APPENDIX

THE 5S MODEL RADIOMETRIC AND ATMOSPHHERIC CORRECTION

The raw satellite images obtained from agencies consist of 8-bit raster containing digital numbers (DNs) between 0 and 255. These digital numbers are controlled by a combination of;

- Sensor parameters (gain and offset).
- Illumination and viewing geometry of the scene.
- Absorption and scattering by the atmosphere.
- Reflectance from the surfaces under consideration.
- Solar irradiance outside the atmosphere.

The raw TM image provided by CHEST has been de-striped. This involves standardizing the values in the scene to a common mean and standard deviation, to compensate for systematic differences in sensitivity between sensors in the array. However, no *absolute* radiometric correction has been carried out. This means that a body reflecting the same in all wavelengths could record different DNs in a TM image taken at a different time. In practice, vegetation signatures, and thus many land cover signatures, will differ greatly over time and growth season. However, the aim is to standardize the images for atmospheric variation such that an object with unchanging spectral properties could, as near as possibly, be recognized by its signature from one scene to the next.

From the DNs of the satellite image, we wish to retrieve the surface reflectance on the ground. This involves modeling the above effects to quantify their contribution to the signal received by the sensor. There are three steps in this process.

1. Convert DN to radiance, *L* (units- Wm-2sr-1)
2. Convert radiance to apparent reflectance - i.e. the reflectance recorded at the sensor.
3. Allow for atmospheric scattering, etc., so that apparent reflectance can be traced back to a surface reflectance value.

Radiation reflected from the target scene is attenuated by atmospheric scattering, caused by gases and suspended particulate matter. This scattering is more severe at shorter wavelengths (i.e. at the 'blue' end of the spectrum). Thus analyses and classifications which rely on band ratios can be affected. Scattered sunlight is also introduced into each pixel from the area surrounding it, and vice versa. This reduces the spatial resolution of the sensor. The 5S model models the optical qualities of the atmosphere using features of the scene, as well as known parameters such as the solar zenith angle.

Inputs to the 5S model are as follows;

- Viewing and Illumination geometry: solar azimuth, view angle etc.
- Atmospheric model - there are 5 standard models supplied with the code, which can be used depending on the time of year and latitude - Tropical, Mid-latitude (summer), Mid-latitude (winter), Sub arctic (summer), Sub arctic (winter).
- Aerosol model - this has 4 components - dust, oceanic, water-soluble and soot. Again, the 5S model has standard models, namely continental, maritime and urban.
- Aerosol concentration - in terms of either the visibility in km, or the aerosol optical depth at 550 *nm*. In practice, this parameter is usually set last, by running the model with a variety of reasonable values until a surface reflectance of near 0 corresponds to the lowest DN in each band. This is equivalent to a dark-target correction, which assumes that somewhere in a scene, probably in deep shade or water bodies, there will be an area reflecting close to zero for at least some of the bands. In fact, there may be no areas of zero reflectance, so that aerosol density is overestimated unless care is taken. However, the practice is broadly reasonable.
- Spectral band under consideration.

The model outputs a conversion table of DN to surface reflectance, but also a variety of coefficients which can be used to invert the model within a GIS and calculate new pixel values for each band. The reflectance values calculated represent percentages, and are scaled between 0 (0%) and 1 (100%).

To calibrate the TM imagery, an adapted version of the 5S code was used, which use standard gain and offset parameters to calculate radiance from DN. These parameters are as supplied by EOSAT, and are applicable to all TM-5 images between 15 Jan 1984 and 1 Oct 1991. Radiance is calculated from DN as follows;

1. L = Gain * DN + Bias.

For the second stage, top-of-atmosphere reflectance is calculated using the following equation;

2. (rho-t.o.a. = radiance * (ssolirr(j) * D * cos (solar zenith (degrees) * (PI/180))

where ssolirr(j) is a standard value for solar irradiance in band j and D is a multiplication factor accounting for earth-sun distance at this latitude.

Ssolirr is a constant, for any spectral band and sensor, measured in *W*m-2sr-1m-1, and is the band-averaged equivalent solar radiance for that band at the mean Earth-sun distance. Variations from this distance due to latitude are corrected for by D.

Finally, top-of-atmosphere reflectance is corrected for atmospheric scattering using coefficients A, B and S, which are output by the model, along with the following two equations.

3. ycoef = (A * (rho-t.o.a.) - B

4. (rho-surface = ycoef / (1 + (ycoef * S)