An evaluation of Quickbird data for assessing woodland resource in deciduous Sal Forests in Bangladesh.

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Abstract:
The models resulted from different forest variables and spectral response patterns of high resolution satellite (Quickbird) image have shown strong association. Band 2 in the visible region and band 4 (NIR) are strongly correlated with forest variables. For instance, high values correlation of coefficients of band 2 with dbh and height (r= -0.65 and r = -0.75 respectively) suggested that Quickbird image could be very useful in this kinds of research. Band 1 and 3 has also revealed significant associations with forest parameters. However, it is evidenced that Quickbird image can most effectively be used for forest variable assessment and predictions at application level even in the third world countries where forest management are hardly practised and forests are heterogenic in nature what, in turn, limits the use of mid resolution TM or ASTER sensor. This attempt provided evidence that analysis of high resolution Quickbird image data coupled with proposed field technique can be used for improving forest statistics in Bangladesh.

1. Introduction

The forest area of Bangladesh is estimated about 1 million (6%), 1.5 million (9%), 2.46 million (15%) hectares by United States Assistance for International Development (USAID) (1990), Government of Bangladesh (GOB) (1992), Food and Agricultural Organization/United Nations Development Programme (FAO/UNDP) (1990) respectively. It is evident that there is a uncertainty about the true forest resource in Bangladesh. Approximate estimation of forest cover and the quality of stand structure are also given for deciduous sal forests. Lack of modern techniques and data sources, poor logistic support in woodland resource assessment in Bangladesh are the main causes that lead to deceptive forest data creation. It is, in this regard, there is a need for reliable sources of data for natural forest resources to quantify and assess their quality in terms of its biophysical variables (*i.e.* diameter at breast height, stand height, species composition, basal area, volume, tree density and age). Quickbird imagery is used for the first time in this context. Linear and non linear regression models are generated on the basis of spectral response pattern of the image and forest variables (three main variables dbh, height and basal area are considered here). The models and methodology (for field and application level) suggest that high resolution satellite data can be used for monitoring woodland resources in tropical/sub-tropical third world forests, where forest management is almost absent and forest piracy is a commonplace phenomenon.

2. Study Area

The study area falls into the Sal Forests of Madhupur Thana under Tangail district (Figure 1) of Bangladesh. The forests are located on flat-topped hillocks separated by an intricate network of depressions in honeycomb pattern layout (Farooque, 1997). The depressions are generally cultivated with paddy. Homesteads, cultivable lands and forests are inextricably mixed making forest boundary demarcation and maintenance extremely difficult.

The annual average rainfall of this area is 2474 mm and heavy rains last for three to four months (April-July). The mean annual temperature is 26.3^{0}C and the average maximum and minimum temperatures are 27.5^{0}C and 18.5^{0}C respectively.

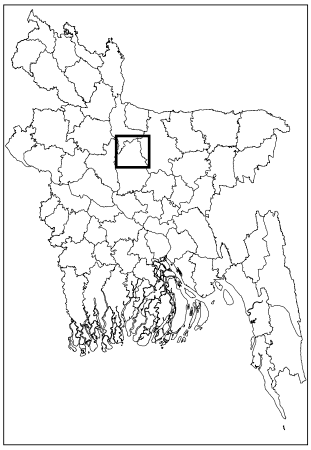

Figure. 1. Study area .

The Sal Forest in the central parts of Bangladesh is one of the three major forest resources of Bangladesh (other types are tropical evergreen, tropical semi-evergreen, mangrove or tidal forests). This moist deciduous forest in the central region is thought to occupy 120,255 hectares (Bangladesh Forestry Department, 2001) of land where sal (*Shorea robusta)* is the predominant species. The Sal Forests comprise of areas containing pure sal crop, mostly of coppice origin. The natural associates of sal in this forest sub-type are bahera (*Terminalia belerica*), sil koroi (*Albizia procera*), ajuli (*Dillenia pentagyana*), haldu (*Adina cordifolia*), kumbhi (*Careya arborea*), jam (*Syzugium cumini*), haritaki (*Terminalia chebula*) and arjun (*T. arjuna*).

3. Satellite data

High spatial resolution Quickbird (2.44 m at nadir) satellite imagery has been used in this research. Multispectral bands of Quickbird image (blue: 450-520 nm, Green: 520-600 nm, red: 630-690 nm and near IR: 760-900 nm) were utilized for generating models in relation to forest structure parameters. Only geometric correction was carried out as image pre-processing; no atmospheric or radiometric corrections were done as these are really essential for comparison of results obtained from different images (Puhr *et al.* 2000, De Wulf *et al*. 1990) although many authors apply radiometric and/or atmospheric corrections before image data analysis (Peterson *et al.* 1987, Ahern *et al.* 1991, Ardo 1992, Danson and Curran 1993).

4. Methodology

4.1 Ground Survey

A ground survey of 71 forest stands was carried out in the study area. Among them 68 plots are within the Quickbird image boundary. The sample plots are taken to represent all the forest management classes. The plots are widely distributed across the study area.

First an unsupervised classification was carried out to detect the major forest classes. Some bigger plots are taken from these classes which formed as the first phase plots. Sub plots (at 5 x 5 meter square plots) are picked up from the first stratum to get second sets of plots. This two phase selection method (Gjertsen, 1991) has been adopted because the forest is heavily dissected by legal and illegal human interventions and attributed with different types of tree species which are recently planted by the forest department as a mechanism for coping with rapid deforestation in the area. So, careful attention was paid while selecting the sample sites so that they can represent the forest structure information for all classes. The forest department does not maintain any permanent test plot in the forest, even there is a lacking of compartment-wise forest map available for forest research. The Bangladesh forest department generally use 1:30,000 aerial photographs to delineate the stands for wood extraction or research purposes. The delineated photographs serve as the field maps and help the forest officials to locate the stands in the forest.

After selecting the sample plots, stand variables (*i.e.* diameter at breast height, height of the stand and species composition) were estimated with the support of relascope and clinometer and then basal area and tree density were calculated from those data. Age was determined by consultation with the forest officials. In tabulating wood volume, Bangladesh Forest Department’s volume chart was used for each species (BFRI, 1992). In addition, quality of the plot, management classes and forest floor conditions were examined by visual inspection and talking to the local and forest people. In this area, forest floors are dominated by different species of creepers and herbs as deep forest floors are humid. But forest floors were found cleared where human access is taking place. Then the spectral bands of Quickbird satellite image were converted to radiance values (ascii files) for those sample plots; and mean spectral values were calculated for each sample plot. A matrix is then generated where the columns represent different forest variables including mean digital numbers of spectral bands and the rows stand for each sample plots. Regression analysis, scatter plots generation for visual inspection was undertaken for data investigation purposes.

4.2 Extracting Reflectance Data from Survey Plots

Some buffer windows were developed around the plot location at different spatial resolution. These windows of 17 x 17, 36 x 36 and 58 x 58 meters are used in this attempt to extract digital numbers of each stand in each reflective Quickbird (multispectral) bands. The buffer windows generally swathe 7 x 7, 15 x 15, 24 x 24 quickbird pixels. Extracted digital numbers are then averaged. The use of mean digital numbers, instead of the exact pixel believed to correspond to the survey plot, should further help reduce potential errors arising from difficulties of finding the exact location of a survey plot on the image (Ahern *et al*. 1991; Puhr *et al.* 2000).

5. Analysis

5.1 Forest Data

Structurally forest plots broadly represent the entire spectrum of *Shorea robusta* stands in the Madhupur forest area. Many other species are also found in different forest patches as those are deliberately introduced through the Forest Department's re-plantation schemes, though some species are naturally occurred. There is a fare difference in under storey vegetation among the forest sample plots. Table 1 shows summary statistics of forest parameters.

Table 1. Summary of measured forest parameters (71 Observations).

Forest variables	Mean	SD	Min.	Max.
Dbh (cm)	17.30	10.64	4	56
Height (m)	11.47	4.79	2	23
Basal area (m^2ha^{-1})	10.31	6.05	0.34	29.54
Volume (m^3ha^{-1})	68.09	58.71	1	314.28
Tree Density (trees ha^{-1})	569	231.36	40	1160
Age (years)	14.7	9.8	1	50

Some plots posses many varieties of creepers, grass, herbs and other small plants, some plots are dissected by human interference that lead clearing of under storey vegetation. These under storey vegetation have a profound impact on the overall reflectance of that particular location/pixel. The summary of forest structure statistics shows diverse characteristics of the forest variables, though they are well correlated (Table 2).

Table 2. Correlation between various forest biophysical parameters.

	Dbh	Height	Basal area	Volume	Tree density	Age
Dbh	1.00					
Height	0.80	1.00				
Basal area	0.69	0.82	1.00			
Volume	0.78	0.76	0.87	1.00		
Tree density	-0.78	-0.77	-0.54	-0.64	1.00	
Age	0.69	0.68	0.62	0.72	0.69	1.00

5.2 Relations between Spectral Data and Forest Structure

Sample plots are not homogenous in terms of structure or species-wise composition because of local poor management practices. Well managed plots represent good quality Shorea robusta trees, where poorly managed plots are with mixed species and often in a damaged condition. Relationships between radiance data and forest variables were found reasonably strong when considering all survey plots are within the analysis (Tables 3 and 4). Franklin (1986) suggested the effects of species composition are important after canopy closure, when background reflectance no longer dominates the remotely sensed signal. Some authors also proposed that the accuracy of predictive models can be improved by stratifying survey plots according to species (Peterson *et al.* 1986, Olsson

1994). Visual inspections of scatter plots (Figure. 2) suggested that relations between reflectance of Quickbird bands 4 and forest structure variables (dbh, height and basal area) decline exponentially towards an asymptote. Band 2 and 4 of Quickbird image show the strongest relationship with forest structure variables.

5.2.1 DBH

The mean diameter at breast height (DBH) of the sample plots range between 20-30cm though some large trees reach 56cm but those only occur in small patches of forest. Most of the points are concentrated at the lower left corner in the scatter plot. In most of the diagrams, the scatter plot shows that reflectance values decrease as dbh increases in Quickbird bands.

5.2.2 Stand Height

Tree height is strongly correlated with reflectance of Quickbird image bands 2 and 4. Reflectance in those bands decreases sharply during the early stages of stand growth and flatten out with lower tree height values.

Table 3. R^2 values of different bands of Quickbird and ASTER image in relation to forest variables.

Quickbird Image		DBH	Height	Basal Area
Band 1	Blue	-0.42	-0.49	-0.43
Band 2	Green	-0.58	-0.66	-0.55
Band 3	Red	-0.49	-0.52	-0.46
Band 4	Near IR	-0.51	-0.61	-0.43

5.2.3 Basal Area

Variable basal area also shows a strong association (Table 4) with radiance data of Quickbird band 2 and 4. In the scatter plot, points are concentrated in the middle parts of the distribution that means the deciduous Madhupur forest is mainly characterised by small sized trees. Only few plots are found with higher basal area with low reflectance values.

Table 4. Regression equations and correlation coefficient values.

Forest Structure Variables (X)	Equations of Quickbird Bands Reflectance to X	Correlation coefficient (r) values
DBH	Band 1 = $-216.04x^{-0.0111}$	-0.52
DBH	Band 2 = $-295.58x^{-0.0362}$	-0.65
DBH	Band 3 = $136.17x^{-0.03}$	-0.63
DBH	Band 4 = $754.57x^{-0.1008}$	-0.65
Height	Band 1 =$215.5x^{-0.0121}$	-0.52
Height	Band 2 = $294.22x^{-0.0407}$	-0.75
Height	Band 3 = $134.57x^{-0.038}$	-0.65
Height	Band 4 = $739.65x^{-0.1104}$	-0.73
Basal Area	Band 1 = $213.62x^{-0.0091}$	-0.52
Basal Area	Band 2 =$285.41x^{-0.035}$	-0.71
Basal Area	Band 3 = $131.31x^{-0.0303}$	-0.68
Basal Area	Band 4 = $671.47x^{-0.0759}$	-0.61

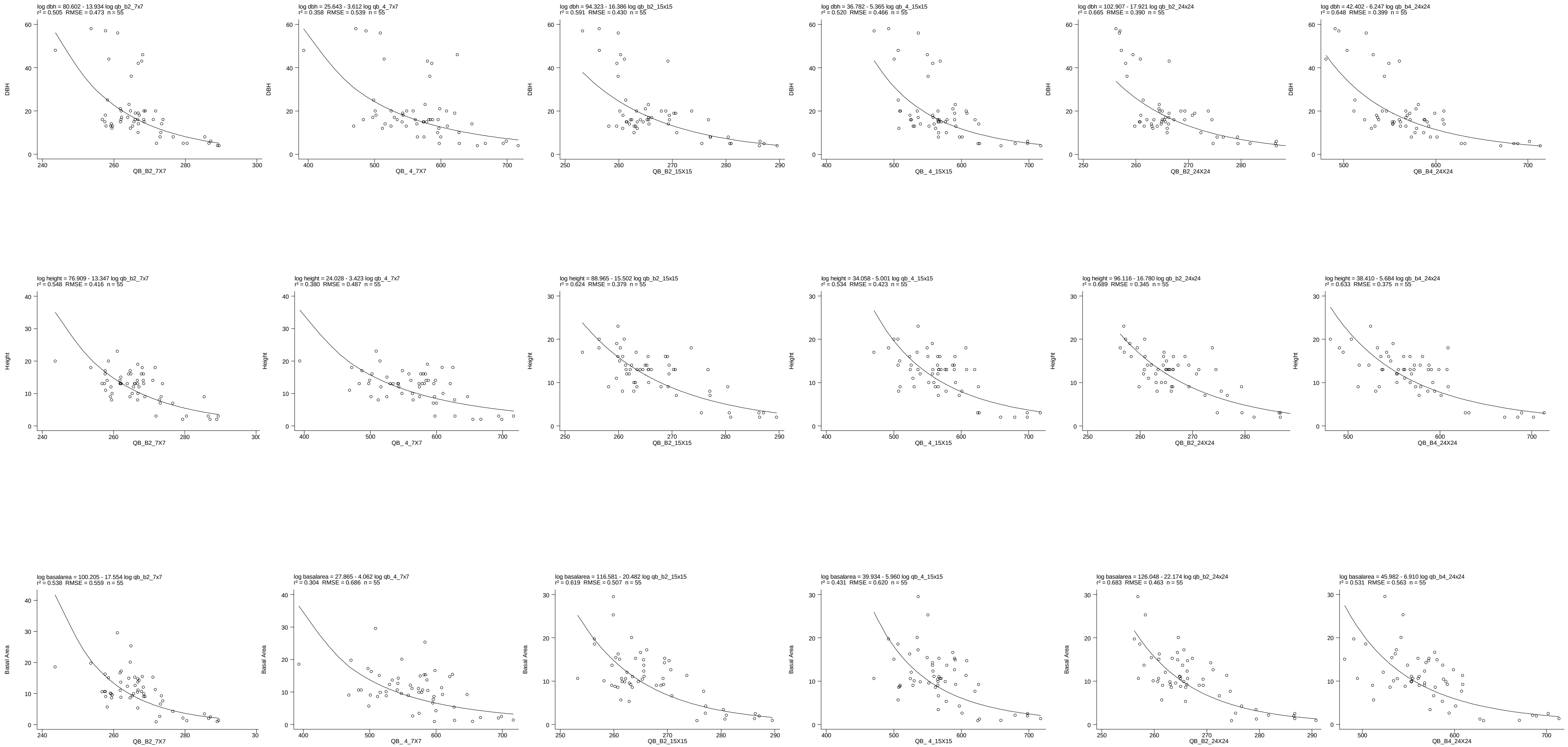

Figure 2. Quickbird image band 4 reflectance against (a) DBH, (b) Height, (c) Basal Area (pixels extracted at different spatial extent).

6. Discussion

The results show that some of the forest variables are strongly correlated with radiance data from satellite imagery. For instance dbh, tree height and basal area are well correlated with Quickbird bands 2 and 4. Many authors (Horler and Ahem 1986, Spanner *et al.* 1990, Olsson 1994) did same types of exercises considering TM bands with forest stand variables. They found that the two shortwave infrared bands of TM (band 5 and 7) are much strongly correlated with forest variables than band 3 in the visible region. The authors argued for this as total reflectance range of forest plots is greater in the SWIR than at visible wavelengths and because there is less atmospheric scattering and more shadowing. Franklin (1986), Danson (1987), Danson and Curran (1993), Gemmel (1995), Puhr *et al.* (2000) suggested that relations in TM band 4 and forest structure are weak. But interestingly, the visible bands 1, 2, 3 and NIR band 4 of Quickbird image shows strong associations with forest variables. It might happen due to its higher resolution where reflectance values are well represented by fairly smaller ground resolution and thus can avoid unexpected signals from the target area.

The forest floors are dominated by under storey vegetation of various kinds. Some forest floors have grass, some are characterised by creepers, and different spice plants (like ginger, turmeric) planted by the forest department through forest improvement projects. Some impurity in pixels representing forest plots may occur due to the impacts of under storey vegetation. The young green saplings of *Shorea robusta* give very high reflectance values (increased digital numbers) and opposite occurrence evidenced as with mature trees (digital numbers decrease as trees get matured and bigger). This pattern can be explained by mutual shadowing: in the NIR region diffuse illumination is weak causing dark shadows. With increasing mutual shadowing as a stand grows older, the net effect is a decrease in reflectance since a larger and larger part of a pixel area will be in shadow. The effect of shadowing compensates the effect of increasing leaf biomass, which would alone increase reflectance in the NIR band (Gjertsen, 1991). Almost all the sample plots are characterised with saplings as this forest is grown up from coppice origin. Therefore, it is obvious that sample plots signals are influenced by the high reflective young saplings.

Puhr *et al.* (2000) argued it is difficult to predict forest structure from coarse resolution Landsat TM data even for the well managed conifer forest plantations in northern Europe. Others like Williams (1986), Nilson and Peterson (1994) also mention the difficulties of using satellite imagery to predict forest parameters from tree stands at a per pixel level. Therefore, it should be more difficult to use coarse resolution data (like TM, ASTER) for predicting poorly managed, dissected forest stands. Puhr *et al.* (2000) also argued that cell structure of leaves does not directly interfere with reflectance/structure relations in the visible and the SWIR bands. Visible bands of Quickbird image (band 1, 2, 3) are therefore suitable for forest parameter predictions (also confirmed by strong association values, see table 3 and 4) in Madhupur forests; band 4 of Quickbird also found useful in this kind of research though some authors like Puhr *et al.* (2000) found NIR band of TM was useless. High resolution Quickbird image, in this context, shows good promise for use in forest variable predictions in sal forests in Bangladesh. Based on Quickbird model predictions, correct assessment of stand properties, proper planning and re-development can be achieved in Bangladesh forest areas.

7. Conclusions

Spectral bands in the visible and NIR of Quickbird image are used to assess the quality of forest biophysical properties of deciduous sal forests in Bangladesh. Most of the bands of Quickbird image show strong association with the forest parameters, especially with dbh, height and basal area. It is difficult to get representative pixels of forest plots in deciduous forests in Bangladesh because of its poor stand quality and lack of sufficient large plots of trees where comparatively low-cost and easily available remote sensing data (*i.e.* Landsat TM) can be used for forest resource assessment. Landsat TM or ASTER data can be used for change detection and stand quantification for a large woodland. In this context, use of high resolution Quickbird image coupled with field methods show a promise to fill the information gap by doing further analysis in forest resources assessment in Bangladesh.

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