Landsat 5 (TM sensor)	Wavelength� (micrometers)	Resolution (meters)
Band 1	0.45 - 0.52	30
Band 2	0.52 - 0.60	30
Band 3	0.63 - 0.69	30
Band 4	0.76 - 0.90	30
Band 5	1.55 - 1.75	30
Band 6	10.40 - 12.50	120
Band 7	2.08 - 2.35	30

Landsat 7 (ETM+ sensor)	Wavelength� (micro...
Band 1	0.45 - 0.515
Band 2	0.525 - 0.60!
Band 3	0.63 - 0.69
Band 4	0.75 - 0.90
Band 5	1.55 - 1.75
Band 6	10.40 - 12.5
Band 7	2.09 - 2.35
Pan Band	.52 - .90

Ground Feature	Bands Used	Contrast Manipulation	Limits
Water	1,2,3; 1,2,4; 1,4,5	No	No
Urban	1,2,3; 1,4,5	Yes band 4 (1,4,5)	Yes band 4 (1,4,5)
Farmland	1,2,3; 1,4,5	Yes band 4 (1,4,5)	Yes band 4 (1,4,5)
Forest	1,2,3; 1,4,5	Yes band 4 (1,4,5)	Yes band 4 (1,4,5)
Salt Scald	1,2,3; 1,4,5	Yes band 4 (1,4,5)	Yes band 4 (1,4,5)
Scrub	1,4,5	Yes band 4 (1,4,5)	Yes band 4 (1,4,5)
Parks/Golf	1,2,3	No	No

Land Cover Type	Spectral Band Combination
Water	Band 1, 4 & 7 / Band 1, 2 & 3
Urban	Band 1,4 & 7
Farmland	Band 1, 2 & 3
Forest	Band 1, 4 & 7
Salt Scald	Band 1, 2 & 3
Remnant Vegetation	Band 1, 4 & 7
Irrigated Vegetation	Band 1, 4 & 7

Terrain Feature	Reflectance Response
Water Bodies	Generally reflect high in the visible spectrum, however, clearer water has less reflectance than turbid water.� In the Near IR and Mid-IR regions water increasingly absorbs the light making it darker.� This is dependent upon water depth and wavelength.� Increasing amounts of dissolved inorganic materials in water bodies tend to shift the peak of visible reflectance toward the red region from the green region (clearer water) of the spectrum.
Soil	Northern latitudes have black soils and tropical regions have red soils.� Soil reflectance decreases as organic matter increases.� As soil moisture increases, reflectance of soil decreases at all wavelengths.� Texture of soil will cause increased reflectance with decreased particle size, i.e., the bigger particles (rocks, sand, and soils) basically cast a larger shadow.
Vegetation	The spectral reflectance is based on the chlorophyll and water absorption in the leaf.� Needles have a�darker response than leaves.� There will be various shades of vegetation based on type, leaf structure, moisture content and health of the plant.
Man-Made Materials	Concrete and asphalt both display spectral curves that generally increase from the visible through the Near IR and Mid-IR regions.� However, as concrete ages, it becomes darker and as asphalt ages it becomes lighter.
Snow and Ice	Old snow may develop a compacted crust and the moisture content increases which make it less reflective in the Near IR and Mid-IR region.� It is possible to compare old and new snow by its Mid-IR reflectance.

R, G, B	Potential Information Content
4,3,2	The standard "false color" composite.� Vegetation appears in shades of red, urban areas are cyan blue, and soils vary from dark to light browns.� Ice, snow and clouds are white or light cyan.� Coniferous trees will appear darker red than hardwoods.� This is a very popular band combination and is useful for vegetation studies, monitoring drainage and soil patterns and various stages of crop growth.� Generally, deep red hues indicate broad leaf and/or healthier vegetation while lighter reds signify grasslands or sparsely vegetated areas.� Densely populated urban areas are shown in light blue.� This TM band combination gives results similar to traditional color infrared aerial photography.
3,2,1	The "natural color" band combination.� Because the visible bands are used in this combination, ground features appear in colors similar to their appearance to the human visual system, healthy vegetation is green, recently cleared fields are very light, unhealthy vegetation is brown and yellow, roads are gray, and shorelines are white.� This band combination provides the most water penetration and superior

	sediment and bathymetric information.� It is also used for urban studies.� Cleared and sparsely vegetated areas are not as easily detected here as in the 4 5 1 or 4 3 2 combination.� Clouds and snow appear white and are difficult to distinguish.� Also note that vegetation types are not as easily distinguished as the 4 5 1 combination.� The 3 2 1 combination does not distinguish shallow water from soil as well as the 7 5 3 combination does.
7,4,2	This combination provides a "natural-like" rendition, while also penetrating atmospheric particles and smoke.� Healthy vegetation will be a bright green and can saturate in seasons of heavy growth, grasslands will appear green, pink areas represent barren soil, oranges and browns represent sparsely vegetated areas.� Dry vegetation will be orange and water will be blue.� Sands, soils and minerals are highlighted in a multitude of colors.� This band combination provides striking imagery for desert regions.� It is useful for geological, agricultural and wetland studies.� If there were any fires in this image they would appear red.� This combination is used in the fire management applications for post-fire analysis of burned and non burned forested areas.� Urban areas appear in varying shades of magenta.� Grasslands appear as light green.� The light-green spots inside the city indicate grassy land cover - parks, cemeteries, golf courses.� Olive-green to bright-green hues normally indicate forested areas with coniferous forest being darker green than deciduous.
� � � � **4,5,1**	Healthy vegetation appears in shades of reds, browns, oranges and yellows.� Soils may be in greens and browns, urban features are white, cyan and gray, bright blue areas represent recently clearcut areas and reddish areas show new vegetation growth, probably sparse grasslands.� Clear, deep water will be very dark in this combination, if the water is shallow or contains sediments it would appear as shades of lighter blue.� For vegetation studies, the addition of the Mid-IR band increases sensitivity of detecting various stages of plant growth or stress; however care must be taken in interpretation if acquisition closely follows precipitation.� Use of TM 4 and TM 5 shows high reflectance in healthy vegetated areas.� It is helpful to compare flooded areas and red vegetated areas with the corresponding colors in the 3 2 1 combination to assure correct interpretation.� This is not a good band combination for studying cultural features such as roads and runways.
� � � **4,5,3**	This combination of near-IR (Band 4), mid-IR (Band 5) and red (Band 3) offers added definition of land-water boundaries and highlights subtle details not readily apparent in the visible bands alone.� Inland lakes and streams can be located with greater precision when more infrared bands are used.� With this band combination, vegetation type and condition show as variations of hues (browns, greens and oranges), as well as in tone.� The 4,5,3 combination demonstrates moisture differences and is useful for analysis of soil and vegetation conditions.� Generally, the wetter the soil, the darker it appears, because of the infrared absorption capabilities of water.
7,5,3	This band combination also provides a "natural-like" rendition while also penetrating atmospheric particles, smoke and haze.� Vegetation appears in shades of dark and light green during the growing season, urban features are white, gray, cyan or purple, sands, soils and minerals appear in a variety of colors.� The almost complete absorption of Mid-IR bands in water, ice and snow provides well defined coast lines and highlighted sources of water within the image.� Snow and ice appear as dark blue, water is black or dark blue.� Hot surfaces such as forest fires and volcano calderas saturate the Mid-IR bands and appear in shades of red or yellow.� One particular application for this combination is monitoring forest fires.� During seasons of little vegetation growth the 7 4 2 combination should be substituted.� Flooded areas should look very dark blue or black, compared with the 3 2 1 combination in which shallow flooded regions appear gray and are difficult to distinguish.
� � **5,4,3**	Like the 4 5 1 combination, this combination provides the user with a great amount of information and color contrast.� Healthy vegetation is bright green and soils are mauve.� While the 7 4 2 combination includes TM 7, which has the geological information, the 5 4 3 combination uses TM 5 which has the most agricultural information.� This combination is useful for vegetation studies, and is widely used in the areas of timber management and pest infestation.
5,4,1	This will look similar to the 7 4 2 combination in that healthy vegetation will be bright green, except the 5 4 1 combination is better for agricultural studies.
� **7,5,4**	This combination involves no visible bands.� It provides the best atmospheric penetration.� Coast lines and shores are well defined.� It may be used to find textural and moisture characteristics of soils.� Vegetation appears blue.� If the user prefers green vegetation, a 7 4 5 combination should be substituted.� This band combination can be useful for geological studies.
5,3,1	This combination display topographic textures while 7 3 1 may display differences in rock types.�

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Landsat Thematic Mapper (TM)

Band 1 (0.45 - 0.52u m): provides increased penetration of water bodies and also capable of differentiating soil and rock surfaces from vegetation and for detecting cultural features.

Band 2 (0.52 - 0.60u m): it is sensitive to water turbidity differences; it highlighted the turbid water in the Barkley Lake. Because it covers the green reflectance peak from leaf surfaces, it has separated vegetation (forest, croplands with standing crops) from soil. In this band barren lands urban areas and roads and highways have appeared as brighter (lighter) tone, but forest, vegetation, bare croplands, croplands with standing crops have appeared as dark (black) tone. Also the Kentucky Lake has

appeared as black tone.

Band 3 (0.63 - 0.69u m): senses in a strong chlorophyll absorption region and strong reflectance region for most soils. It has discriminated vegetation and soil. But it couldn�t separated water and forest. Forest land and water both have appeared as dark tone. This band has highlighted barren lands, urban areas, street pattern in the urban area and highways. It has also separated croplands with standing crops from bare croplands with stubble.

Band 4 (0.76 - 0.90u m): operates in the best spectral region to distinguish vegetation varieties and conditions. Because water is a strong absorber of near IR, this band has delineated water bodies (lakes and sinkholes), distinguished between dry and moist soils (barren land and croplands). In this band croplands and grasslands have showed higher reflectance (brighter tone) than the forest. This band has also separated croplands from bare croplands. Since standing crops (vegetation) has higher reflectance in the near IR region, they have appeared as brighter tone and due to presence of moisture content in the bare croplands, they have appeared as darker tone. In the band 4 barren lands, urban areas and highways have not been highlighted and they appeared as dark tone. Band 4 is useful for crop identification and emphasizes soil-crop and land-water contrast.

Band 5 (1.55 - 1.75u m): is sensitive to the turgidity or amount of water in plants. Band 5 has separated forest lands, croplands, water body distinctly. Forests have appeared as comparatively darker tone than the croplands (light gray).Band 5 has separated water body (dark tone) from barren lands, croplands, and grass lands (lighter tone). Since urban area and croplands have responded almost in same spectral reflectance band 5 could not be able to separate these areas.

Band 7 (2.08 -2.35u m): has separated land and water sharply. Band 7 has strong water absorption region and strong reflectance region for soil and rock. Urban area, croplands, highways, bare croplands have appeared as bright tone and water body, forest have appeared as dark tone.

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Ratio transformations of the remotely sensed data can be applied to reduce the effects of environment. �Ratios also provide unique information and subtle spectral-reflectance or color differences between surface materials that are often difficult to detect in a standard image. It is also useful for discriminating between soils and vegetation.

The number of possible ratio combinations for a multispectral sensor with P bands is n= P(P-1). �Thus for the TM�s six reflectance bands there are thirty different ratio combinations - 15 original and 15 reciprocal. For the purpose of this study ten band ratios were examined to identify the LULC features.

TM3/TM4: This ratio has defined barren lands and urban area uniquely. But it could not define water body, forests and croplands.

TM4/TM3: This ratio distinguished vegetation, water and croplands. It has enhanced forests, barren lands. Because forests or vegetation exhibits higher reflectance in near IR region (0.76 -0.90u m) and strong absorption in red region (0.63-0.69u m) region. This ratio uniquely defines the distribution of vegetation. The lighter the tone, the greater the amount of vegetation present.

TM5/TM7: This ratio separated land and water uniquely. Since soils exhibit strong absorption in the band 7 (2.08 -2.35u m) and high reflectance in band 5 (1.55 - 1.75u m), soil has been enhanced in this ratio. Land has appeared as lighter tone and water appeared as dark tone.

TM2/TM3: this ratio has distinguished croplands, barren lands sharply. But it hasn�t separated croplands, forests and water body. Both forests and water body has appeared as lighter tone and barren land appeared has dark tone. It did not enhance urban area. Chlorophyll has strong reflectance in the band 2 (0.52 -0.60u m) region and strong absorption in the band 3(0.63 -0.69u m) region, vegetation has appeared as higher tone.

TM3/TM2: This ratio has separated forests and croplands. Because band 3 (0.63-0.69m m) is the red chlorophyll absorption band of healthy green vegetation and band 2 (0.52-0.69m m) is the reflectance band from leaf surfaces. This ratio can be useful to discriminate broad classes of vegetation. Croplands have appeared as lighter (brighter) tone and forests appeared as dark tone.

TM4/TM5: It enhances the water body, vegetation and presence of moisture content in the croplands. Water body has appeared as dark tone and vegetation as lighter tone. Because water is a strong absorber in near IR region(band4) and higher reflectance in band 5 region. It can be useful for discriminating water bodies from land.

TM5/TM4: It has separated water body from forest, barren lands and vegetation. In this ratio water has appeared as dark tone and forest, barren lands, bare croplands all have exhibited brighter tone.

TM5/TM7: It has separated water body from lands (soils). It has also enhanced presence of moisture in croplands. All water bodies appeared as dark tone. Both band 5 and band 7 are sensitive to moisture content variation in soils and vegetation. This ratio is useful for crop-drought studies and plant vigor investigations.

TM3/TM5: This ratio enhances barren lands, highways, street patterns within the urban areas and urban built-up or cemented areas. It could not enhance the clear water but it enhanced turbid water. This ratio is useful for observing differences in water turbidity. Barren lands, highways, urban and built-up areas have appeared as lighter tone and forests, water body and croplands appeared as dark tone.

TM7/TM2: This ratio has separated forests and croplands. But it could not separated forests from water body; both features have appeared as dark tone. It enhances highways, urban and built-up areas and croplands and all of them have appeared as lighter tone.

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