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Article · May 2015

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Exploring Landsat 8

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ABSTRACT

Landsat has been providing moderate spatial resolution, global, synoptic, and repetitive coverage of the Earth's land surfaces. Landsat 8 extends the remarkable 40 year Landsat record and has enhanced capabilities. This paper introduces overview of sensors and their standard data products Preliminary evaluation of Landsat 8 capabilities and identification of new science and applications opportunities are explored.

Keywords
Landsat, Landsat 8, Satellite Imagery, Band Combination.

1. INTRODUCTION

Satellite observations of Earth's land and ocean surfaces are very important for understanding the processes and rhythms of our planet. There has been many such satellites has been providing services every hour. Many new such advanced programs are being added year by year. Among the most successful and reliable program has been Landsat program.

The Landsat era began in 1972, providing moderate spatial resolution, global, synoptic, and repetitive coverage of the Earth's land surfaces, continues at a scale where natural and human-induced changes can be detected, differentiated, characterized, and monitored over time (USGS, 2013). Landsat data from the United States Geological Survey (USGS) is one of the best sources for mapping and monitoring of land cover and land surface biophysical and geophysical properties over the last 40 years (Hansen & Loveland, 2012; Wulder et. al., 2012). Of the last three Landsats, Landsat 7 reached orbit but in 2003 incurred a problem that created ongoing striping of missing data on imagery, Landsat 6 did not reach orbit, and Landsat 5 operated successfully well beyond its expectancy.

Landsat 5 which produced images since the 1980s but at a fairly low rate and which stopped delivering image with its main sensor in 2011. Landsat 7 before the SLC failure in 2003 produced a good and high quality coverage of most of the earth but these are meanwhile more than 10 years old so can be outdated for a lot of applications. As the coverage is limited, images from more remote regions are possibly with frequent cloud cover or for a certain time of the year often good images cannot be found.

With the launch of Landsat 8 in February of this year, the continuity of the program is assured into at least the next decade. And in case of successful operation, the refinements and new bands will overcome the previous necessities with more detail and accuracy (USGS, 2013).

2. LANDSAT 8 PROGRAM

The Landsat Data Continuity Mission has a successful launch February 11th 2013. It was officially renamed to Landsat 8 on May 30, 2013. The newest satellite in the Landsat series offers scientists a clearer view with better spatial resolution than most ocean-sensing instruments and greater sensitivity to brightness and color than previous Landsats. Most significantly, it can observe the Earth in wavelengths that allows scientists to adjust for the distortions especially caused by the atmosphere near the coast (http://earthobservatory.nasa.gov/IOTD/).

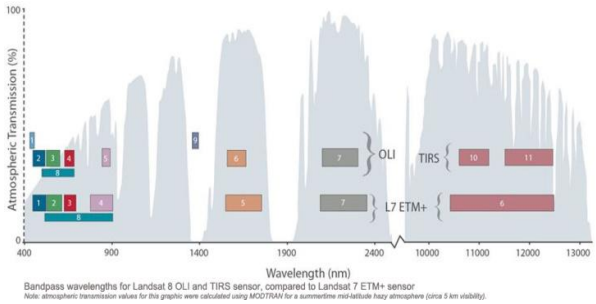


Fig. 1. Bandpass wavelengths for the landsat 8 OLI and TIRIS sensors, compared to Landsat 7 ETM+ sensors (USGS, 2013)

Landsat 8 carries two instruments: The Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS). The OLI, a push-broom sensor with a four mirror telescope, collects data in visible, near infrared, and shortwave infrared wavelength regions as well as a panchromatic band. Two new spectral bands have been added: a deep-blue band for coastal water and aerosol studies (band 1), and a band for cirrus cloud detection (band 9) (Fig. 1). A Quality Assurance band is also included to indicate the presence of terrain shadowing, data artifacts, and clouds (USGS, 2013). Panchromatic, multispectral are taken in 15m, 30m resolution respectively. The TIRS collects data in two long wavelength thermal infrared bands. The 100-meter spatial resolution of TIRS data is registered to the

OLI data to create radiometrically and geometrically calibrated, terrain-corrected 16-bit Level 1 data products.

Table 1. Processing parameter for Landsat 8 standard data products (USGS, 2013)

Product Type	Level 1T (terrain corrected)
Data type	16-bit unsigned integer
Output format	GeoTIFF
Pixel size	15 meters/30 meters/100 meters (panchromatic/multispectral/thermal)
Map projection	UTM (Polar Stereographic for Antarctica)
Datum	WGS 84
Orientation	North-up (map)
Resampling	Cubic convolution
Accuracy	OLI: 12 meters circular error, 90 % confidence
	TIRS: 41 meters circular error, 90 % confidence

On March 18, 2013, the first images were taken with both the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS) onboard the Landsat Data Continuity Mission (LDCM) spacecraft. The Landsat 8 satellite images the entire Earth every 16 days in an 8-day offset from Landsat 7. It promises to produce images at a significantly higher rate than Landsat 7 (up to 400 scenes per day). Both sensors provide improved signal-to-noise (SNR) radiometric performance quantized over a 12-bit dynamic range. Improved signal to noise performance enable better characterization of land cover state and condition.

Data collected by the instruments onboard the satellite, are available to download at no charge from GloVis, EarthExplorer, or via the LandsatLook Viewer within 24 hours of reception (USGS, 2013). Approximate scene size is 170 km north-south by 183 km east-west (106 mi by 114 mi) and have a large file size of about 1 GB compressed.

Landsat 8 data products are consistent with the all standard Level-1 (orthorectified) data products created using Landsat 1 to Landsat 7 data. It consists of quantized and calibrated scaled Digital Numbers (DN) representing multispectral image data acquired by both the Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS). The products are delivered as 16-bit unsigned integer format (scaled to 55,000 grey levels), and can be rescaled to the Top Of Atmosphere (TOA) reflectance and/or radiance using radiometric rescaling coefficients provided in the product metadata file (MTL file). The MTL file also contains the thermal constants needed to convert TIRS data to the at-satellite brightness temperature.

The level of detail (spatial resolution) is often the most interesting aspect of viewing a satellite image, but less appreciated is how changes in irradiative energy reflected by different surface materials are used to identify features of interest. Landsat 8 provides continuity to the previous sensors and also with its addition of new multispectral and thermal bands enables additional analysis in future.

Table 2. Landsat 8 bands properties and applications

Landsat 8 Sensors	Band	Band Name	Wavelength (µm)	Resolution (m)	Applications
Operational Land Imager (OLI)	1	Coastal / Aerosol	0.433-0.453	30	Coastal and Aerosol studies
	2	Blue	0.450-0.515		Bathymetric mapping, distinguishing soil from vegetation and deciduous from coniferous vegetation
	3	Green	0.525-0.600		Emphasizes peak vegetation, which is useful for assessing plant vigour
	4	Red	0.630-0.680		Discriminates vegetation slopes
	5	Near Infrared (NIR)	0845.-0.885		Emphasizes biomass content and shorelines
	6	Short-wave Infrared (SWIR) 1	1.560-1.660		Discriminates moisture content of soil and vegetation; penetrates thin clouds
	7	Short-wave Infrared (SWIR) 2	2.100-2.300		Improved moisture content of soil and vegetation and thin cloud penetration
	8	Panchromatic	0.500-0.680	15	Sharper image definition
	9	Cirrus	1.360 -1.390	30	Improved detection of cirrus cloud contamination
Thermal Infrared Sensor (TIRS)	10	Long-wave Infrared (LWIR) 1	10.30 – 11.30	100*	Thermal mapping and estimated soil moisture
	11	Long-wave Infrared (LWIR) 2	11.50-12.50		Improved thermal mapping and estimated soil moisture
	BQA	Quality Assessment			Quality assessments for every pixel in the scene
* TIRS bands are acquired at 100 meter resolution, but are resampled to 30 meter in delivered data product.					

3. PROPERTIES

In Landsat 8, the heritage bands are similar but refined to avoid atmospheric absorption features (enabled by higher signal to noise ratio inherent in push-broom architecture). Due to improvement, it is capable of providing a 12-bit range (4,096 levels) of pixel values, improving precision.

Table 3. Comparing the differences to previous version of Landsat

Band Name	Band Number			Differences in LS8
	LS8	LS7	LS5	
Coastal/ Aerosol	1	-	-	new
Blue	2	1	1	more narrow
green	3	2	2	more narrow
red	4	3	3	more narrow
Near Infrared (NIR)	5	4	4	more narrow
Short-wave Infrared (SWIR) 1	6	5	5	more narrow
Short-wave Infrared (SWIR) 2	7	7	7	more narrow
Panchromatic	8	8	-	more narrow, only visible (red-green)
Cirrus	9	-	-	new
Long-wave Infrared (LWIR) 1	10	6	6	two bands instead of one
Long-wave Infrared (LWIR) 2	11	6	6	two bands instead of one

The thermal infrared band from Landsat 7 is now split into two bands for Landsat 8. Whereas before you had one thermal band that was acquired at 60 m resolution (and resampled to 30 m) now you have increased spectral resolution at the cost of spatial resolution. Both bands 10 and 11 are useful in providing more accurate surface temperatures and support emerging applications such as modeling evapotranspiration for monitoring water use consumption over irrigated lands.

The new infrared bandwidth is more improved and more uniform across the scene. It will not get absorbed as much by atmospheric water as NIR bands of previous Landsats. As shown in the Method, guide, and accuracy page in the Atmospheric Correction folder, an adjustment is needed to correct the NIR band for Landsat 5 and 7 due to absorption of the radiation by atmospheric perceptible water (Wu et al., 2005) to retrieve accurate enough reflectance. The refinement of the Landsat 8 NIR bandwidth helps solve this problem. Landsat 7 NIR (band 4) bandwidth is 0.775–0.900 µm while Landsat 8 NIR (band 5) bandwidth 0.845–0.885 µm. Landsat 8 NIR is in much more of an atmospheric window in regards to absorption by water; radiation will not get absorbed enough for it to be necessary to apply the atmospheric water absorption correction factor.

The Coastal/Aerosol is blue water penetrating and aerosol detecting band. It has been added at request of ocean color investigators requiring higher resolution of coastal water relative to MODIS and SeaWiFS. Relative to the MODIS and the SeaWiFS sensor, the Landsat 8 sensor allows for better imaging of these shallow waters due to its superior spatial and radiometric resolutions. By comparing with blue band, correction for the difference can be applied which will help in better and closer inspection of coastal and inland waters. It can also help in estimation of carbon exchange at the land-water interface such as salt marshes, wetlands, harbors where ocean color instruments fail due to coarse pixel size. Scientists also hope to make clearer observations of sediments, particles, organic matter, coral reefs, and suspended chlorophyll-rich phytoplankton in these bodies of water. The same band, Coastal/Aerosol (its radiance value) can be used with two other bands for estimating the concentration of aerosols in the atmosphere, which may be used to refine the atmospheric correction procedures such as dark object subtraction.

Another new band, Cirrus allows for better detection of cirrus cloud contamination in each scene. The old Landsat sensors included bands that made it hard to detect these high-altitudes, cold, and wispy difficult-to-detect clouds. This new cirrus band with center wavelength of 1.375 microns attempts to detect the light, which is reflected by the high-altitude clouds but is absorbed by the water vapor closer to the ground. In this band, cirrus clouds will appear bright while most land surfaces will appear dark through the atmospheres that contain water vapor. If the atmosphere is relatively dry, the one risk having some of the land surfaces appear bright as well. Using the cirrus band requires careful interpretation techniques. This band is not to be used together with other multispectral bands but, as a cloud masking.

Similarly, the new Quality Assessment band represents bit-packed combinations of surface, atmosphere, and sensor conditions that can affect the overall usefulness of a given pixel. It provides weather a pixel is good or bad to produce more accurate and precise results for each user's application. It also helps in differentiating between snow covered mountains and highly reflective urban areas (USGS, 2014).
Some of Landsat 8's bands exhibit striping in the images, probably due to sensor calibration problems. So far the thermal, cirrus, and coastal aerosol bands have been identified as those that show striping most prominently. The stripes in the thermal bands are the most problematic, because even though they are narrow and short in length, they show the biggest offset in pixel values. The stripes in the cirrus and coastal aerosol bands are easier to detect since they are broad and long. However, the offsets in

pixel values in these two bands are minimal (Yale University, 2013).

4. APPLICATION

A. Study Scene

The study scene is North East part of South Korea. It consists mostly of Gangwon province and some part of Gyeonggi, Chungcheongbuk and Gyeongsangbuk provinces. It also includes DMZ boarder and small part of North Korea.

B. Data set and methodology

Imagery data for the study were acquired from the United States Geological Survey (USGS) website using its online interface, the GLOVIS (http://glovis.usgs.gov/). The data were acquired as zipped Georeferenced Tagged Image File Format (GeoTIFF) representing systematically terrain corrected data (L1T). The properties and the natural color image and quality assessment band of scene are as shown in table 4 and Fig. 2.

The software used for processing and information extraction are ArcGIS 10.2 (ESRI, 2013) and ENVI 5.1 (EVIS, 2013). Both of the software support Landsat metadata file.

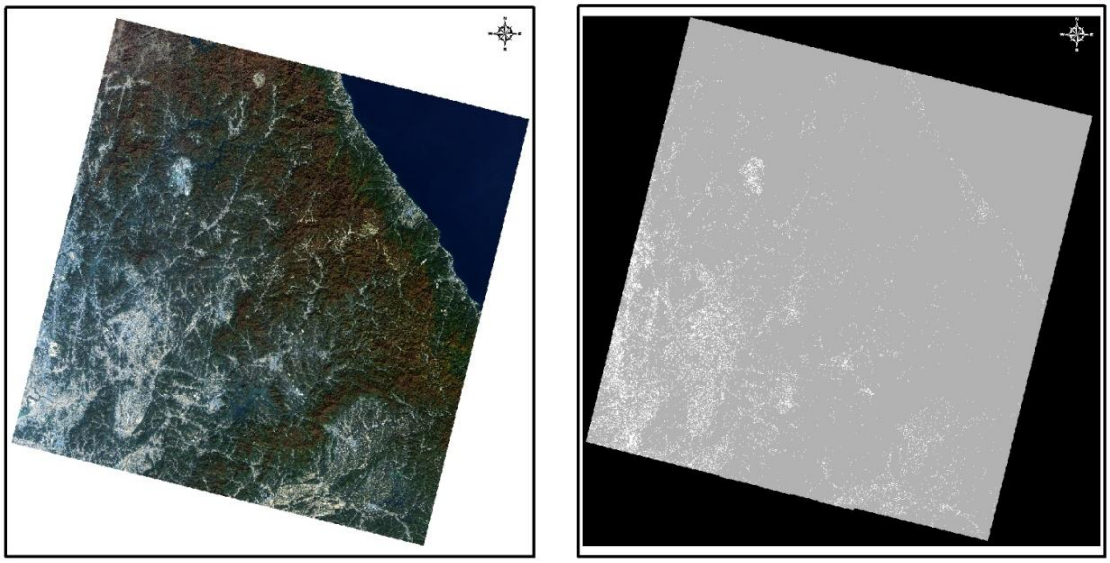


Fig. 2. Scene from path 34 and row 115 a. Natural color composite (432); b. Quality Assessment Band

Table 4. Details of the study scene

Data Set Attribute	Attribute Value
Landsat Scene Identifier	LC81150342013300LGN00
WRS Path	115
WRS Row	034
Nadir Off Nadir	NADIR
Full or Partial Scene	FULL
Data Category	NOMINAL
Roll Angle	-0.001
Station Identifier	LGN
Day/Night	DAY
Data Type Level 1	Level 1T
Sensor Identifier	OLI_TIRS
Date Acquired	10/27/2013
Start Time	2013:300:02:06:20.0758020
Stop Time	2013:300:02:06:52.0761252
Image Quality	9
Scene Cloud Cover	1.31
Sun Elevation	37.67814162
Sun Azimuth	159.9862116
Geometric RMSE Model	5.013
X	
Geometric RMSE Model Y	6.036
Browse Exists	Yes
Center	37°28'27.88"N, 128°11'42.65"E
NW Corner	38°31'42.06"N, 127°23'25.98"E
NE Corner	38°07'46.92"N, 129°30'41.51"E
SE Corner	36°24'21.35"N, 128°58'21.79"E
SW Corner	36°48'11.84"N, 126°53'59.93"E

5. RESULTS

The GeoTIF imageries were opened with the metadata file in ENVI 5.1. It categorized all separate bands into Multispectral (1, 2, 3, 4, 5 6 and 7), Panchromatic (8), Cirrus (9), Thermal Infrared (10, 11) and Quality (BQA).

Each group was exported to individual set. Radiometric calibration was performed to convert DN value of multispectral imagery to At-sensor reflectance. After calibration, bands were explored individually or in different combinations.

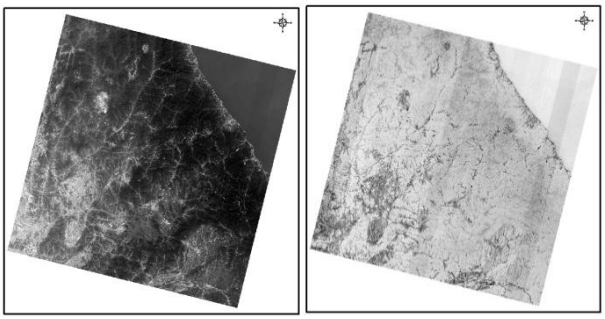


Fig 3. a. Band 1; b. Difference between Band 1 and Band 2

Coastal/Aerosol band senses blue and violet. It is very hard to collect as it gets scattered by small dust, water particle in air and even air molecules themselves. The difference between band 1 and 2 shows the ocean and living plants reflect greener color. The effect in vegetation is due to Epicuticular wax on growing plants to reflect harmful radiations. It also reveals some stripping effect (Fig.3).

The heritage bands Blue, Red and Green produce more clearly natural color image. Fig. 4 shows the natural color composite of Gangneung area. Sea looks dark blue whereas forests are green and brown. Urban areas are light grey.

Fig 4. Gangenung area a. Band 432; b. Band 5

Near Infrared band is small part of spectrum which is refraction towards the sky form water content of healthy plant leaves. Fig 4.b shows the bright part as densely growing vegetation. Shortwave Infrared I and II are the useful in determining the wetland from dry, differentiating different rock and soil types that look similar.

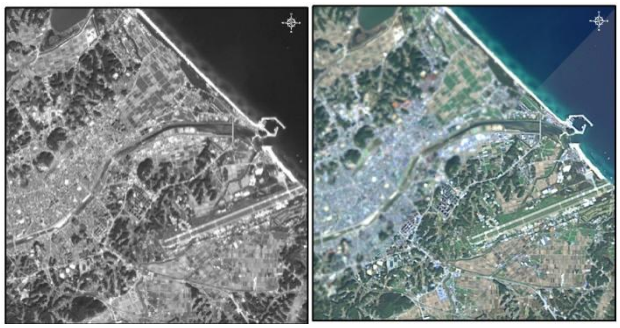


Fig 5. a. Band 6; b. Image comparison (diagonal) with original 432 resolutions and pansharpened image

Panchromatic band is black and white band which collects energy from visible spectrum combined. As combined helps in more collection of light, the images are sharper, which is actually 15m resolution. These are used in pansharpening the regular lower resolution images. Fig. 5 shows images with and without sharpening; the sharpened image shows more crisp details than blur original resolutions.

Cirrus band is one of the new and important features of Landsat 8. It collects a very narrow wavelength: only 1370 ± 10 nanometers. Few space-based instruments collect this part of the spectrum, because the atmosphere absorbs almost all of it. The ground is barely visible in this band and anything that appears clearly in, it must be reflecting very brightly and/or be above most of the atmosphere.

Thermal infrared or TIR bands measures the temperature on the ground itself. Analysing these bands, heat islands can be identified in urban areas. Both these bands show stripping effect but band 11 shows more instability in values than band 10. Fig 6.b shows the corner parts ocean and city are little hotter than the mid forest hills. The river channel shows moderate temperature.

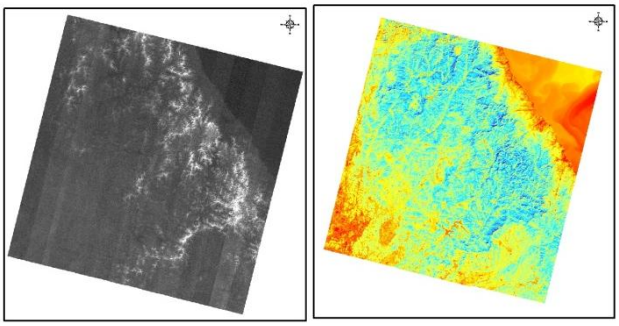
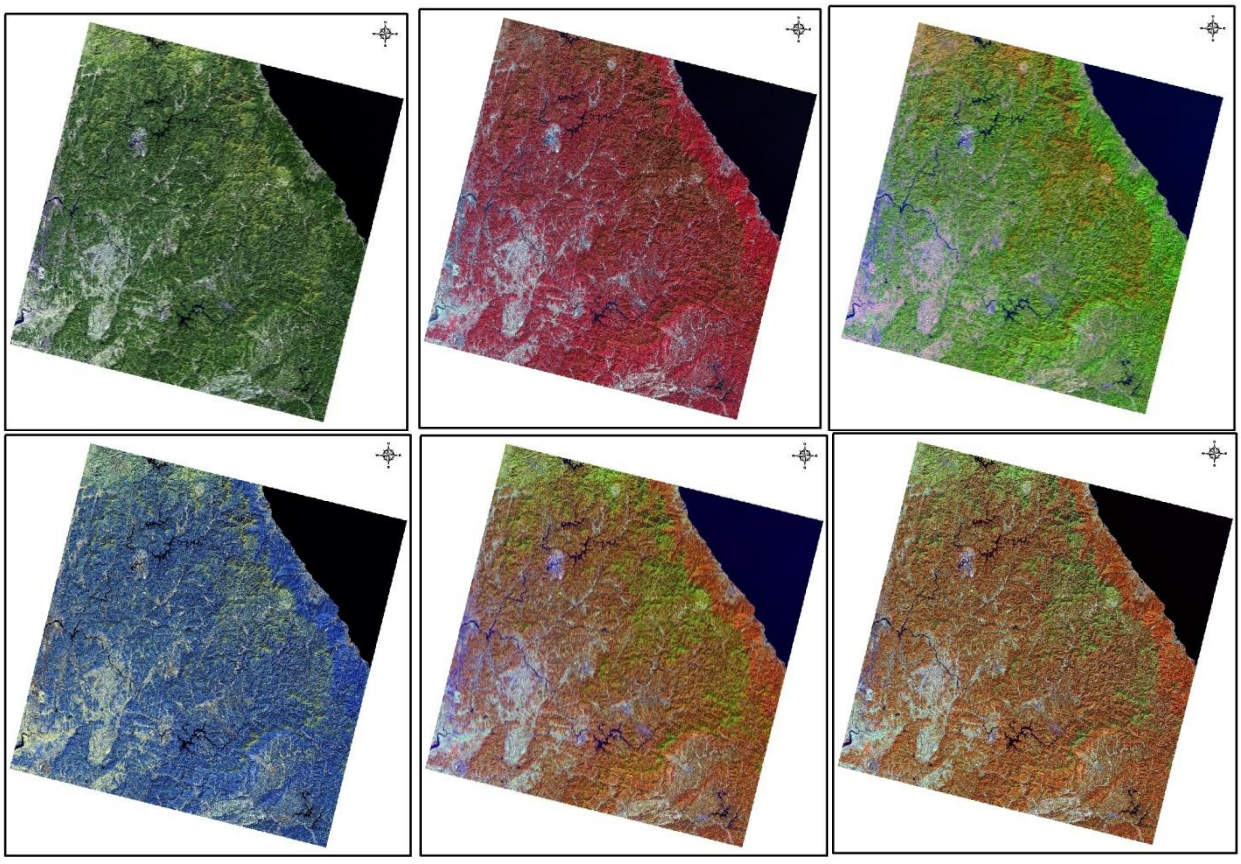


Fig 6. a. Band 9; b. Thermal band 10

As all bands are collected exactly the same time and place, all eleven bands can be used together. Allowing artificial colors to data form different spectral bands for display helps scientists to distinguish between different surface features according to their reflection intensity. Some common band combinations applied to Landsat 8, displayed as a red, green, blue (RGB) are shows in Fig. 7 and table 5.

Table 7. Application of various band combinations

Application	Band Combination	Sample Scene
False Colour (urban): The violet blue shows the city expansion.	7 6 4	Fig 7a
Colour Infrared (vegetation): One of the most used false colour image to identify vegetation cover.	5 4 3	Fig 7b
Agriculture: The composite differentiate agricultural area in light yellow display.	6 5 2	Fig 7c
Atmospheric Penetration: The all infrared composite shows how much penetration is made through the atmosphere by the spectrum.	7 6 5	Fig 7d
Healthy Vegetation: The composite helps in more detail status of vegetation health.	5 6 2	Fig 7e
Land/Water: Water bodies are easily separated with this composite.	5 6 4	Fig 7f
Natural With Atmospheric Removal: The composite gives the natural like view with the help of infrared atmospheric window.	7 5 3	Fig 7g
Vegetation Analysis: Vegetation can be categories more easily and health conditions can also be analysed.	6 5 4	Fig 7h
Thermal Variation: Water surfaces are redder i.e. hotter than land surface. Sea breeze caused the east shores hotter which is within mountain range of Taebaek Some light blue cold areas are due to clouds. The coloured strips on either side of the image are areas where not all sensors have coverage.	10 7 3	Fig 7i



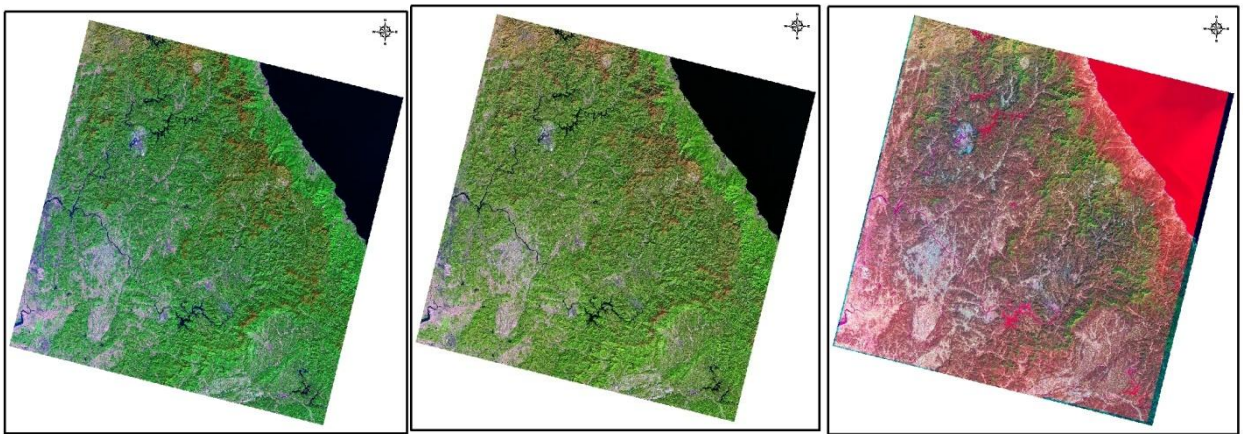


Fig. 7. Band compositions: (a) 7 6 4; (b) 5 4 3; (c) 6 5 2; (d) 7 6 5; (e) 5 6 2; (f) 5 6 4; (g) 7 5 3; (h) 6 5 4; (i) 10 7 3

Beside band combination, ratios and indices are also very important for studying the earth surface, which could reveal more detail and accurate detection for scientific studies.

6. CONCLUSION

Landsat program has been providing space-based moderate-resolution land remote sensing data continuously since four decades. The acquired imageries are the used in many different applications in the field of agriculture, forestry, geology, regional planning, education, mapping, and global landuse/cover change. With the launch of Landsat 8, the legacy has been forwarded to future.

Landsat 8 has improved its features as well as introduced new bands for more accurate studies in broader fields. It offers more combinations with more narrow classification. Yet, more has to be explores about Landsat 8, scientific research as well as whole mankind will be benefited with its improved imagery archives.

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