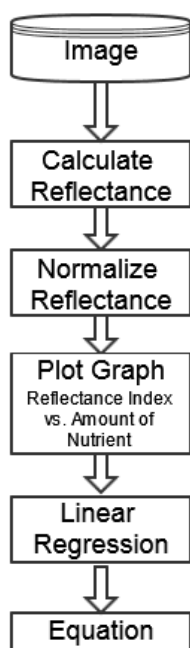
3.2 Process

- a) Get all images of different bands captured by satellite.
 - 1) For best performance it required to get images of bare soil (with least possible vegetation).
- b) Calculate reflectance from images.
 - 1) Normalize reflectance from 0-1 (reflectance index).
- c) Plot a graph reflectance index verses amount of available nutrient (from soil test result).
- d) Generate equation from graph using linear regression.
 - 1) Find first order, second order or third order equation.
 - 2) Find out which equation gives the most accurate values.

Use the equation found in step (IV) to measure amount of nutrients avail in soil unknown instances.

3.3 Description

Process flowchart:



To calculate reflectance first DN is converted to radiance using following equation [10]:

$$L_{\lambda} = \frac{LMAX_{\lambda} - LMIN_{\lambda}}{QCALMAX - QCALMIN} * (QCAL - QCALMIN) + LMIN_{\lambda}$$

- L_{λ} = Spectral Radiance at the sensor's aperture in watts/(meter squared * ster * μm)
- QCAL = the quantized calibrated pixel value in DN
- $LMIN_{\lambda}$ = the spectral radiance that is scaled to QCALMIN in watts/(meter squared * ster * μm)
- $LMAX_{\lambda}$ = the spectral radiance that is scaled to QCALMAX in watts/(meter squared * ster * μm)
- QCALMIN = the minimum quantized calibrated pixel value (corresponding to $LMIN_{\lambda}$) in DN = 0
- QCALMAX = the maximum quantized calibrated pixel value (corresponding to $LMAX_{\lambda}$) in DN = 255

All required values are available in the image metadata file. Calculated radiance is then converted to reflectance using following formula [10]:

$$\rho_{\lambda} = \frac{\pi * L_{\lambda} * d^2}{ESUN_{\lambda} * \cos\theta_s}$$

- Where,
- ρ_{λ} = Unit less planetary reflectance
- L_{λ} = spectral radiance (from earlier step)
- d = Earth-Sun distance in astronomical units
- $ESUN_{\lambda}$ = mean solar exoatmospheric irradiances
- θ_s = solar zenith angle

Calculated reflectance is normalized using the following equation:

$$I_{\lambda} = \frac{\rho_{\lambda} - \rho_{MIN}}{\rho_{MAX} - \rho_{MIN}}$$

- Where,
- I_{λ} = normalized reflectance value
- ρ_{λ} = reflectance value to be normalized
- ρ_{MIN} = minimum of reflectance values
- ρ_{MAX} = maximum of reflectance values

Now for each pixel of the image we have a reflectance value. From sample soil test data we can find amount of soil nutrient matching the latitude and longitude. Using linear regression [11] method we can find an equation from the reflectance (I_{λ}) vs. amount of nutrient (z).

Following code (written in python) can calculate reflectance index for band1 using the method described previously:

```

import math

LMAX_BAND = 191.600
LMIN_BAND = -6.200
QCALMAX = 255.0
QCALMIN = 1.0
ESUN = 1997
day_num = 48 # 17th Feb is the 48th of the year
D = 1 + 0.0334 * math.cos(0.01721*(day_num) - 0.0552)
ZENITH_ANG = 98.9636
  
```

```
def radiance(QCAL):
    _L = LMAX_BAND1 - LMIN_BAND1
    _QL = QCALMAX - QCALMIN
    _A = QCAL - QCALMIN
    L = (_L / _QL) * _A + LMIN_BAND1
    return L

def reflectance(radiance):
    A = math.pi * radiance * D**2
    B = ESUN * math.cos(ZENITH_ANG)
    return A/B

ref = []
for DN in range(1, 255):
    ref.append(reflectance(radiance(DN)))
for each in ref:
    print round((each-ref[0])/(ref[ref.__len__()-1]-ref[0]),3)
```

Values LMAX_BAND and LMIN_BAND are band specific, provided in a meta file with image. Distance between SUN and EARTH (in Astronomical Unit) ($D = 1 + 0.0334 * \text{math.cos}(0.01721 * (\text{day_num} - 0.0552))$) is day (day / month / year) specific. Zenith angle is calculated from online calculator [12] provided by Solar Radiation Monitoring Laboratory of University of Oregon.

Digital number is measured by OPTICKS [13] – an open source tool.

4. Result and Equations

4.1 Relation between Nitrogen and reflectance indexes

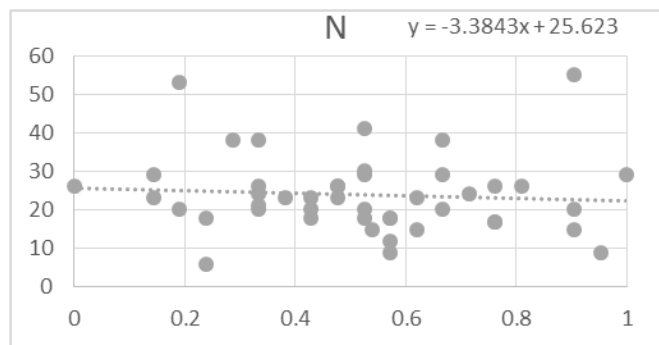


Figure 1: Reflectance index of band1 vs. amount of Nitrogen

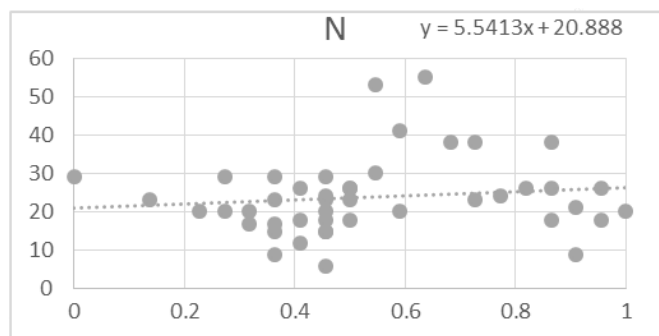


Figure 2: Reflectance index of band2 vs. amount of Nitrogen

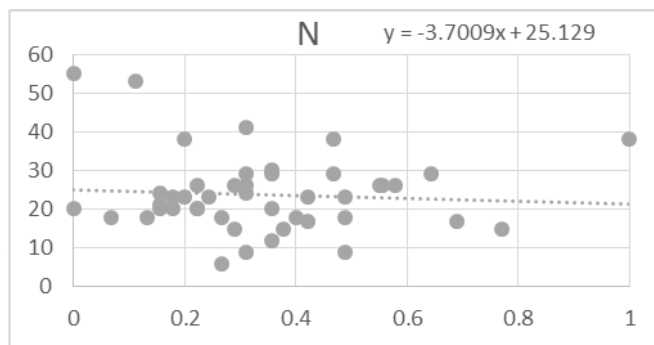


Figure 3: Reflectance index of band3 vs. amount of Nitrogen

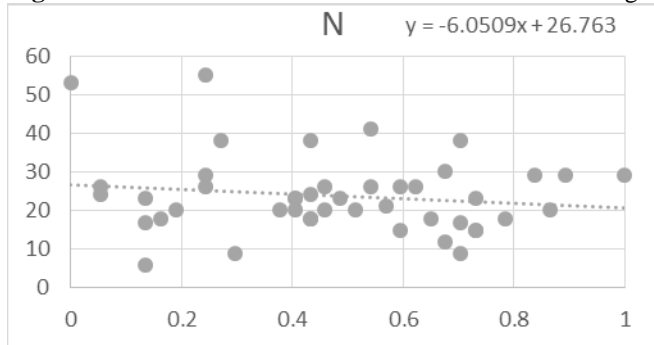


Figure 4: Reflectance index of band4 vs. amount of Nitrogen

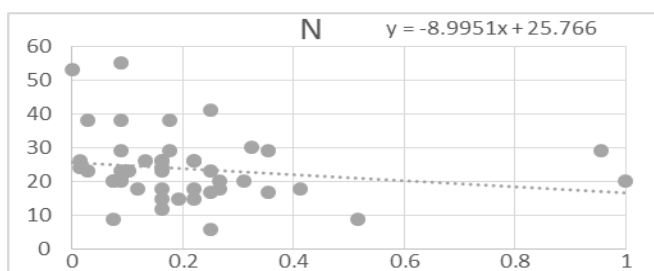


Figure 5: Reflectance index of band5 vs. amount of Nitrogen

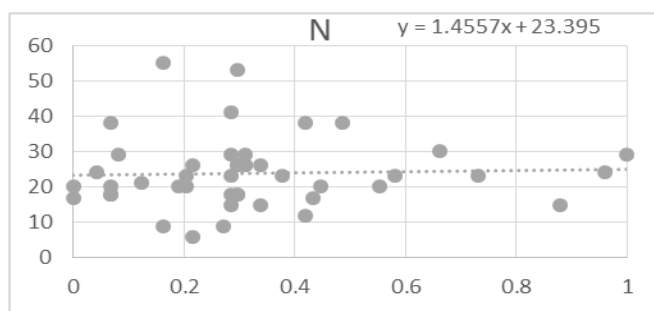


Figure 6: Reflectance index of band6 vs. amount of Nitrogen

Figure 4 shows that it has more data density near the trend line, which means equation of the trend line can give more accurate result compare to the trend lines generated using other bands others. This trend gives the following equation:

$$y = -6.0509x + 26.763$$

Where,

y = amount of nutrient

x = reflectance index

4.2 Relation between Potassium and reflectance indexes

Relation between reflectance index and Amount of potassium shows that band2 gives a more accurate result comparing to other bands.

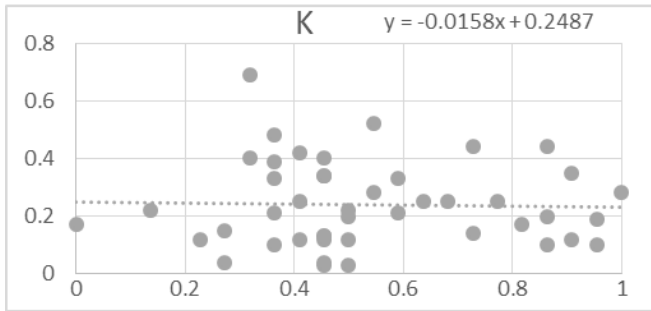


Figure 7: Reflectance index of band2 vs. amount of Potassium

4.3 Relation between Magnesium and reflectance indexes

Relation between reflectance index and Amount of magnesium shows that band2 gives a more accurate result than other bands.

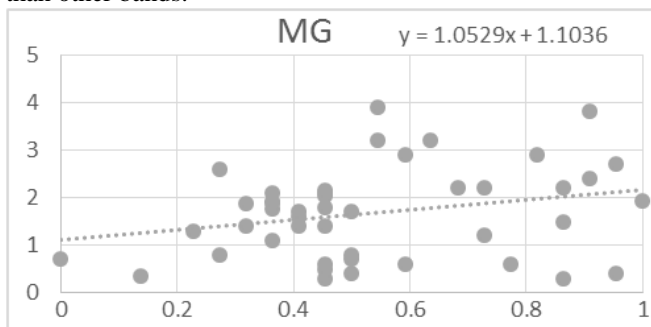


Figure 8: Reflectance index of band2 vs. amount of Magnesium

5. Conclusion

This work prove that it is possible to determine the amounts of important soil nutrients using satellite imagery. More than 150 satellites are orbiting the earth – collecting data continuously. These data are the source of the information required for this work, which requires zero additional cost. Though the results from the process are not 100% accurate because of unavailability of accurate match of time between of soil test data and imagery – it can give a satisfactory result with an increased amount of data.

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Author Profile



Sabbir M Saleh received the B.Sc. and M.Sc. degrees in Computer Science and Software Engineering from American International University- Bangladesh in 2013 and 2015, respectively. During 2013-2014, he stayed in various IT Farms and Group of Companies in Bangladesh as Content Engineer, Web Developer, and Programmer Analyst. On November 2014 he has joined at University of South Asia as a Lecturer in Computer Science & Engineering Department, and he has a dream to complete his PhD from abroad.



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Md. Imran Hossain graduated in Electrical and Electronic Engineering from American International University- Bangladesh. His previous research work includes solar energy home systems and microcontroller based robotics. He is working with News Technology Ltd. As an Engineering Executive. He is also a member of the Institution of Engineers, Bangladesh (IEB)



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