UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 5 Examination in Engineering: October 2019

Module Number: CE5255 **Module Name: Remote Sensing and GIS**

[Three Hours]

[Answer all questions. Each question carries **TWELVE** marks]

All standard notations denote their regular meanings

State any assumptions made

Q1. a) The horizontal plate bubble of a theodolite was found to be off by an angle α. The theodolite was used to measures a horizontal angle (Z) which records the angle as z. Prove that the following relationship holds. (*Hint: model this problem as a spherical trigonometric problem*)

$$Sin^2(\alpha) = \frac{\cos(Z) - \cos(z)}{1 + \cos(Z)}$$

[3.0 Marks]

b) During the calibration process of the theodolite stated in Q1(a), several standard angles were measured using the theodolite. Table Q1-1 shows the values of the standard angle and the corresponding angle recorded by the theodolite. Determine the slope (α) of the horizontal plate bubble of the theodolite with the horizontal plane using a graphical method by adopting the equation given in Q1. (a) or by using the least square error method.

[2.0 Marks]

c) 'A' and 'K' are two GPS survey stations which are located at Adam's peak and Kirigalpotta peak having coordinates of 6° 48′41.62″N, 80° 29′59.10″E and 6° 47′57.69″N, 80° 46′ 00.78″E respectively. By using the earth curvature data pertaining to Everest 1830 datum given in Table Q1-2, answer the following questions.

i. Draw the rough locations of 'A' and 'K' in a grid and indicate $\mu\Delta L$, $\lambda\delta\phi$ and α_m.

ii. Determine the;

I. Mean latitude (φ_m) of points 'A' and 'K'

II. Correction due to convergence of meridians ($\delta\alpha$)

III. Length of the 1″ arc of latitude (λ) at the mean latitude

IV. Length of the 1″ arc of longitude (μ) at the mean latitude

V. Azimuth from A to K

VI. Reverse azimuth (i.e. From K to A)

[7.0 Marks]

Q2. a) Alnilam, a star in the constellation of Orion was observed from a survey peg station P1 on the ground with a theodolite on October 16th, 2019 at 8:00 pm GMT. The corrected altitude and azimuth of Alnilam were 50° 19′ 42″ and 80° 43′ 51″, respectively. Answer the following using the data given above and using the extract from the Star almanac given in Table Q2-1.

i. Draw a 3D view of the northern celestial hemisphere for a viewer located at a northerly latitude, as seen from the east indicating the positions of pole (P), zenith (Z), latitude (φ), and celestial equator (eq). Draw the path of a star which will not set (i.e. the path of a star which will be always above the observer's horizon). Using the figure, show that the stars having declinations greater than (90-φ) will not set.

ii. **Re-draw** the 3D view of the northern celestial hemisphere stated in Q2. (a) i to form a spherical triangle with nodes as pole, zenith, and the star Alnilam indicating all relevant values of the triangle.

iii. Using the spherical triangle formed in Q2. (a) ii, determine the hour angle of the star Alnilam with the northern arm of the local meridian (angle $Z\hat{P}A$).

iv. Draw a 2D view of the celestial hemisphere as seen from directly above the northern pole indicating all relevant points and determine the longitude of the point of observation.

v. Determine the local sidereal time of the observation

[9.0 Marks]

b) Determine the GMT when the star Alnilam will achieve the highest altitude (i.e. the GMT of the star crossing the local meridian).

[3.0 Marks]

Q3. a) A tower 'Δh' meter high is built on a ground 'h' meters above the datum is imaged in a vertical aerial photograph. If the image of the top of the tower is 'a', bottom of the tower is 'b' centre of the photo is 'o' and flying height is 'H' meters above the datum, show that the height of the tower is given by:

$$\Delta h = (H - h)\frac{ab}{ob}$$

[3.0 Marks]

b) Prove that the photo coordinates of a point 'a' (x_a, y_a) of a vertical aerial photo are related to its ground coordinates (X_A, Y_A) with usual notations by:

$$X_A = \frac{(H - h_A)}{f}\, x_a \qquad \text{and} \qquad Y_A = \frac{(H - h_A)}{f}\, y_a$$

[2.0 Marks]

c) Use the data shown in Table Q3-1 for two towers X and Y which are imaged on a vertical aerial photograph taken while flying 1000 m above the datum to answer the following questions. Assume a camera focal length of 150 mm. Determine;

i. the height of the towers X and Y.
ii. the ground coordinates of the towers X and Y.
iii. the ground distance between the towers X and Y.
iv. whether the top of the tower X will be visible above the top of the tower Y when the towers are observed from a point Z (h_z=200.00 m) located 400 m away from Y in the extended XY line.

[7.0 Marks]

Q4. The Sun is the energy source used in many of the remote sensing applications. Although the Sun emits Electro-Magnetic (EM) waves having wavelengths from 250 nm to 2500 nm, only limited portions of EM spectrum can be used for remote sensing applications. The usable region of the EM spectrum is called the atmospheric window is divided into bands.

a) Explain why only limited portions of EM spectrum are available for remote sensing applications.

[2.0 Marks]

b) Describe how the usable portion of the EM spectrum is divided into several bands in order to enable the identification of different objects.

[3.0 Marks]

c) Figure Q4-1 shows the matrix representation of a part of the raster data obtained, for bands 3, 4 and 5 of Landsat-8 (refer Table Q4-1), over a forested area. Values in the matrix indicate the reflectance value for the particular band for the relevant pixel. Answer the following questions based on the data provided.

i. If the spatial resolution of the Lansat-8 bands is 30 m, determine the area covered by the data given in Figure Q4-1.
ii. Using spectral reflection curves of green and dry vegetation (Figure Q4-2), explain how NDVI can be used to differentiate green and dry vegetation.
iii. Determine $MSAVI_2$ values for the part of the raster data given in Figure Q4-1.
iv. Determine the NDVI values for the part of the raster data given in Figure Q4-1.

[7.0 Marks]

Q5. a) Explain the difference between GIS and GNSS (GPS).

[3.0 Marks]

b) List the equipment needed to perform a 'kinematic' GNSS surveying.

[2.0 Marks]

c) Compare and contrast the kinematic GNSS surveying with detailing survey carried out with a total station.

[4.0 Marks]

d) Outline the process of calculating NDVI using LANDSAT-8 raster data in the ArcGIS environment.

[3.0 Marks]

ANNEX: Figures, Tables and Equations

$$L = \frac{\lambda\delta\phi}{\mathrm{Cos}\left(\alpha_m + \frac{\delta\alpha}{2}\right)}$$

$$\varphi_m = \frac{\varphi_A + \varphi_B}{2}$$

$$r = -58\cot(H_O)$$

$$\mathrm{BC}^2 = \mathrm{AB}^2 + \mathrm{AC}^2 - 2\mathrm{AB} \times \mathrm{AC}\ \mathrm{CosA}$$

$$\delta\alpha = \Delta \mathrm{L} \sin(\varphi_m)$$

$$H = H_o + r$$

$$GSrT = RA - \lambda_E$$

$$\mathrm{CosA} = \frac{\mathrm{Cos}\ a - \mathrm{Cos}\ (b) \times \mathrm{Cos}\ (c)}{\mathrm{Sin}\ (b) \times Sin\ (c)}$$

$$\alpha_m = \tan^{-1}\left[\frac{\mu\Delta L}{\lambda\delta\phi}\right]$$

$$Sin(A + B) = Sin(A)Cos(B) + Cos(A)Sin(B)$$

$$NDVI = \frac{NIR - Red}{NIR + Red}$$

$$RA^h = (360 - SHA)/15^{\circ}$$

$$MSAVI_2 = \frac{\left(2 \times NIR + 1 - \sqrt[2]{(2 \times NIR + 1)^2 - 8 \times (NIR - RED)}\right)}{2}$$

Table Q1-1 Standard value of the angel and the measured value

No	Standard Angle	Measured Angle
1	120°00′00″	120°01′23″
2	100°00′00″	100°02′00″
3	90°00′00″	90°02′23″
4	70°00′00″	70°03′25″
5	60°00′00″	60°04′08″

Table Q1-2 Earth curvature data based on Everest 1830 datum

At Latitude	Length of 1" of Longitude (m)	Length of 1" of Latitude (m)
6° 40′ 00″	30.707599	30.916646
7° 00′ 00″	30.686059	30.916506

Table Q2-1 Extract from the Star almanac for year 2019

October 16, 17 ,18 (Wed., Thu., Fri.)

	Aries	Venus		Mars		Jupiter		Saturn	
Wed	GHA	GHA	Dec	GHA	Dec	GHA	Dec	GHA	Dec
0	24°13.3	167°25.8	S14°09.2	196°51.6	S02°11.1	124°34.2	S22°52.1	98°27.8	S22°29.3
1	39°15.8	182°25.2	10.3	211°52.6	11.8	139°36.2	52.1	113°30.2	29.3
2	54°18.3	197°24.7	11.4	226°53.6	12.4	154°38.2	52.1	128°32.5	29.3
3	69°20.7	212°24.1	·· 12.5	241°54.6	·· 13.1	169°40.2	·· 52.2	143°34.8	·· 29.3
4	84°23.2	227°23.6	13.6	256°55.6	13.7	184°42.2	52.2	158°37.2	29.3
5	99°25.7	242°23.1	14.6	271°56.6	14.4	199°44.3	52.2	173°39.5	29.3
6	114°28.1	257°22.5	S14°15.7	286°57.5	S02°15.0	214°46.3	S22°52.3	188°41.9	S22°29.3
7	129°30.6	272°22.0	16.8	301°58.5	15.7	229°48.3	52.3	203°44.2	29.3
8	144°33.1	287°21.4	17.9	316°59.5	16.3	244°50.3	52.3	218°46.6	29.2
9	159°35.5	302°20.9	·· 19.0	332°00.5	·· 17.0	259°52.3	·· 52.4	233°48.9	·· 29.2
10	174°38.0	317°20.3	20.0	347°01.5	17.6	274°54.3	52.4	248°51.2	29.2
11	189°40.4	332°19.8	21.1	2°02.5	18.3	289°56.3	52.4	263°53.6	29.2
12	204°42.9	347°19.2	S14°22.2	17°03.4	S02°18.9	304°58.3	S22°52.5	278°55.9	S22°29.2
13	219°45.4	2°18.7	23.3	32°04.4	19.6	320°00.3	52.5	293°58.3	29.2
14	234°47.8	17°18.1	24.3	47°05.4	20.2	335°02.4	52.5	309°00.6	29.2
15	249°50.3	32°17.6	·· 25.4	62°06.4	·· 20.9	350°04.4	·· 52.6	324°03.0	·· 29.2
16	264°52.8	47°17.1	26.5	77°07.4	21.5	5°06.4	52.6	339°05.3	29.2
17	279°55.2	62°16.5	27.6	92°08.3	22.1	20°08.4	52.7	354°07.6	29.2
18	294°57.7	77°16.0	S14°28.6	107°09.3	S02°22.8	35°10.4	S22°52.7	9°10.0	S22°29.2
19	310°00.2	92°15.4	29.7	122°10.3	23.4	50°12.4	52.7	24°12.3	29.2
20	325°02.6	107°14.9	30.8	137°11.3	24.1	65°14.4	52.8	39°14.7	29.1
21	340°05.1	122°14.3	·· 31.9	152°12.3	·· 24.7	80°16.4	·· 52.8	54°17.0	·· 29.1
22	355°07.5	137°13.8	32.9	167°13.2	25.4	95°18.4	52.8	69°19.3	29.1
23	10°10.0	152°13.2	34.0	182°14.2	26.0	110°20.4	52.9	84°21.7	29.1
Mer.pass.:22:19		v-0.5 d-1.1 m-3.8		v1.0 d-0.6 m1.8		v2.0 d-0.0 m-1.8		v2.3 d0.0 m0.5	

Thu	GHA	GHA	Dec	GHA	Dec	GHA	Dec	GHA	Dec
0	25°12.5	167°12.7	S14°35.1	197°15.2	S02°26.7	125°22.4	S22°52.9	99°24.0	S22°29.1
1	40°14.9	182°12.1	36.1	212°16.2	27.3	140°24.5	52.9	114°26.4	29.1
2	55°17.4	197°11.6	37.2	227°17.2	28.0	155°26.5	53.0	129°28.7	29.1
3	70°19.9	212°11.0	·· 38.3	242°18.2	·· 28.6	170°28.5	·· 53.0	144°31.0	·· 29.1
4	85°22.3	227°10.4	39.3	257°19.1	29.3	185°30.5	53.0	159°33.4	29.1
5	100°24.8	242°09.9	40.4	272°20.1	29.9	200°32.5	53.1	174°35.7	29.1
6	115°27.3	257°09.3	S14°41.5	287°21.1	S02°30.6	215°34.5	S22°53.1	189°38.1	S22°29.1
7	130°29.7	272°08.8	42.5	302°22.1	31.2	230°36.5	53.1	204°40.4	29.1
8	145°32.2	287°08.2	43.6	317°23.1	31.9	245°38.5	53.2	219°42.7	29.0
9	160°34.7	302°07.7	·· 44.7	332°24.0	·· 32.5	260°40.5	·· 53.2	234°45.1	·· 29.0
10	175°37.1	317°07.1	45.7	347°25.0	33.2	275°42.5	53.2	249°47.4	29.0
11	190°39.6	332°06.6	46.8	2°26.0	33.8	290°44.5	53.3	264°49.8	29.0
12	205°42.0	347°06.0	S14°47.9	17°27.0	S02°34.5	305°46.5	S22°53.3	279°52.1	S22°29.0
13	220°44.5	2°05.4	48.9	32°28.0	35.1	320°48.5	53.4	294°54.4	29.0
14	235°47.0	17°04.9	50.0	47°28.9	35.8	335°50.5	53.4	309°56.8	29.0
15	250°49.4	32°04.3	·· 51.1	62°29.9	·· 36.4	350°52.5	·· 53.4	324°59.1	·· 29.0
16	265°51.9	47°03.8	52.1	77°30.9	37.1	5°54.5	53.5	340°01.4	29.0
17	280°54.4	62°03.2	53.2	92°31.9	37.7	20°56.6	53.5	355°03.8	29.0
18	295°56.8	77°02.6	S14°54.2	107°32.9	S02°38.4	35°58.6	S22°53.5	10°06.1	S22°29.0
19	310°59.3	92°02.1	55.3	122°33.8	39.0	51°00.6	53.6	25°08.5	28.9
20	326°01.8	107°01.5	56.3	137°34.8	39.7	66°02.6	53.6	40°10.8	28.9
21	341°04.2	122°01.0	·· 57.4	152°35.8	·· 40.3	81°04.6	·· 53.6	55°13.1	·· 28.9
22	356°06.7	137°00.4	58.5	167°36.8	40.9	96°06.6	53.7	70°15.5	28.9
23	11°09.2	151°59.8	59.5	182°37.8	41.6	111°08.6	53.7	85°17.8	28.9
Mer.pass.:22:15		v-0.6 d-1.1 m-3.8		v1.0 d-0.6 m1.8		v2.0 d-0.0 m-1.8		v2.3 d0.0 m0.5	

Fri	GHA	GHA	Dec	GHA	Dec	GHA	Dec	GHA	Dec
0	26°11.6	166°59.3	S15°00.6	197°38.7	S02°42.2	126°10.6	S22°53.7	100°20.1	S22°28.9
1	41°14.1	181°58.7	01.6	212°39.7	42.9	141°12.6	53.8	115°22.5	28.9
2	56°16.5	196°58.1	02.7	227°40.7	43.5	156°14.6	53.8	130°24.8	28.9
3	71°19.0	211°57.6	·· 03.7	242°41.7	·· 44.2	171°16.6	·· 53.8	145°27.1	·· 28.9
4	86°21.5	226°57.0	04.8	257°42.7	44.8	186°18.6	53.9	160°29.5	28.9
5	101°23.9	241°56.5	05.8	272°43.6	45.5	201°20.6	53.9	175°31.8	28.9
6	116°26.4	256°55.9	S15°06.9	287°44.6	S02°46.1	216°22.6	S22°53.9	190°34.1	S22°28.8
7	131°28.9	271°55.3	07.9	302°45.6	46.8	231°24.6	54.0	205°36.5	28.8
8	146°31.3	286°54.8	09.0	317°46.6	47.4	246°26.6	54.0	220°38.8	28.8
9	161°33.8	301°54.2	·· 10.0	332°47.6	·· 48.1	261°28.6	·· 54.0	235°41.1	·· 28.8
10	176°36.3	316°53.6	11.1	347°48.5	48.7	276°30.6	54.1	250°43.5	28.8
11	191°38.7	331°53.0	12.1	2°49.5	49.4	291°32.6	54.1	265°45.8	28.8
12	206°41.2	346°52.5	S15°13.2	17°50.5	S02°50.0	306°34.6	S22°54.2	280°48.1	S22°28.8
13	221°43.7	1°51.9	14.2	32°51.5	50.7	321°36.6	54.2	295°50.5	28.8
14	236°46.1	16°51.3	15.3	47°52.5	51.3	336°38.6	54.2	310°52.8	28.8
15	251°48.6	31°50.8	·· 16.3	62°53.4	·· 52.0	351°40.6	·· 54.3	325°55.2	·· 28.8
16	266°51.0	46°50.2	17.4	77°54.4	52.6	6°42.6	54.3	340°57.5	28.8
17	281°53.5	61°49.6	18.4	92°55.4	53.3	21°44.6	54.3	355°59.8	28.7
18	296°56.0	76°49.1	S15°19.5	107°56.4	S02°53.9	36°46.6	S22°54.4	11°02.2	S22°28.7
19	311°58.4	91°48.5	20.5	122°57.3	54.5	51°48.6	54.4	26°04.5	28.7
20	327°00.9	106°47.9	21.5	137°58.3	55.2	66°50.6	54.4	41°06.8	28.7
21	342°03.4	121°47.3	·· 22.6	152°59.3	·· 55.8	81°52.6	·· 54.5	56°09.1	·· 28.7
22	357°05.8	136°46.8	23.6	168°00.3	56.5	96°54.6	54.5	71°11.5	28.7
23	12°08.3	151°46.2	24.7	183°01.3	57.1	111°56.6	54.5	86°13.8	28.7
Mer.pass.:22:11		v-0.6 d-1.1 m-3.8		v1.0 d-0.6 m1.8		v2.0 d-0.0 m-1.8		v2.3 d0.0 m0.5	

Stars	SHA	Dec
Alpheratz	357°38.7	29°12.1
Ankaa	353°11.0	-42°12.0
Schedar	349°35.1	56°38.8
Diphda	348°51.1	-17°52.7
Achernar	335°22.9	-57°08.3
Hamal	327°55.6	23°33.3
Polaris	315°27.7	89°20.6
Akamar	315°14.6	-40°13.5
Menkar	314°10.2	4°10.0
Mirfak	308°33.7	49°55.7
Aldebaran	290°44.2	16°32.9
Rigel	281°07.7	-8°10.7
Capella	280°27.8	46°00.9
Bellatrix	278°27.2	6°22.0
Elnath	278°07.0	28°37.3
Alnilam	275°41.8	-1°11.4
Betelgeuse	270°56.5	7°24.6
Canopus	263°54.1	-52°42.1
Sirius	258°29.7	-16°44.3
Adara	255°09.1	-28°59.8
Procyon	244°55.1	5°10.6
Pollux	243°22.4	27°58.6
Avior	234°16.4	-59°34.0
Suhail	222°49.4	-43°30.4
Miaplacidus	221°39.2	-69°47.5
Alphard	217°52.0	-8°44.5
Regulus	207°39.1	11°52.3
Dubhe	193°46.9	61°38.6
Denebola	182°29.5	14°27.9
Gienah	175°48.1	-17°38.8
Acrux	173°05.2	-63°12.2
Gacrux	171°56.7	-57°13.1
Alioth	166°17.4	55°51.3
Spica	158°27.0	-11°15.6
Alcaid	152°55.9	49°13.1
Hadar	148°42.4	-60°27.9
Menkent	148°02.9	-36°27.8
Arcturus	145°52.0	19°05.3
Rigil Kent.	139°46.5	-60°54.8
Zubenelg.	137°01.0	-16°07.2
Kochab	137°21.1	74°04.7
Alphecca	126°07.7	26°39.2
Antares	112°21.2	-26°28.4
Atria	107°19.5	-69°03.8
Sabik	102°07.8	-15°44.8
Shaula	96°16.3	-37°07.0
Rasalhague	96°02.6	12°33.1
Eltanin	90°44.4	51°29.6
Kaus Aust.	83°38.2	-34°22.4
Vega	80°36.2	38°48.4
Nunki	75°53.1	-26°16.3
Altair	62°04.1	8°55.4
Peacock	53°12.3	-56°40.4
Deneb	49°28.5	45°21.4
Enif	33°42.7	9°58.1
Alnair	27°38.0	-46°52.0
Fomalhaut	15°19.0	-29°31.1
Scheat	13°49.0	28°11.5
Markab	13°33.8	15°18.8

Oct 16 Wed	SHA	Mer.pass
Venus	143°12.4	12:51
Mars	172°38.3	10:52
Jupiter	100°20.9	15:40
Saturn	74°14.5	17:23

Oct 17 Thu	SHA	Mer.pass
Venus	142°00.2	12:52
Mars	172°02.7	10:50
Jupiter	100°10.0	15:36
Saturn	74°11.5	17:20

Oct 18 Fri	SHA	Mer.pass
Venus	140°47.7	12:53
Mars	171°27.1	10:49
Jupiter	99°59.0	15:33
Saturn	74°08.5	17:16

Horizontal parallax	
Venus:	0.1
Mars:	0.1

Table Q3-1 Data related to towers X and Y

Name of Tower	Elevation of base (m)	Photo coordinates			
		Base		Top	
		x (mm)	y (mm)	x (mm)	y (mm)
X	120.10	20.50	31.60	25.10	37.10
Y	97.56	15.60	-23.80	19.30	-29.44

Band 3-Green

$$\begin{bmatrix} \ddots & & & & \\ & 530 & 634 & 800 & \\ & 490 & 410 & 430 & \\ & 620 & 542 & 580 & \\ & & & & \ddots \end{bmatrix}$$

Band 4-Red

$$\begin{bmatrix} \ddots & & & & \\ & 300 & 340 & 320 & \\ & 190 & 180 & 220 & \\ & 321 & 132 & 184 & \\ & & & & \ddots \end{bmatrix}$$

Band 5-NIR

$$\begin{bmatrix} \ddots & & & & \\ & 1820 & 1760 & 1408 & \\ & 1830 & 1901 & 1850 & \\ & 1860 & 1800 & 1800 & \\ & & & & \ddots \end{bmatrix}$$

Figure Q4-1 Parts of 8-bit raster data for different bands (values indicate raw reflectance values)

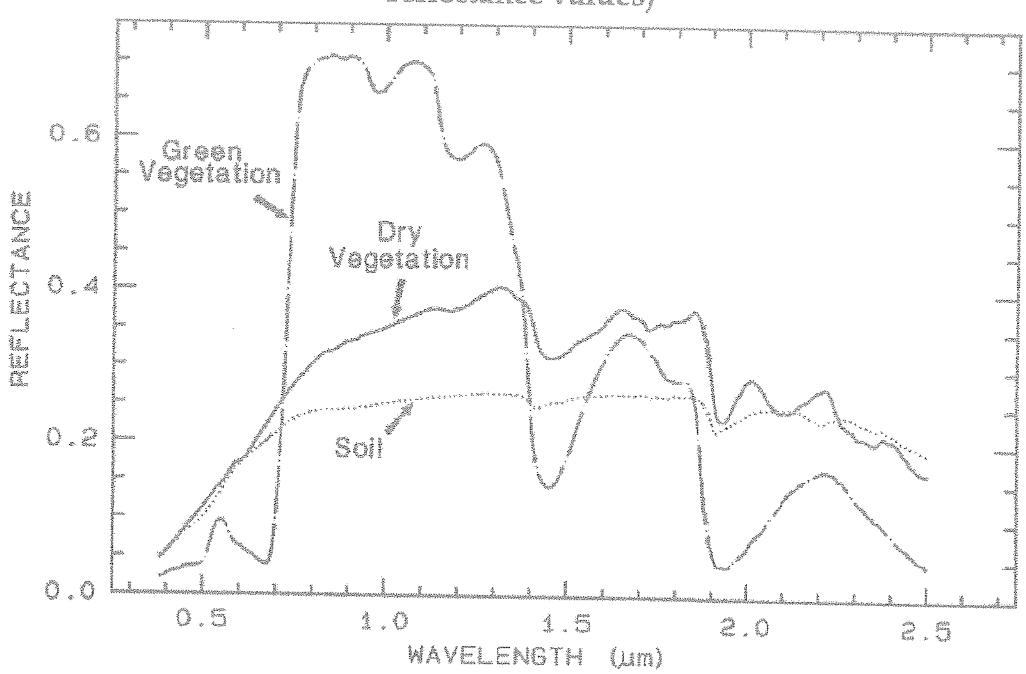

Figure Q4-2 Spectral reflectance curves for green vegetation and dry vegetation

Table Q4-1 Bands of Landsat-8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS)

Band	Wavelength (μm)	Useful for mapping
Band 1 – Coastal Aerosol	0.43 - 0.45	Coastal and aerosol studies
Band 2 – Blue	0.45 - 0.51	Bathymetric mapping, distinguishing soil from vegetation, and deciduous from coniferous vegetation
Band 3 - Green	0.53 - 0.59	Emphasizes peak vegetation, which is useful for assessing plant vigour
Band 4 - Red	0.64 - 0.67	Discriminates vegetation slopes
Band 5 - Near Infrared (NIR)	0.85 - 0.88	Emphasizes biomass content and shorelines
Band 6 - Short-wave Infrared (SWIR) 1	1.57 - 1.65	Discriminates moisture content of soil and vegetation; penetrates thin clouds
Band 7 - Short-wave Infrared (SWIR) 2	2.11 - 2.29	The improved moisture content of soil and vegetation and thin cloud penetration
Band 8 - Panchromatic	0.50 - 0.68	15-meter resolution, sharper image definition
Band 9 – Cirrus	1.36 - 1.38	Improved detection of cirrus cloud contamination
Band 10 – TIRS 1	10.60 – 11.19	100-metre resolution, thermal mapping and estimated soil moisture
Band 11 – TIRS 2	11.5 - 12.51	100-metre resolution, Improved thermal mapping and estimated soil moisture