Dirasat, Human and Social Sciences, Volume 46, No. 1, Supplement 2, 2019

GIS and Remote Sensing-based Evaluation of Vegetation Diversity due to Topography in Semi-Arid Environment

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ABSTRACT

This study aims at investigating the possible relation between topography and the spatial distribution of vegetation cover within a semi-arid environment in Irbid region, Jordan. To accomplish this, various topographic variables including elevation, slope, and aspect; and land cover distribution within the study area are used. The methodology comprised a spatial analysis of digital elevation data (i.e., ASTER-GDEM) and remote sensing data (i.e., Landsat8 images). In terms of vegetation cover distribution; (the same before) five major types including: forest, field crops, vegetables, tree crops, and pastures were identified.Through the results, (the same before) a strong relation between topography and vegetation cover diversity in Irbid governorate could be identified. Several environmental factors are proposed that might overprint the topography-vegetation cover association. Overall, this study expands the geographic context of the link between topography and vegetation cover in semi-arid environment, while also demonstrating the utility of remote sensing and GIS in environmental modeling.

Keywords: Spatial analysis; NDVI; DEM; topography; land use.

Introduction

Understanding vegetation variation of a landscape or region is among the most fundamental aspects in environmental studies (Yavitt et al. 2009; Lennon et al. 2011, Zhang et al., 2013). Physical geographers and ecologists have successfully related changes in vegetation types to environmental gradients at different spatial scales including local, regional, and global scales (Basnet 1992; Porembski et al. 1995; Chen et al. 1997; Härdtle et al. 2005; Wang et al. 2009; Pajunen et al. 2010; Zhuang et al. 2012). Perhaps, with larger scales (e.g., global or regional) climatological elements are the most influencing factors on vegetation distribution (Jarema et al. 2009). However, at local scales (e.g., catchment, hilly landscape) topographic factors are the major ones (Itoh et al. 2003; Cui et al. 2009). As they might act through microclimate and soil properties (John et al. 2007; Yavitt et al. 2009). In addition, such topographic factors might provide insight into the environmental requirements for the successful growth of vegetation species and plantations process at small scales (Toledo et al. 2012).

Among the topographic factors, elevation, aspect, and slope were found to have superior influence and control on the distribution, patterns and types of vegetation in terrain areas (Coblentz and Keating, 2008; Zhao et al., 2010; Wang et. al., 2015). For instance, aspects have critical effects on the incident solar radiation on a surface (McCune and Kean, 2002), where surface facing north in the northern hemisphere receives less irradiance, thus; it experiences cooler temperature and more moisture microclimate; and vice versa for southern oriented surfaces (Ahrens, 2008). On the other side, slope affects vegetation growth and distribution as steeper surfaces experience greater runoff comparing to flat surfaces which tends to conserve moisture (Bennie et al., 2008; Zhang et al., 2013). Elevation affects near surface temperature, surface temperature and soil moisture (Coblentz and Riitters, 2004; Bennie et al., 2008). Furthermore, ruggedness (i.e., horizontal change of elevation fluctuations) results in a potential greater vegetation diversity as it creates a patch-like distribution of vegetation types (Coblentz and Riitters, 2004; Pérez et al., 2008). In general, the above mentioned topographic parameters have been found to have greater effects on microclimates at mid-to-high

* Faculty of Arts, Yarmouk University, Jordan. Received on 30/10/2017 and Accepted for Publication on 6/9/2018.

latitudes due to greater variation and distribution of incoming solar radiation (Coblentz and Riitters, 2004; Bennie et al., 2008). It is worth mentioning that other factors such as land use changes, natural disasters (e.g., flood, drought, landslide) might affect vegetation distribution. However, studies suggested that topographic variability, especially in mid-to-high latitudes, attributed vegetation distribution (e.g., Hoersch et al., 2002; Coblentz and Riitters, 2004; Hofer et al., 2008; Pérez et al., 2008; Lowe et al., 2012).

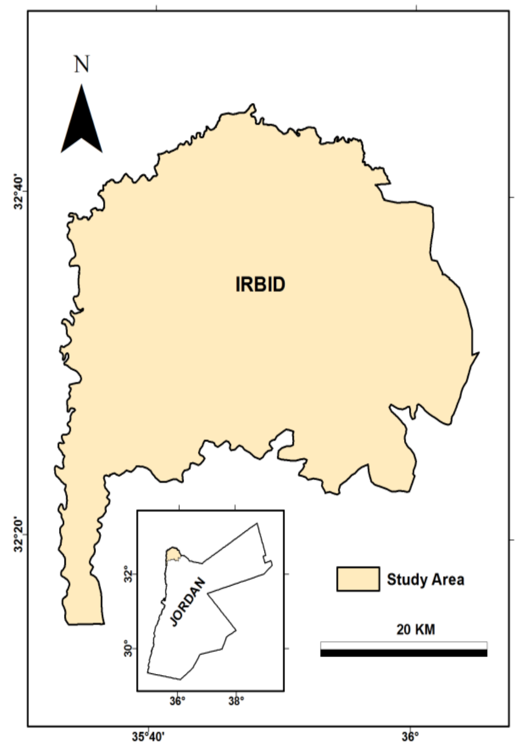
Topographic factors along with land cover information can be readily computed with the improved digital terrain and remote sensing data and geographical information systems. Such improvements - in comparison to field and conventional methods - supported the quantitative and qualitative evaluation of association between topography and vegetation distribution (Kerr et al., 2001; Coblentz and Riitters, 2004; Pérez et al., 2008). To date, several studies have been conducted to evaluate and understand the relation between topography and vegetation and plantation in various aspects including plant growth, forest productivity and plant species (Mokarram and Sathyamoorthy 2015; Laamrani et al., 2014; Garca-Aguirre et al.,2007). In some studies, one main topographic factor was found to be the major controlling factor of vegetation distribution for specific locations. For example, plantation in various aspects including plant growth, forest productivity and plant species Matsuura and Suzuki, (2013) found that elevation was the main factor in the Oide River watershed in Japan. Davies et al., (2007) and Lin et al., (2014) found that slope was the only factor correlated plant species in southeastern Oregon in USA; and in Jinsha River valley in China, respectively. Other researchers figured two or more topographic factors related to vegetation distribution, such as wetness and aspect in a dry warm river valley, in southwestern China (Xu et al., 2008); elevation and slope in the Atlantic Rainforest in southeastern Brazil (Eisenlohr et al., 2013); elevation and aspect in a deciduous forest in Beijing, China (Fu et al., 2004); and elevation, slope, and aspect in moist forest of Wondo Genet, in south central Ethiopia (Kebede et al., 2013).These example studies showed that topographic effects on vegetation distribution might widely vary through different environments. Therefore, this type of approach has yet to be applied to improve vegetation cover and plantation process management for sustainable development, especially; in regions with terrain and environmental variations and limited natural resources.

In Jordan, as a semi- arid environment with very limited natural and water resources; the process of managing natural vegetation and plantation process received major concerns by both the governmental and private sectors. Jordan is naturally divided into three major geographical regions with more than 88% of desert and semi-desert (Badia). The northwestern part of the country is constructed of very contrast terrain and contained the major green land cover including forested and agricultural areas. This area has significant role on country’s environmental, agricultural and economical activates. This study presented a quantitative and qualitative geospatial analysis of topographic effects on vegetation and plantation diversity. In addition, it determined to which degree the topography control land cover in the northwest region of Jordan by considering Irbid governorate as our case study.

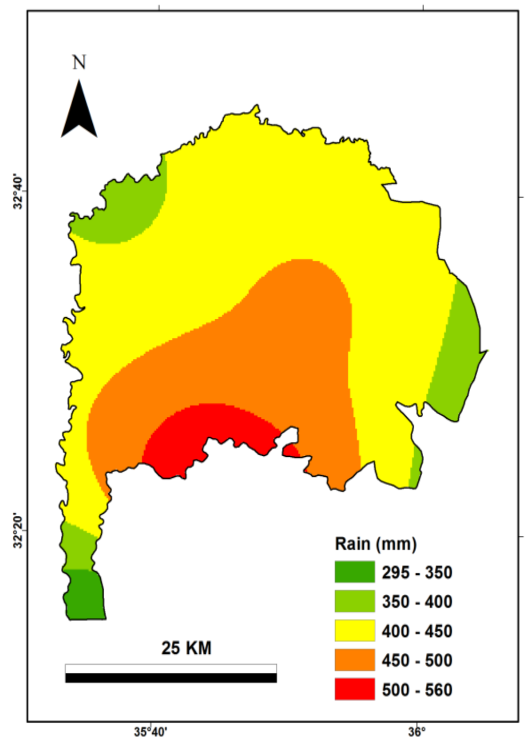
2. MATERIALS AND METHODS

2.1 Study Area

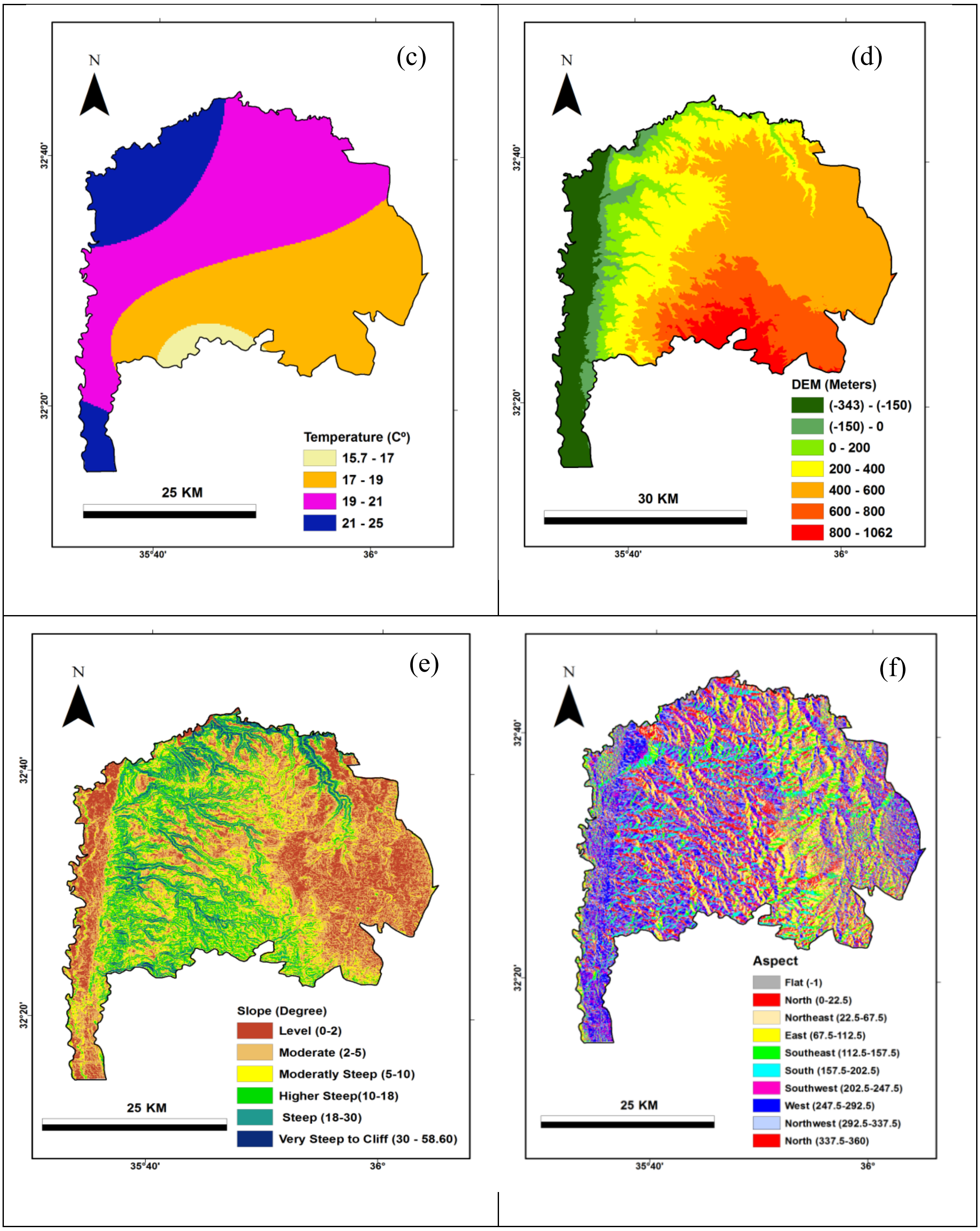
The study area is Irbid governorate which is located in the Northwestern part of Jordan / Middle East as our study area (see Figure 1a). The area is about 1577 km^2 and located between 32° 75' to 32° 24' north and 36° 08' to 35° 54' east, covering approximately 2% of Jordan. It includes the main agricultural practices including both rainfed and irrigated plantations. In this area, the growing season of rainfed agriculture usually starts in November and ends in June. The major crops include cereals such as wheat, barley, and lentil; grasslands and rangelands; and orchards such as olives and fruit trees. The irrigated areas are planted around the year due to the use of irrigation and greenhouse agriculture practices with concentrating on vegetable crops such tomato, cabbage, pepper and cauliflower, and others; and fruit trees such as citrus and bananas. In terms of topography, the study area has a complex terrain with elevation vary between -343 m in the western part and 1062 m in the southern parts above mean sea level within less than 50 km transect. Slopes vary between 0-58^o, where the plain surfaces with slopes less than 2^o occupy the western parts (i.e., the alluvial plains of Jordan river), and the eastern parts (i.e., Irbid-Horan plains). The land surfaces with slope greater than 50º are found in the mountainous region. Aspects are mainly north and northwest oriented (see Figures 1b, c, and d, for elevation, slope, and aspects, respectively). Climatologically, the area is dominated by a semi-arid climate regime, with mean annual minimum and maximum temperature between 16ºC and 25ºC, respectively. The long-term analysis of rainfall showed that the area receives approximately 420 mm annually (i.e., 280 mm minimum to 560 mm maximum averages) between September and May with major concentration in December to February(see Figures 1e, and f, for rainfall and temperature annual averages, respectively). Also, it showed variations in rainfall distribution and density which affected agricultural and other vegetation practices (Al-Salihi 2003, Al-Qinna et al., 2011, and, Hazaymeh and Hassan, in press). In terms of soil and geology, the study area consisted of 15 soil units that varies in their chemical and physical properties and distribution due to topography and other factors (see Figure 1g and Table 1 for details); and four major geological compositions (see figure 1h) (Ministry of Agriculture 1993). The land cover and land use consisted of four major types such as build-up area (i.e., 4 %), rock and barren lands (i.e., 10 %), water bodies (i.e., 2 %) and vegetation cover and agriculture (i.e., 84%)(see Figures 1i, j).



(a)



(b)


(c)
N
32°40'
32°20'
35°40'
36°
Temperature (C°)
15.7 - 17
17 - 19
19 - 21
21 - 25
25 KM
(d)
N
DEM (Meters)
(-343) - (-150)
(-150) - 0
0 - 200
200 - 400
400 - 600
600 - 800
800 - 1062
30 KM
(e)
N
Slope (Degree)
Level (0-2)
Moderate (2-5)
Moderatly Steep (5-10)
Higher Steep(10-18)
Steep (18-30)
Very Steep to Cliff (30 - 58.60)
25 KM
(f)
N
Aspect
Flat (-1)
North (0-22.5)
Northeast (22.5-67.5)
East (67.5-112.5)
Southeast (112.5-157.5)
South (157.5-202.5)
Southwest (202.5-247.5)
West (247.5-292.5)
Northwest (292.5-337.5)
North (337.5-360)
25 KM

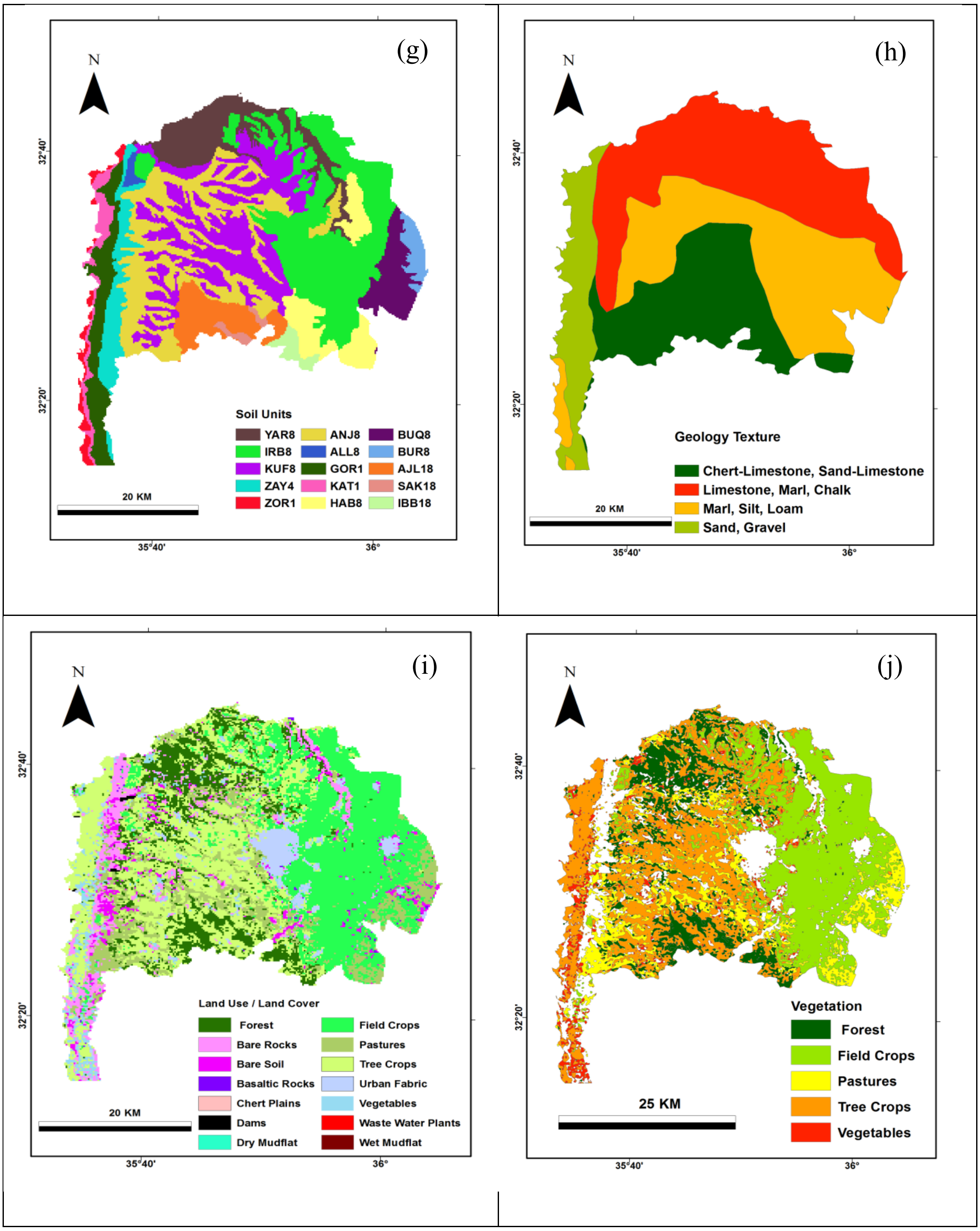


Figure1: (a) location of the study area, (b) rainfall, (c) temperature, (d) elevation, (e) slope (f) aspect, (g) soil units, (h) geology, (i) land use and land cover, and (j) vegetation cover.

2.2 Methods

Figure 2 shows a schematic diagram of the general framework of this study. Here, two remote sensing datasets were obtained such as: (i) Landsat-8 surface reflectance data freely available from United States Geological Survey (USGS) during the growing seasons 2014-2016; and (ii) ASTER GDEM data freely available from NASA. For Landsat-8 images, there were seven and nine free cloud images available during the growing seasons 2014-15 and

2015-16 respectively, then the images were subset to the boundary of the study area. Note that all images were quality checked by employing the Landsat-8 quality assessment (QA) band for determining the cloud-contaminated pixels; and excluded them from further analysis.After that, the normalized difference vegetation index (NDVI) for each image was calculated using equation (1) to be used as input variables to the supervised classification process of land cover and land use types. Then field surveying was performed to identify vegetation cover types in major details such as forest, field crops, pastures, tree crops, and vegetables and used them as training sites to perform a supervised classification based on maximum likelihood classification (MLC) model (Jensen 2007). Finally, the accuracy of the land cover map was assessed using confusion matrix measurements.

$$NDVI = \frac{\rho_{NIR} - \rho_{R}}{[illegible]} \quad (1)$$

Where, ρ is the surface reflectance value of red (R) and near infrared (NIR) red.

For ASTER GDEM data, one image covering the northern part of Jordan and was obtain, then a subset of the image within the boundaries of the study area was performed Then, spatial analysis tools were employed to create elevation, slope, and aspect maps of the study area. Upon generating the required dataset (i.e., vegetation types, and topographic variables), a spatial overlay analysis was applied and evaluated the relationship between the distribution of vegetation cover types and topographical variables. This step was performed through applying a spatial join function which allows for joining the attributes from one feature to another based on the spatial relationship.

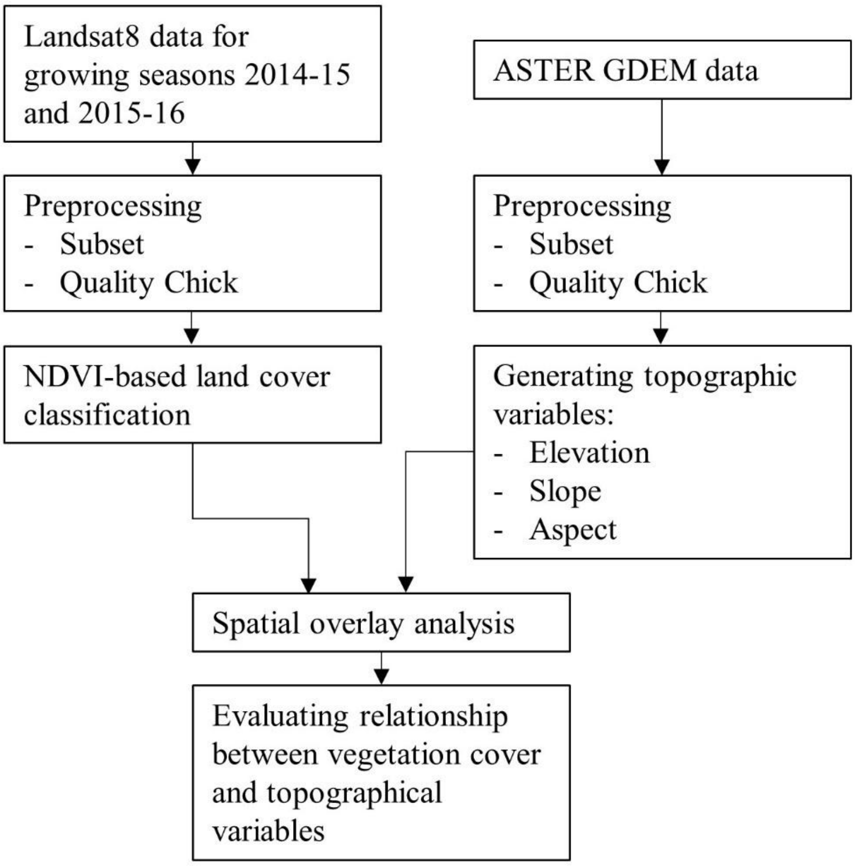


Figure (2): Schematic diagram of methodology flowchart

3. RESULTS

3.1 Vegetation cover types and topographic variables categories

Using MLC-based NDVI images, vegetation cover was mapped, and five vegetation types were identified namely forest 14 %, field crops 32 %, pastures 15 %, tree crops 34 %, and vegetables 4 % (see figure 1j). Results of accuracy assessment revealed moderate to strong agreement between classified maps and reference dataset (i.e., 82% overall accuracy, 70-100% user's accuracy, 73-100% producer's accuracy, and 78% Kappa coefficient). Table (1) shows the details of the confusion matrix of the classification process.

Table (1): Confusion matrix of the maximum likelihood classification process.

Class Name	Forest	Field crops	Pastures	Tree crops	Vegetables	User's accuracy
forest	8	0	0	2	0	80%
field crops	0	7	0	0	3	70%
pastures	0	2	8	0	0	80%
tree crops	0	0	0	10	0	100%
vegetables	0	1	1	0	8	80%
Produce's accuracy	100%	70%	89%	83%	73%	
Overall Accuracy	82%					
Kappa	78 %					

The topographic variables (i.e., elevation, slope, and aspect)were categorized into distinct categories according to potential relation to vegetation distribution (see table 2 for details). The categories included: (i) seven levels of elevation varies by 200m, as vegetation cover and agriculture crops might significantly vary within this range in Mediterranean semi-arid environments due to local climate variations (i.e., aridity, wetness) (Heshmati 2007; Boulos et al., 1994); (ii) six classes of slope degrees according to Young et al., (1974); and nine of aspect expressing the nine possible directions divided by 45 degrees.

Table (2): Statistical description of topographic variables in the study area

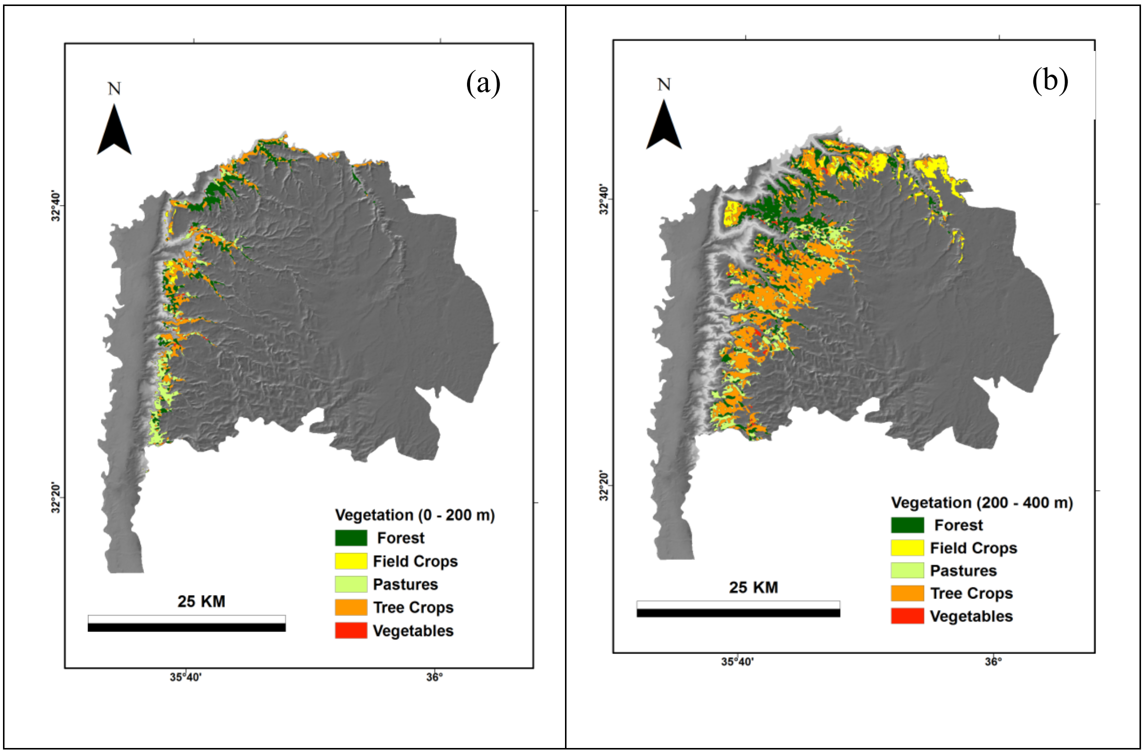
Aspect	Area (Km²)	(%)	Elevation (m)	Area (Km²)	(%)	Slope (Degree)	Area (Km²)	(%)
Flat	203	13	(-343) - (-150)	198.4	12.6	0-2	361.1	23
North	266.2	17	(-150) - 0	71.4	4.5	2-5	475.1	30
North East	187.1	12	0 - 200	125	7.9	5-10	325.7	21
East	97.3	6	200 - 400	311.2	19.7	10-18	244	16
South East	149.2	10	400 - 600	602.2	38.3	18-30	133	8
South	226	14	600 - 800	197.2	12.5	30-58	38	2
South West	101	6	800 - 1068	71.3	4.5	Total	1577	100
West	156	10	Total	1577	100			
North West	191.1	12						
Total	1577	100						

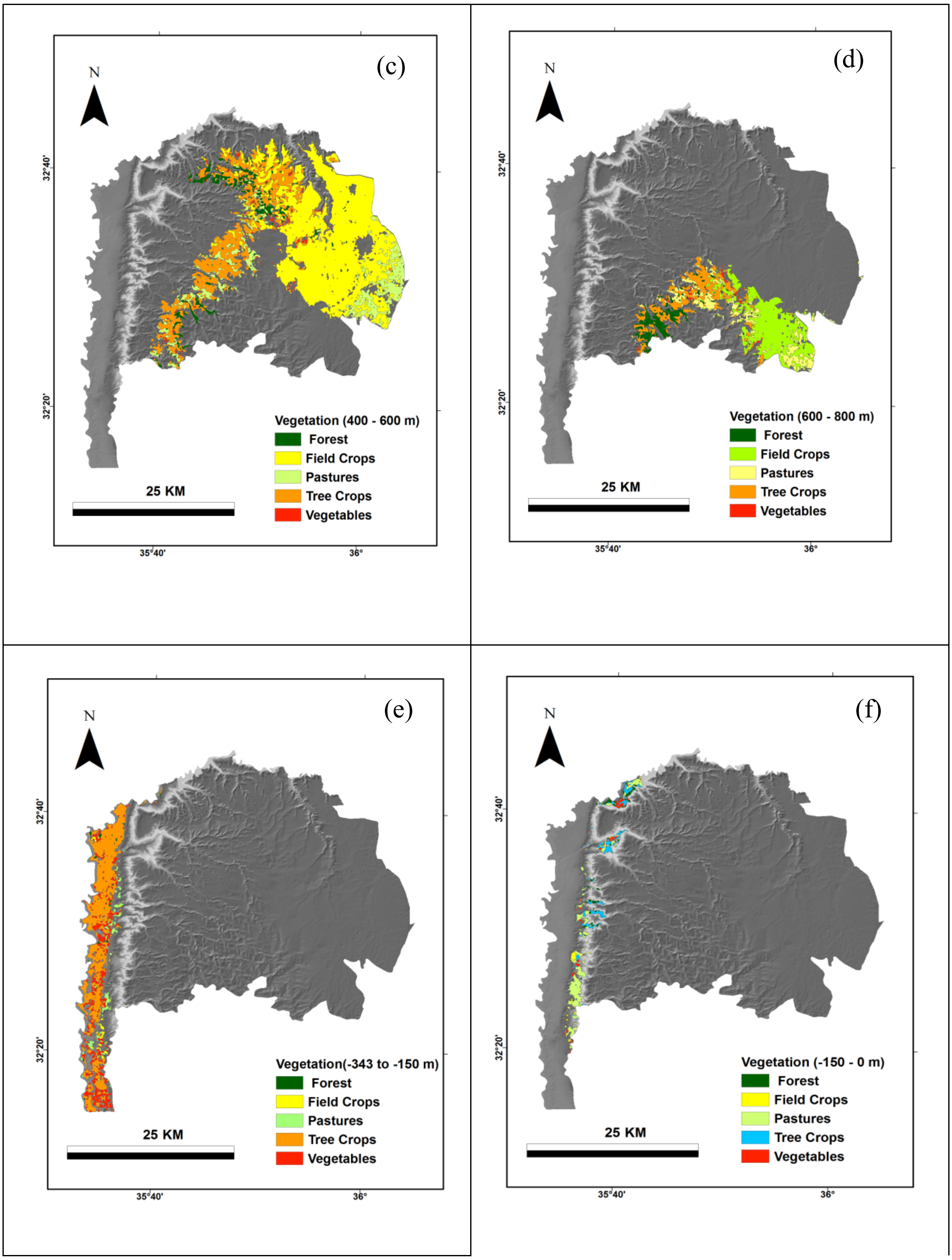
3.2 Relation between elevation and vegetation cover

Table (3) shows vegetation distribution with elevation levels in the study area. It revealed that majority of vegetation cover (i.e., ~ 40.3%) was dominant at elevations between 400-600 m a.m.s.l. That is coincided with the appropriate temperature (i.e., 17-20 C^0) and rainfall rates (400mm) for vegetation growth in the study area (Saba 2010). On the contrary, low vegetation percentage (~ 3%) was identified at low elevations (i.e., 0-150m a.m.s.l). These areas are consisted of very relief fluctuations, rock surfaces, and poor-immature soils. Table (3) and Figure (2 a-g) show statistical and spatial description of vegetation cover relative to elevation levels, respectively.

Table (3): Statistical description of vegetation cover in the study area according to elevation levels

Elevation (m)	Area (Km²)					Total	(%)
	Pasture	Vegetable	Tree Crops	Forest	Field Crops		
(-343) - (-150)	9	31	89	2	3	134	10.09
(-150) - 0	18	4	9	4	2	37	2.78
0 - 200	24	2	37	33	3	99	7.45
200 - 400	41	6	123	72	35	277	20.84
400 - 600	64	9	122	33	307	535	40.26
600 - 800	34	3	44	22	75	178	13.39
800 - 1068	9	1	31	25	3	69	5.19
Total	199	56	455	191	428	1329	100




(c)
N
32°40'
32°20'
Vegetation (400 - 600 m)
Forest
Field Crops
Pastures
Tree Crops
Vegetables
25 KM
35°40'
36°
(d)
N
32°40'
32°20'
Vegetation (600 - 800 m)
Forest
Field Crops
Pastures
Tree Crops
Vegetables
25 KM
35°40'
36°
(e)
N
32°40'
32°20'
Vegetation(-343 to -150 m)
Forest
Field Crops
Pastures
Tree Crops
Vegetables
25 KM
35°40'
36°
(f)
N
32°40'
32°20'
Vegetation (-150 - 0 m)
Forest
Field Crops
Pastures
Tree Crops
Vegetables
25 KM
35°40'
36°

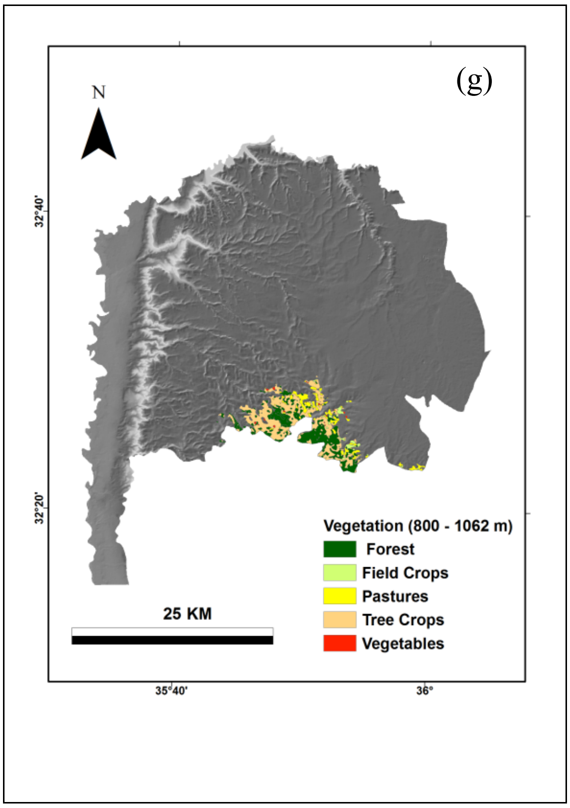


Figure (3): Spatial distribution of vegetation cover at different elevation levels in the study area. (a) < - 150, (b) (-150) - 0, (c) 0 - 200, (d) 200 - 400, (e) 400 - 600, (f) 600 - 800, and (g) > 800. Elevation measured in meters above mean sea level.

Figures 3a-g show the spatial distribution of vegetation types according to elevation levels. It showed that approximately 70% of pastures were found at elevations between 200 – 800m a.m.s.l with major concentration (i.e., ~ 32%) between 400-600m a.s.m.l. For forest land cover 38% were found over hillslopes between 200-400m a.m.s.l. These areas mainly contain Oak species. However, conifer and cypress species are found at higher elevations due to low temperature and higher rainfall rates. Agricultural lands including vegetables, citrus, and bananas were found at elevations below -150m were irrigated agricultural practices and hot temperature were dominated. These agriculture types occupied approximately 63% of the area. Olive trees and fruits were concentrated with approximately 54% between 200-400m a.s.m.l. Field crops including wheat, lentil, and barley were concentrated between 400-600m a.s.m.l. Figures 4a show to location of transects, 4b and 4c, show vegetation types variations over 35 km north-south, and 45 km east-west transects in the study area.

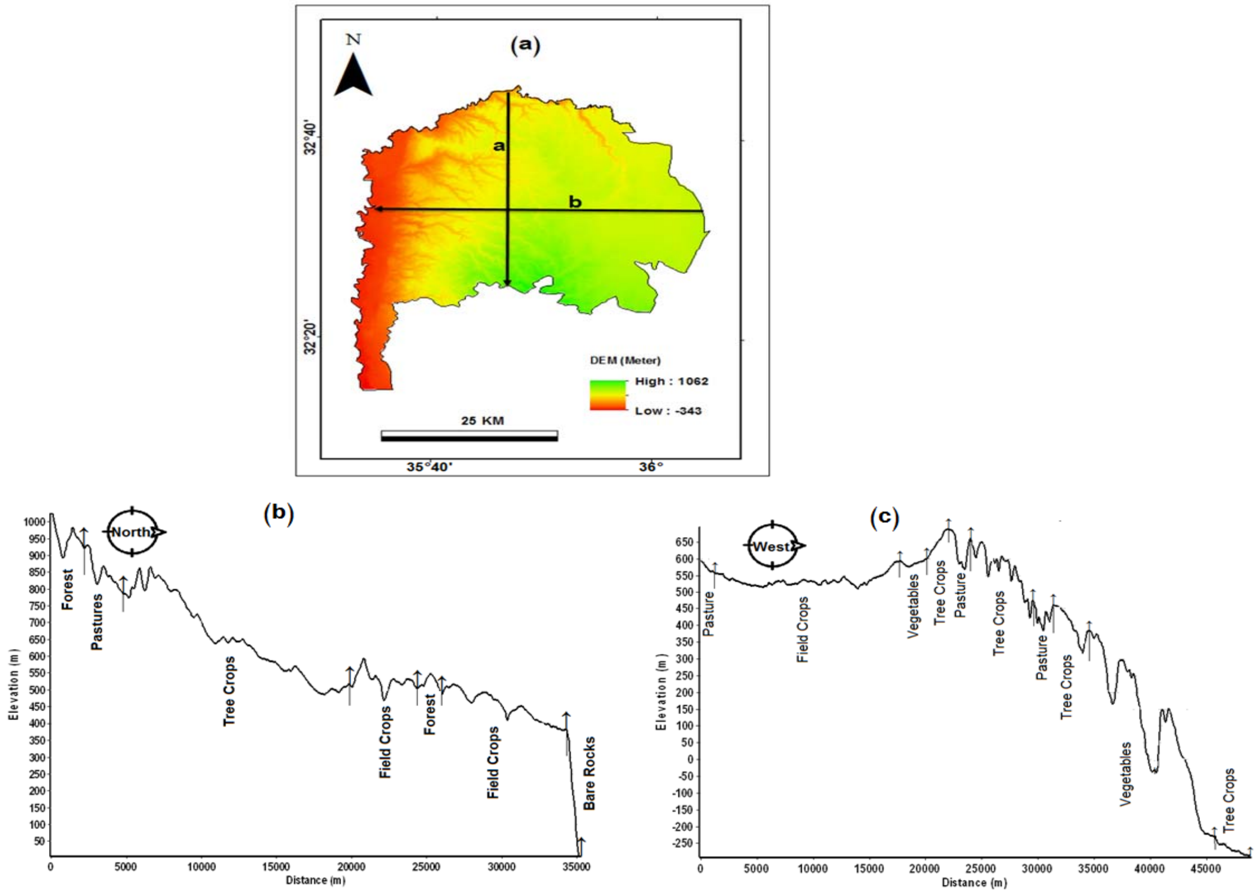


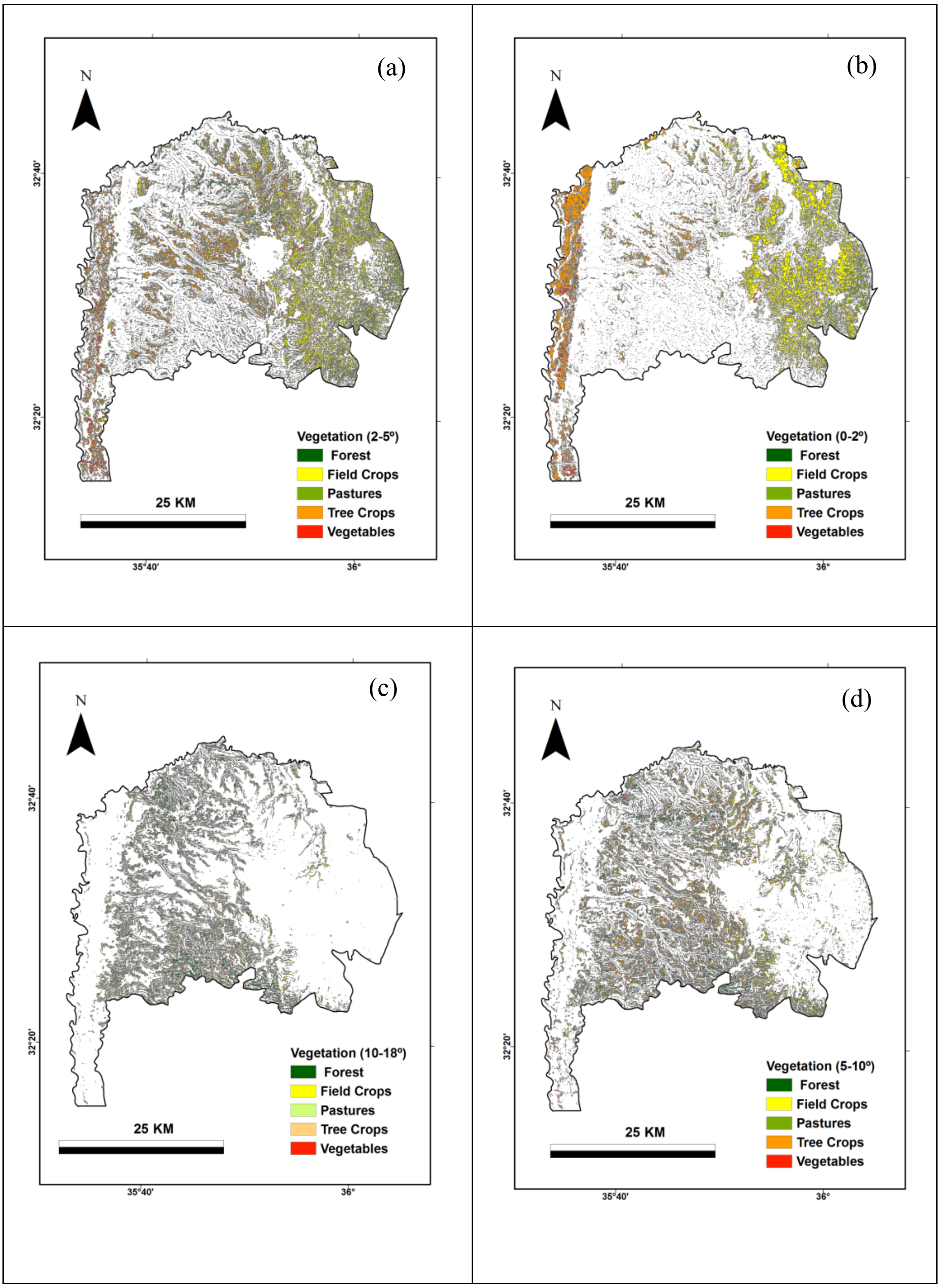
Figure (4): Map of vegetation cover with the two spatial transects crossing the study area from north to south (i.e., 35 km) and east to west (i.e., 45 km). (b) 35km north-south direction, and (c) 45 km east-west direction. It shows that strong relationship between vegetation types and elevation levels were existed in the study area.

3.3 Relation between slope and vegetation cover

Table (4) and Figures 5a- f show statistical and spatial description of vegetation covers at various slope degrees in the study area. It showed that slopes less than 18 degrees were mainly contained most of vegetated area (i.e., cumulative percentage 89.1%). In which, ~ 86% of pastures, ~96% of vegetables, 89% of tree crops, 72% of forest, and 98% of field crops.

Table (4): Statistical description of vegetation cover in the study area according to elevation levels

Slope (Degree)	Area (Km²)					Total	(%)
	Pasture	Vegetable	Tree Crops	Forest	Field Crops		
0-2	25	16	89	8	173	311	23.40
2-5	50	23	127	27	178	402	30.30
5-10	50	10	109	47	52	268	20.20
10-18	46	5	79	56	16	202	15.20
18-30	23	2	39	40	6	110	8.30
30-58	5	0	12	13	3	33	2.60
Total	199	56	455	191	428	1329	100


(a)
N
32°40'
32°20'
Vegetation (2-5º)
Forest
Field Crops
Pastures
Tree Crops
Vegetables
25 KM
35°40'
36°
(b)
N
32°40'
32°20'
Vegetation (0-2º)
Forest
Field Crops
Pastures
Tree Crops
Vegetables
25 KM
35°40'
36°
(c)
N
32°40'
32°20'
Vegetation (10-18º)
Forest
Field Crops
Pastures
Tree Crops
Vegetables
25 KM
35°40'
36°
(d)
N
32°40'
32°20'
Vegetation (5-10º)
Forest
Field Crops
Pastures
Tree Crops
Vegetables
25 KM
35°40'
36°

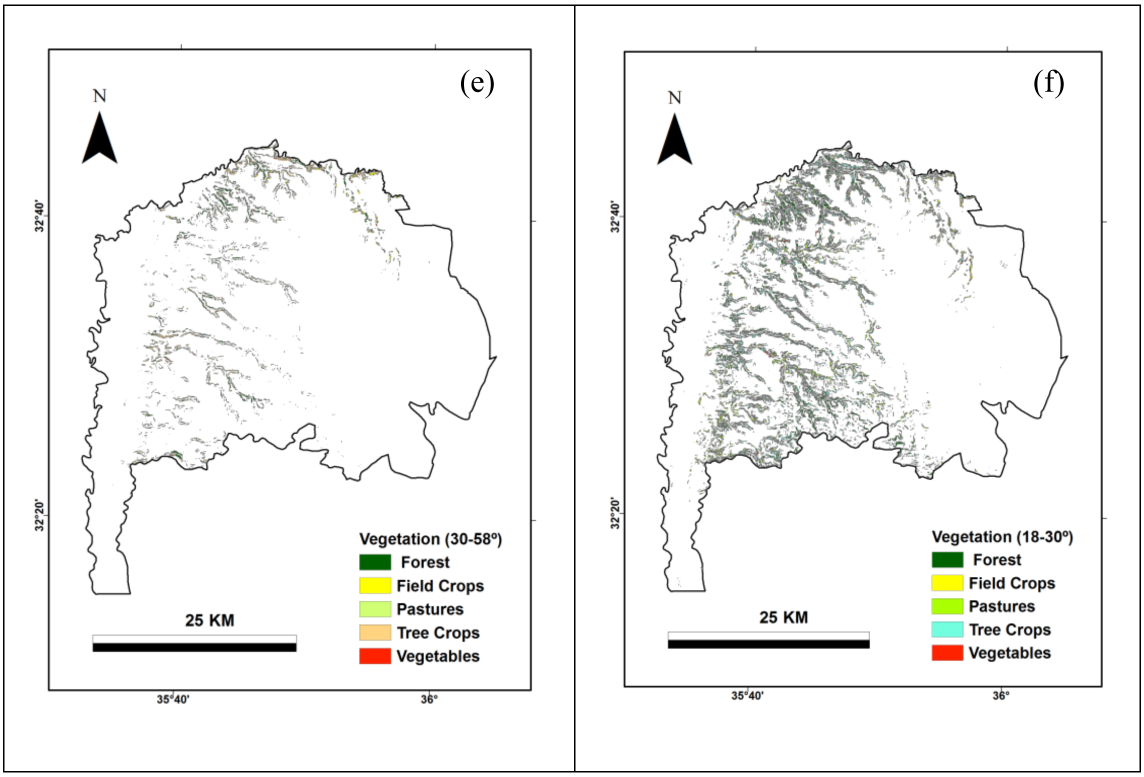


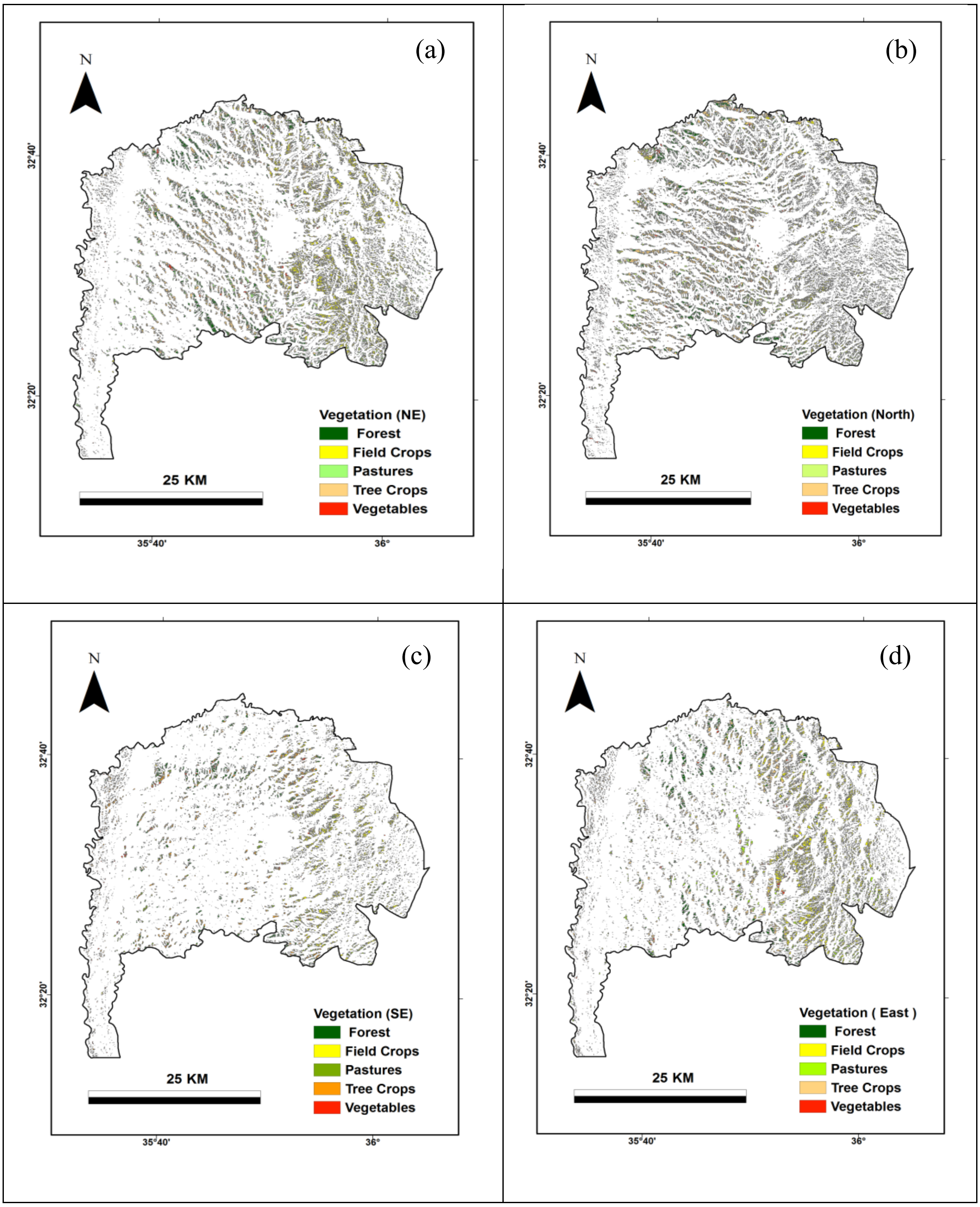
Figure (5): Spatial distribution of vegetation cover at different slope gradients in the study area. (a) 0-2, (b) 2-5, (c) 5-10, (d) 10-18, (e) 18-30, (f) 30-58. Slope measured in degrees.

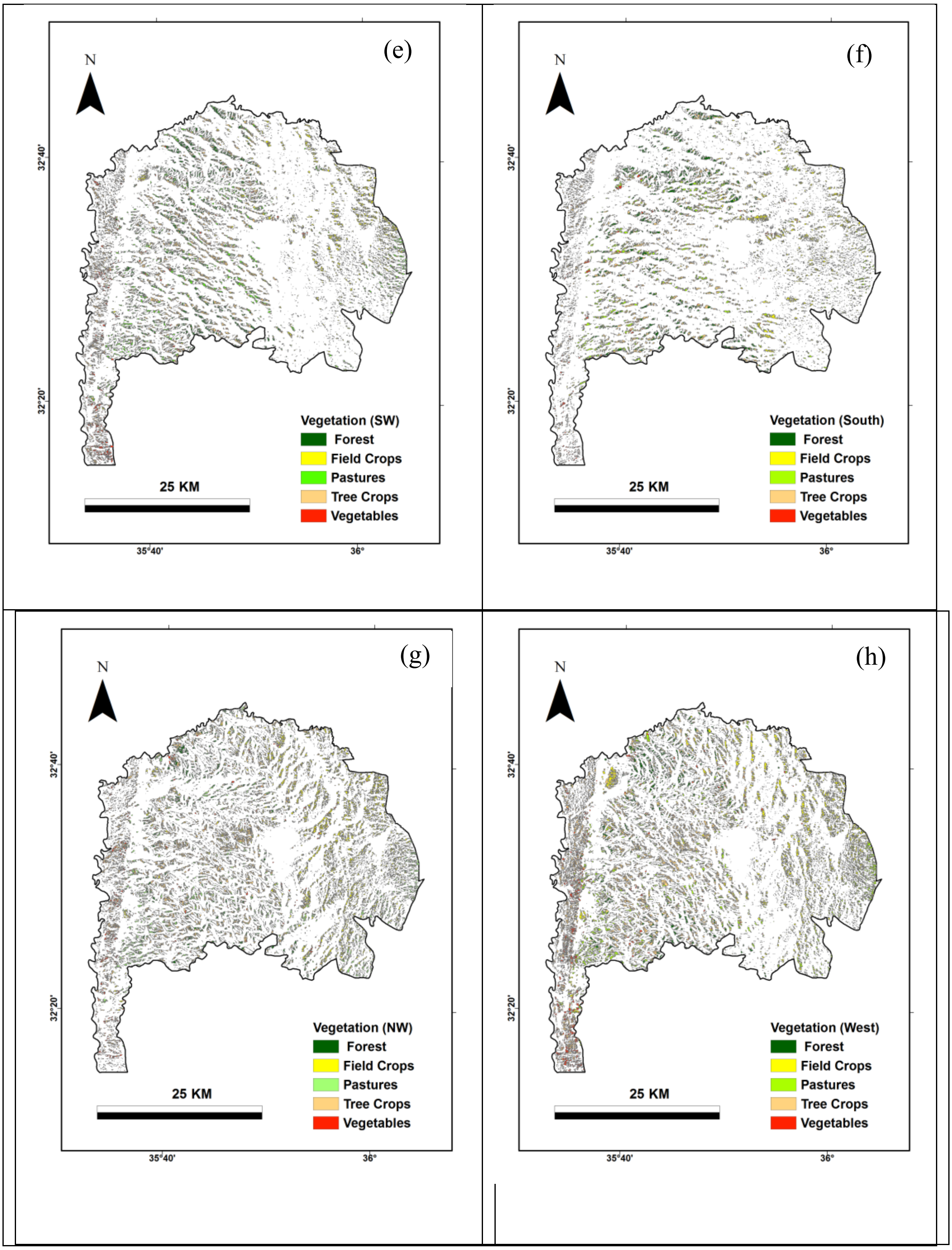
3.4 Relation between aspect and vegetation cover

Table (5) and Figures 5a- h provide detailed statistical and spatial distribution of vegetation cover at different aspects in the study area. It showed that 50% of western, northwestern, and southwestern aspects were covered by pastures which are rarely found at other aspects. Forests were dominant at equal percentages at northern, southern, western, and southwestern aspects. In total ~ 55% of these aspects are covered by forests. On the other hand, western, northwestern and southwestern aspects were majorly agricultural lands with approximately 61% of vegetables, 45% of tree crops, and 26% of field crops. Also, it was noted that the flat aspects were occupied by agricultural practices such as 56% and 29% of field crops and tree crops respectively.

Table (5): Statistical description of vegetation cover in the study area according to aspect categories in the study area

Aspect	Area (Km²)					Total	(%)
	Pasture	Vegetable	Tree Crops	Forest	Field Crops		
Flat	7	3	25	3	48	86	6.5
North	27	5	68	28	50	178	13.4
North East	19	3	53	27	68	170	12.8
East	14	3	36	19	62	134	10
South East	10	3	23	13	33	82	6.2
South	24	5	43	27	27	126	9.5
South West	29	10	59	27	29	154	11.6
West	37	15	81	27	52	212	16
North West	32	9	67	20	59	187	14
Total	199	56	455	191	428	1329	100


(a)
N
32°40'
32°20'
Vegetation (NE)
Forest
Field Crops
Pastures
Tree Crops
Vegetables
25 KM
35°40'
36°
(b)
N
32°40'
32°20'
Vegetation (North)
Forest
Field Crops
Pastures
Tree Crops
Vegetables
25 KM
35°40'
36°
(c)
N
32°40'
32°20'
Vegetation (SE)
Forest
Field Crops
Pastures
Tree Crops
Vegetables
25 KM
35°40'
36°
(d)
N
32°40'
32°20'
Vegetation (East)
Forest
Field Crops
Pastures
Tree Crops
Vegetables
25 KM
35°40'
36°


(e)
N
32°40'
32°20'
Vegetation (SW)
Forest
Field Crops
Pastures
Tree Crops
Vegetables
25 KM
35°40'
36°
(f)
N
32°40'
32°20'
Vegetation (South)
Forest
Field Crops
Pastures
Tree Crops
Vegetables
25 KM
35°40'
36°
(g)
N
32°40'
32°20'
Vegetation (NW)
Forest
Field Crops
Pastures
Tree Crops
Vegetables
25 KM
35°40'
36°
(h)
N
32°40'
32°20'
Vegetation (West)
Forest
Field Crops
Pastures
Tree Crops
Vegetables
25 KM
35°40'
36°

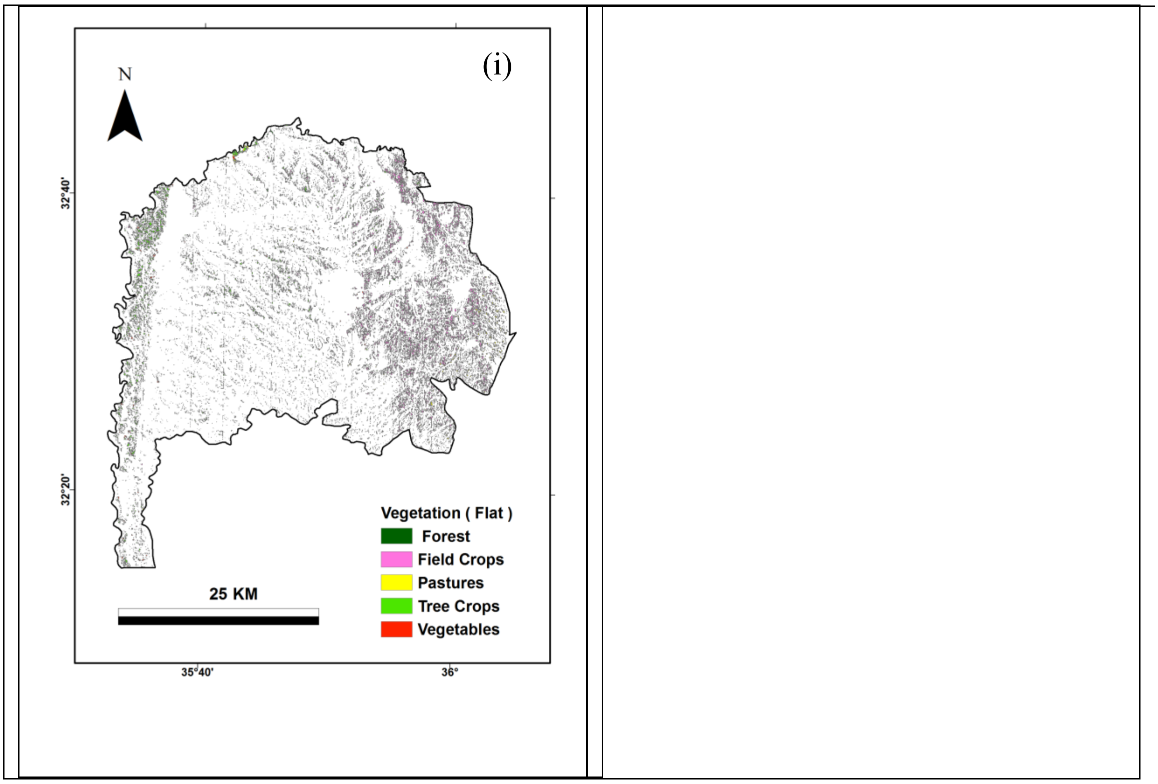


Figure (6): Spatial distribution of vegetation cover at different aspect categories in the study area. (a) Flat, (b) North, (c) North East, (d) East, (e) South East, (f) South, (g) South West, (h) West, and (i) North West.

4. DISCUSSION

Vegetation distribution and diversity are important in semi-arid environments. Results of the relation between elevation and vegetation cover showed that a clear relationship is established between elevation and vegetation distribution as the magnitude of topographic relief accounted for the variability in the vegetation cover diversity. This is due to the fact that more pronounced topography (i.e. mountains area) can exhibit vertical patches of land cover communities; thereby it might increase diversity due to greater topographic relief (Coblentz and Riitters, 2004). In terms of slope, vegetated areas were found at various slope categories and gradually degraded with higher slope values and rarely found at slope degrees greater than 30. It is worthwhile to mention that agriculture including vegetable and field crops were mainly concentrated at slopes less than 5 degrees in the study area due to appropriate natural conditions for agricultural practices including surface flatness, soil water content, and mature soil types (Ministry of Agriculture 2001). It is worthwhile to mention that the results showed comparable results to other previous studies that have evaluated the linkage between topography and land cover diversity (e.g., Hoersch et al., 2002; Coblentz and Riitters, 2004; Pérez et al., 2008). This study examined the topographic influence on vegetation cover in a heterogeneous semi-arid region in Irbid governorate Jordan, Middle East. For this purpose, the employed digital elevation and classified remote sensing data showed that local vegetation types are the result of variability in the topographic variables (i.e., elevation, slope, and aspect). Comparing to traditional surveys, digital remote sensing and GIS technique are superior in mapping and monitoring spatial vegetation variability in associations to topography for large or inaccessible areas.

ACKNOWLEDGMENTS

We would like to thank USGS and NASA for providing Landsat-8 and ASTER GDEM images at free of cost.

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تقييم التنوع النباتي بفعل الطبوغرافيا في البيئات شبه الجافة اعتماداً على نظم المعلومات الجغرافية والاستشعار عن بعد

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ملخص

هدفت هذه الدراسة إلى تحري العلاقة المحتملة للخصائص الطبوغرافية في التنوع المكاني للغطاء النباتي في البيئة شبه الجافة في منطقة إربد في الأردن. ولتحقيق ذلك، فقد استخدام العديد من المتغيرات الطبوغرافية كالارتفاع والانحدار واتجاه المنحدرات والغطاءات الأرضية في منطقة الدراسة. وقد تضمنت منهجية البحث استخدام التحليل المكاني لبيانات الارتفاع الرقمي من القمر الصناعي ASTER-GDEM و بيانات القمر الصناعي Landsat-8. حيث تم تحديد خمسة أصناف من الغطاء النباتي تمثلت بالغابات والمحاصيل الحقلية والخضروات والمحاصيل الشجرية والمراعي. وقد أظهرت النتائج وجود علاقة قوية بين المتغيرات الطبوغرافية وتنوع الغطاء النباتي في منطقة إربد. وقد تم تحديد العديد من العوامل البيئية ذات الصلة بالتنوع النباتي–الطبوغرافي. وبشكل عام، فقد أسهمت هذه الدراسة في زيادة مستوى الفهم للعلاقة بين التنوع النباتي والطبوغرافيا في منطقة الدراسة، كما أظهرت أهمية الاعتماد تقنيات الاستشعار عن بعد ونظم المعلومات الجغرافية في عمليات النمذجة البيئية.

الكلمات الدالـة: التحليل المكاني، مؤشر التغطية النباتية، نموذج الارتفاع الرقمي، الطبوغرافيا، استعمالات الأرض.

* جامعة اليرموك، الأردن. تاريخ استلام البحث 2017/10/30، وتاريخ قبوله 2018/9/6.