

# A State-of-the-Art Vegetation Map for Jordan

Subjects: Remote Sensing

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Jordan's forested regions account for 0.71% of the total land area, with acacia woodland and forests combined totalling 2.3%. From the satellite image interpretation, two maps were created: an unsupervised land cover/land use map and a supervised map of present-day vegetation types, both consisting of 18 categories. These new maps should inform ecosystem management and conservation planning decisions in Jordan over the coming years.

Keywords: remote sensing ; Jordan ; land cover ; land use ; vegetation map ; vegetation type ; phytogeography

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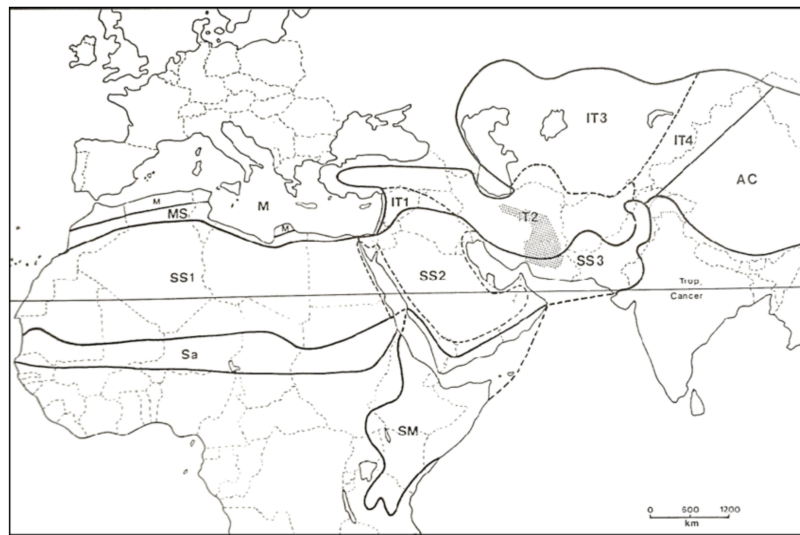
## 1. Introduction

If natural resources are to be managed sustainably, it is crucial to assess land cover/land use and the spatial distribution of vegetation types. This is also helpful for protecting habitats and for providing data for vegetation cover modelling. The goal here in this research is to derive accurate maps and cover estimates for vegetation in Jordan through the use of both field study and satellite imagery. Jordan is a region of high vegetation complexity and provides an ideal testing ground for methods in land cover and vegetation type mapping.

Since Alexander von Humboldt first began categorising vegetation zones in 1807, biogeographers have classified the planet into chorological units. Prior to his work, it was typical to focus on individual plants; Humboldt shifted this towards a more collective focus on species—their distribution, growth forms, and how they relate to their surroundings <sup>[1]</sup>. This new approach meant that communities and associations among plants were able to be identified <sup>[2]</sup>. August Grisebach utilised this new approach to develop what would become known as phytogeographic regions, including the Mediterranean and Irano–Turanian regions, according to the species composition and physiognomy of individual vegetation groups <sup>[2][3]</sup>.

Jordan is situated at the meeting point of Europe, Asia, and Africa <sup>[4]</sup>. This is rare among countries, as four main plant geographical regions meet at this point. The first person to map these areas was Eig <sup>[5][6]</sup>, who used his analysis of plant lists and assessment of the physiognomic characteristics of the region's geography and topography to develop his maps. He denoted four main units for this region, all with discrete climate and flora: Irano–Turanian, Mediterranean, Saharo–Sindian, and minor Sudano–Decanian enclaves. Eig's <sup>[5]</sup> findings revealed that around 30% of plant species were found in two or more phytogeographic regions. Attempts have been made by researchers such as Whyte to either amend the existing boundaries or to subdivide the regions further <sup>[4]</sup>; moreover, Zohary posited that as more reliable analytical tools are devised, more appropriate boundary changes may be possible <sup>[3]</sup>.

The research of Zohary <sup>[3]</sup> into the origins and categorisation of Middle Eastern vegetation has been the standard by which phytogeography in the region has been interpreted for much of the last five decades. His work separated Arabia into two main floral areas, with the southern region belonging to the Sudano–Decanian, and the central and northern regions to the Saharo–Sindian <sup>[3]</sup>. This was not disputed until 1991, when White and Léonard <sup>[7]</sup> revised Zohary's approach and extended the Somalia–Masai Regional Centre of Endemism and the Afro–Montane archipelago-like Regional Centre of Endemism into southwest Arabia and divided their Saharo–Sindian zone into the Nubo–Sindian subzone, which represents the old Sudano–Decanian tropical vegetation, of Zohary (with *Vachellia tortilis*), and the Saharo–Arabian subzone (extra-tropical vegetation), which represents (in Jordan) the Saharo–Sindian of Zohary (with *Vachellia gerardii*). White and Léonard suggested that the Saharo–Sindian and Irano–Turanian zones are the two main phytochoria that influence Jordan <sup>[7]</sup>, with each further subdivided subsequently into smaller, Middle East region-specific phytochoria <sup>[8]</sup>, as illustrated in **Figure 1**.



**Figure 1.** Main phytogeographical regions covering Asia and Africa (Reprinted/adapted from [7]). Regional zones are represented by: SS = Saharo-Sindian, SS1 = Sahara regional subzone, SS2 = Arabian regional subzone, SS3 = Nubo-Sindian local centre of endemism, M = Mediterranean; IT = Irano-Turanian, IT1 = Western Irano-Turanian regional subcentre, IT2 = Southern Irano-Turanian regional subcentre, IT3 = Northern Irano-Turanian regional subcentre, IT4 = Eastern Irano-Turanian regional subcentre, AC = Central Asiatic, Sa = Sahel, SM = Somalia-Masai.

Expanding on the work of Long [9], Al-Eisawi [10] determined that there are nine bioclimatic areas in Jordan, which are categorised into four overarching clusters: Saharan Mediterranean (cool, warm, very warm); arid Mediterranean (cool, warm, very warm); semi-arid Mediterranean (cool, warm); and sub-humid Mediterranean. Later, Al-Eisawi [11] also created a map based on the delineations made by Zohary [3] of the regions of vegetation in the Middle East.

The flora in the region under study is very species rich due to the area being situated at the meeting point of three phytogeographic regions [3][11][12][13]. The land changes from Mediterranean maquis and forests to grassland, steppes, and extremely arid desert biomes within a relatively short space. While edaphic influences do have an effect on vegetation, it is the climate that has a greater impact [13]. As well as vegetation being influenced by environmental pressures, human activities also affect the way plants are distributed. Some research has accounted for forestry, agriculture, and grazing potential along with human activity when classifying vegetation [9][14][15][16].

The vegetation types of the region have also been mapped. While earlier work (e.g., [3][5][6]) was conducted prior to modern development and experienced fewer restrictions on political boundaries, other modern works were either restricted by political boundaries or the study was conducted across limited borders based on extensive fieldwork [11][14][16][17]. The most recent and updated map of vegetation for Jordan was produced by Albert et al. [14]. The map included 19 vegetation types and was primarily based on topography and coarse-resolution satellite images to describe vegetation cover of the country at a scale of 1:1 M. However, no map to date has combined state-of-the-art earth observation approaches with extensive field data to ground-truth remote sensing data.

Remote sensing data have contributed to land cover and vegetation type mapping by applying advanced digital classification techniques to derive both land cover and vegetation types at different spatial resolutions [18]. For vegetation mapping, the outputs from digital classification of remotely sensed data are intensively used to map land cover dynamics [19], floristic diversity, phytogeography [20], and vegetation [21] over large geographic areas. In order to identify and map land cover and vegetation in a continuous manner, remote sensing is vital. Data from sensors such as Landsat, MODIS, Sentinel, SPOT, and ASTER can be obtained cheaply or free of charge, with some providing wide swath-width images (over 290 km).

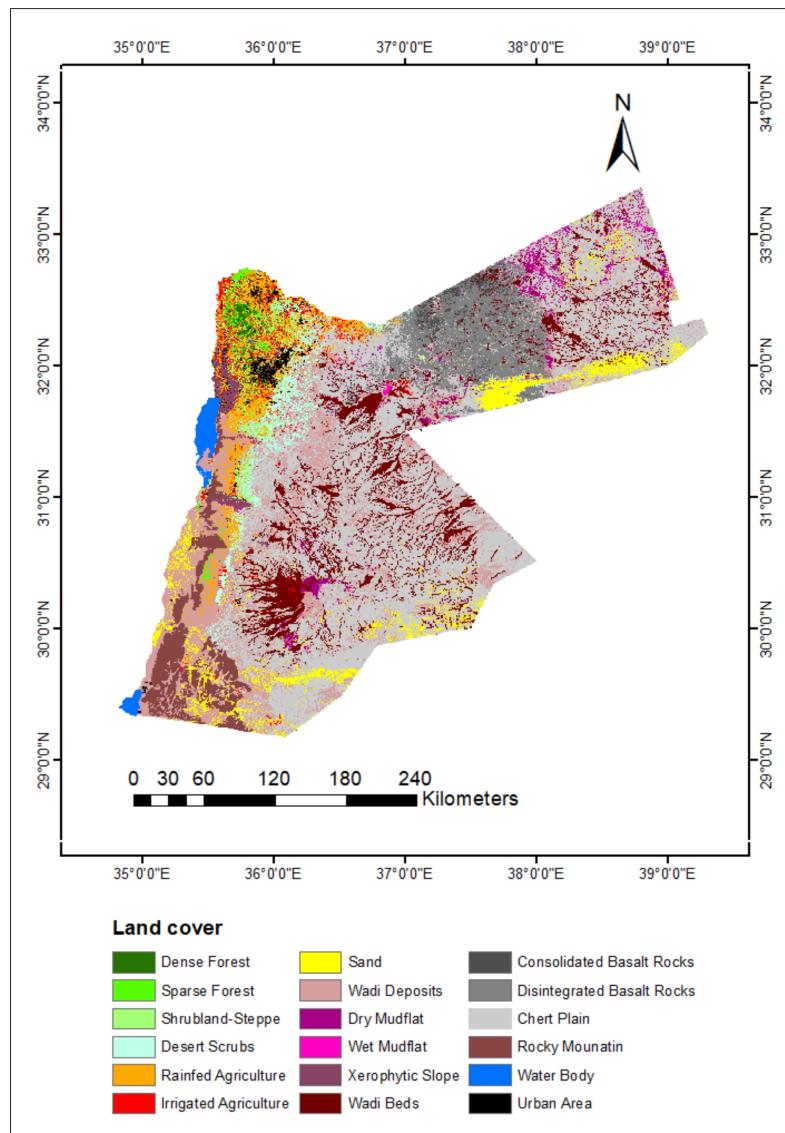
Vegetation mapping of Jordan is now urgently required so that appropriate and effective planning can be made for managing agriculture, afforestation, and rangeland, and for the degradation of habitats to be reduced. Prior research has been less than ideal for a multitude of reasons; for instance, studies did not utilise satellite imaging, were not comprehensive enough, or did not include field observations to support mapping and definition of the areas under investigation. Further, much of the existing research fails to include data from maps based on land use, geological or meteorological information, vegetation sampling, or GIS methodologies, and often does not utilise herbarium specimens or pictures to identify the species found in each region.

Taking all of the abovementioned points into consideration, it is clear that no study currently exist that describes Jordan's vegetation in a spatial context for use in mapping or restoring particular kinds of vegetation. This would be extremely useful in the management and conservation of the country's biodiversity [22].

## 2. Detailed Analysis

### 2.1. Land Cover/Land Use Map

The land cover map is the result of the integration of remotely sensed data with thematic features from land cover models. According to this interpretation of satellite images, the map shows 18 classes of land cover (**Figure 2, Table 1**).



**Figure 2.** Land cover/land use map of Jordan produced from the unsupervised classification.

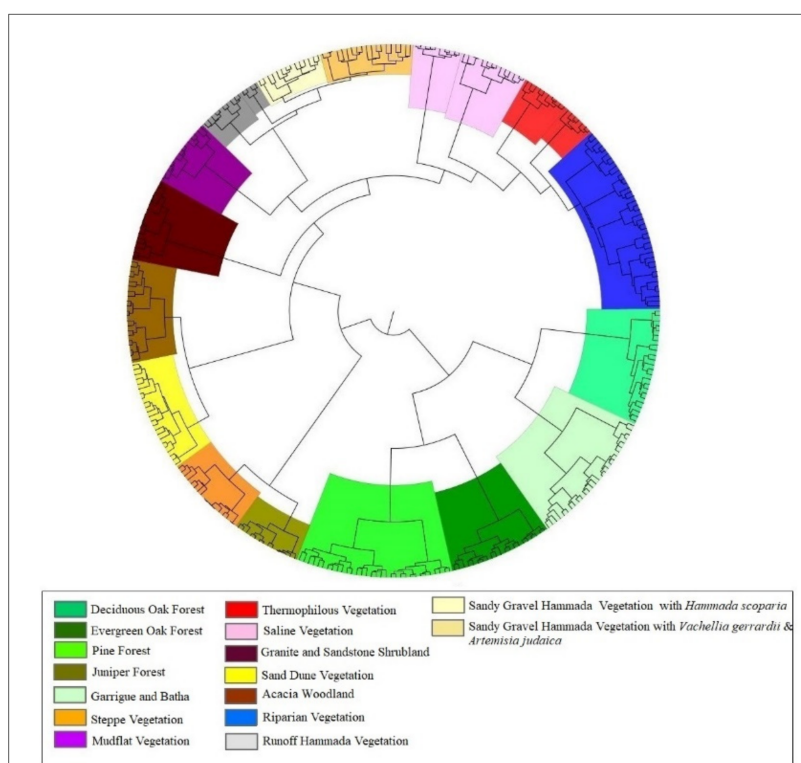
**Table 1.** Land cover statistics in Jordan.

	Land Cover Class	Total Km <sup>2</sup>	Percentage	Total Percentage
Forests	Dense Forest	398.2	0.45	0.89
	Sparse Forest	394.3	0.44	
Highly productive rangelands	Shrubland/Steppe	1484.0	1.66	14.1
	Desert Scrubs	3023.8	3.38	
	Wadi Beds	8098.0	9.06	
Arable lands	Rainfed Agriculture	3532.4	3.95	5.39
	Irrigated Agriculture	1289.8	1.44	

	Land Cover Class	Total Km <sup>2</sup>	Percentage	Total Percentage
Dry lands	Sand	5114.6	5.72	77.9
	Wadi Deposits	15981.4	17.89	
	Dry Mudflat	1667.4	1.87	
	Wet Mudflat	342.6	0.38	
	Xerophytic Slope	1009.4	1.13	
	Consolidated Basalt Rocks	691.0	0.77	
	Disintegrated Basalt Rocks	7261.7	8.13	
	Chert Plain	33744.4	37.77	
	Rocky Mountain	3788.6	4.24	
Others	Water Body	540.7	0.62	1.72
	Urban Area	980.0	1.1	

## 2.2. Vegetation Map

Sixteen groups, or vegetation type classifications, were produced from hierarchical cluster analysis (**Figure 3**). Sampling sites were grouped together based on the composition of the perennial vegetation present in each site. Two overarching vegetation groups emerged from the cluster analysis (**Table 2**).



**Figure 3.** Site classification based on Agglomerative Hierarchical Clustering analysis.

**Table 2.** Vegetation groups sorted according to the composition of the perennial plants.

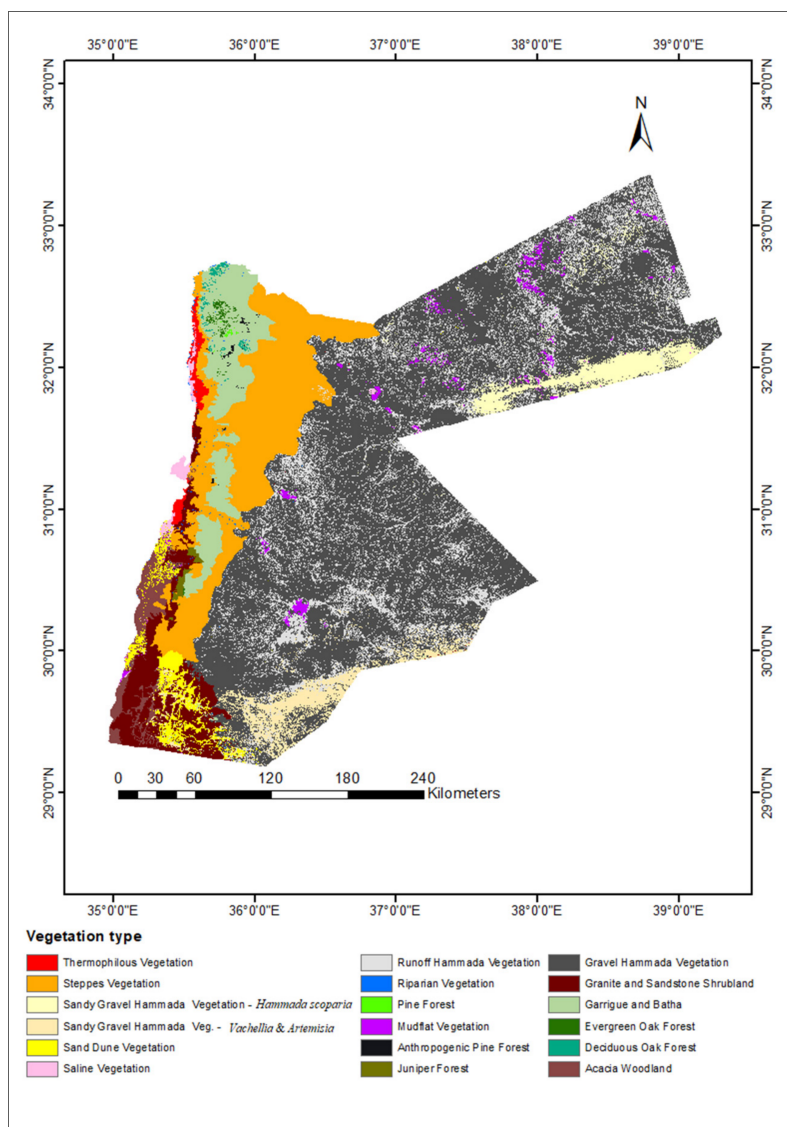
Vegetation Group	Vegetation Type
Mesic group	Deciduous Oak Forest
	Evergreen Oak Forest
	Pine Forest
	Garrigue and Batha

Vegetation Group	Vegetation Type
Xeric group	Juniper Forest
	Acacia Woodland
	Steppe Vegetation
	Sand Dune Vegetation
	Sandy Gravel Hammada Vegetation with <i>Hammada scoparia</i>
	Sandy Gravel Hammada Vegetation with <i>Vachellia gerrardii</i> and <i>Artemisia judaica</i>
	Granite and Sandstone Shrubland
	Mudflat Vegetation
	Runoff Hammada Vegetation
	Riparian Vegetation
	Saline Vegetation
	Thermophilous Vegetation

From the species composition analysis, 54 indicator species were identified that could then be used to classify species of vegetation. Annual plant species were not included in the cluster analyses, but one vegetation type, specifically Gravel Hammada vegetation, lacks perennials. For this type, annual indicator species were added based on researcher experience and field records.

### 2.3. Using Remote Sensing to Classify Vegetation Types

Based on the land cover/land use map and as a result of using the supervised classification method in interpreting the satellite images, a current vegetation map was produced at a scale of 1:50,000 that contains 18 vegetation types (**Figure 4, Table 3**).



**Figure 4.** Vegetation map based on the interpretation of satellite images.

**Table 3.** Vegetation map statistics in Jordan.

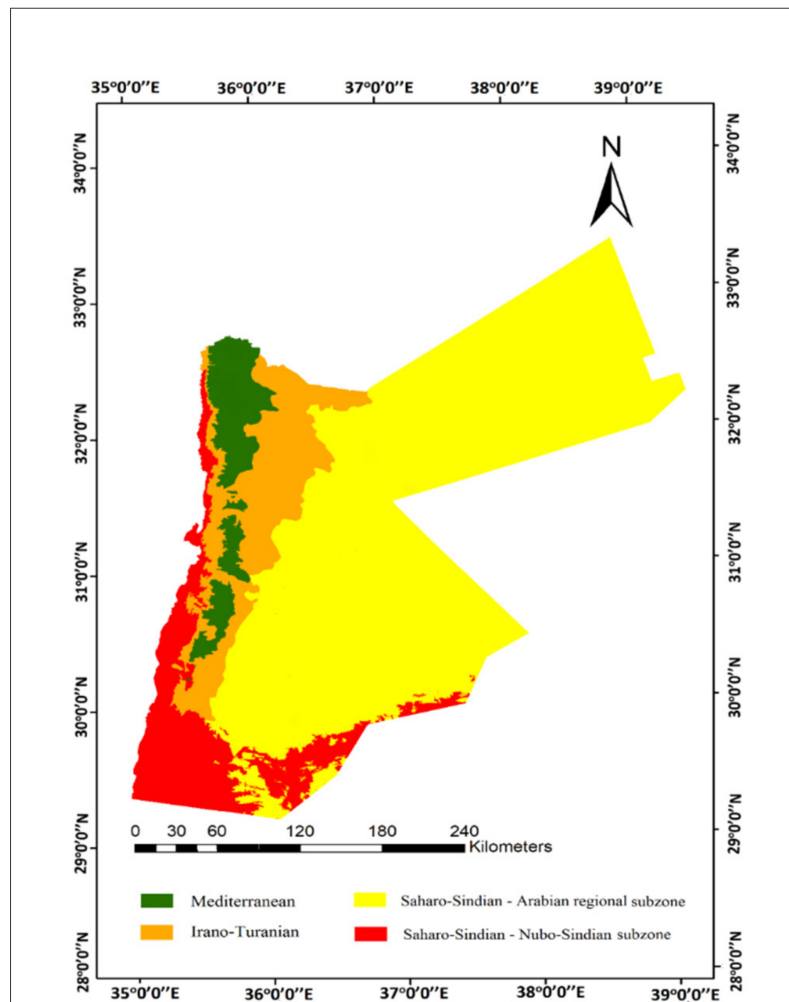
Vegetation Type	Total Km <sup>2</sup>	Percentage (%)
Gravel Hammada Vegetation	45871.9	51.34
Sand Dune Vegetation	1760.7	1.97
Steppe Vegetation	11293.4	12.24
Granite and Sandstone Shrubland	4079.7	4.57
Acacia Woodland	1453.7	1.63
Sandy Gravel Hammada Vegetation with <i>Hammada scoparia</i>	2408.5	2.70
Sandy Gravel Hammada Vegetation with <i>Vachellia gerrardii</i> and <i>Artemisia judaica</i>	2909.8	3.26
Garrigue and Batha	4815.2	5.39
Runoff Hammada Vegetation	11677.4	13.07
Mudflat Vegetation	893.1	2.00
Saline Vegetation	392.7	0.44
Juniper Forest	191.7	0.21
Deciduous Oak Forest	156.3	0.17
Anthropogenic Pine Forest	116.3	0.13

Vegetation Type	Total Km <sup>2</sup>	Percentage (%)
Riparian Vegetation	71.9	0.08
Thermophilous Vegetation	534.3	0.60
Pine Forest	18.3	0.02
Evergreen Oak Forest	156.7	0.18

Two vegetation types—anthropogenic pine forest and gravel hammada vegetation—were added to the map, although they were not included in the cluster analysis. The reason for this is that there were no perennial indicator species for the gravel hammada vegetation, and there were no unique indicator species that distinguished both the natural and anthropogenic pine forest. According to the interpretations of the satellite images, there are 68 areas in which riparian habitats occur, mostly along tributaries of the Jordan River and Yarmouk River or wadis flowing towards the Dead Sea.

## 2.4. Phytogeographical Regions

The four main phytochoria are described below, each subdivided into specific Middle Eastern phytochoria that have influence in Jordan: the Mediterranean, Irano–Turanian, Saharo–Sindian–Nubo–Sindian subzone, and the Saharo–Sindian–Arabian regional subzone (Figure 5).



**Figure 5.** Phytogeographical regions of Jordan based on the updated vegetation map.

The Mediterranean region is restricted to the Highlands extending from Irbid in the north to Ras An-Naqab in the south, in addition to some isolated representation in the southern mountains. The Irano–Turanian zone separates the Mediterranean from the Saharo–Sindian–Arabian regional subzone on one side, and the Mediterranean from the Saharo–Sindian–Nubo–Sindian subzone on the other side [7]. The Saharo–Sindian–Arabian regional subzone is located at the eastern desert and accounts for the greatest proportion of land cover in Jordan—about 72%. The Saharo–Sindian–Nubo–Sindian subzone penetrates into Jordan, following Red Sea coastal areas, from tropical regions of the Arabian Peninsula and northeast Africa. A summary of each bio-geographic region and their associated vegetation types is presented in Table 4.

**Table 4.** Vegetation types and the bio-geographic region they represent.

Bio-Geographic Region	Vegetation Type
Mediterranean	Deciduous Oak Forest
	Evergreen Oak Forest
	Pine Forest
	Garrigue and Batha
	Juniper Forest
	Riparian Vegetation
Irano–Turanian	Steppe Vegetation
	Riparian Vegetation
Saharo–Sindian–Arabian regional subzone	Mudflat Vegetation
	Gravel Hammada Vegetation
	Runoff Hammada Vegetation
	Sandy Gravel Hammada Vegetation with <i>Hammada scoparia</i>
Saharo–Sindian–Nubo-Sindian subzone	Mudflat Vegetation
	Granite and Sandstone Shrubland
	Riparian Vegetation
	Thermophilous Vegetation
	Saline Vegetation
	Sand Dune Vegetation
	Acacia Woodland
	Sandy Gravel Hammada Vegetation with <i>Vachellia gerrardii</i> and <i>Artemisia judaica</i>

## 2.5. Accuracy Assessment of Vegetation Maps

In this research, four accuracy measures of each typology of the maps were calculated: the user's accuracy, the producer's accuracy, the overall accuracy, and the Kappa coefficient. The overall accuracy and Kappa coefficient statistics were used to examine the quality of land cover and vegetation maps as a whole. The Kappa coefficient was used to determine the agreement between the map and reality, where 0 = complete disagreement and 1 = complete agreement.

All vegetation maps previously produced by experts and reviewed in this research were of poor to moderate accuracy, where the confusion matrices showed a diagonal line that illustrates a weak to medium agreement between the layers (land cover layer and ground-truth points). The classification accuracy of these maps indicated by the Kappa index also showed a low classification accuracy. On the other hand, the results of the analysis showed high overall accuracy for both the unsupervised land cover/land use map and the supervised vegetation map. The Kappa index also showed a high agreement for these two produced maps, as the result was more than 80%, indicating very good classification accuracy. **Table 5** below summarises the accuracy and Kappa coefficient for all maps.

**Table 5.** Accuracy and Kappa coefficient for the vegetation maps.

Map	Accuracy Assessment (%)	Overall Accuracy	Kappa Coefficient	Classification Accuracy
Vegetation map produced by Kasapligil (1956)	47	Low	0.38	Weak
Vegetation map produced by Al-Eisawi (1996)	50	Moderate	0.43	Weak

Map	Accuracy Assessment (%)	Overall Accuracy	Kappa Coefficient	Classification Accuracy
Vegetation map produced by Danin (1999a)	59	Moderate	0.47	Weak
Vegetation map produced by Albert et al. (2003)	61	Moderate	0.55	Weak
Land cover/land use map	91	High	0.90	Very good
Current vegetation map	95	High	0.94	Very good

## References

- Nicolson, M. Alexander von Humboldt, Humboldtian science and the origins of the study of vegetation. *Hist. Sci.* 1987, 25, 167–194.
- Whittaker, R.H. Classification of natural communities. *Bot. Rev.* 1962, 28, 1–239.
- Zohary, M. *Geobotanical Foundations of the Middle East*; Gustav Fischer: Stuttgart, Germany, 1973.
- Por, F.D. The Levantine landbridge. Historical and present patterns. In *Proceedings of the Symposium of the Fauna and Zoogeography of the Middle East*; Krupp, F., Schneider, W., Kinzelbach, R., Eds.; Ludwig Reichert Verlag: Wiesbaden, Germany, 1987; pp. 23–28.
- Eig, A. Les elements et les groupes phytogeographiques auxiliaires dans la flore Palestinienne'. *Repert. Spec. Nov. Regni Veg.* 1931–1932, 63, 1–201, 63, 1–120.
- Eig, A. On the phytogeographical subdivision of Palestine. *Palestine J. Bot.* 1938, 1, 4–12.
- White, F.; Léonard, J. Phytogeographical links between Africa and Southwest Asia. *Flora Veg. Mundi* 1991, 9, 229–246.
- Léonard, J. Contribution à L'Étude de la Flore et de la Vegetation des Deserts D'Iran (Dasht-e-Kavir, Dasht-e-Lut, Jaz Kurian). *Considerations Phytogeographiques sur les Phytochories Irano–Touranienne, Saharo-Sindienne et de la Somalie-Pays Masai*; Jardin Botanique National de Belgique: Meise, Belgium, 1989.
- Long, G. *The Bioclimatology and Vegetation of East Jordan*; UNESCO/FAO: Rome, Italy, 1957.
- Al-Eisawi, D.M. Vegetation of Jordan. In *Studies in the History and Archaeology of Jordan*; Hadidi, A., Ed.; Ministry of Archaeology and Tourism: Amman, Jordan, 1985; Volume 1, pp. 45–56.
- Al-Eisawi, D.M. Vegetation of Jordan; UNESCO (ROSTAS): Cairo, Egypt, 1996; p. 284.
- Danin, A. *Distribution Atlas of Plants in the Flora Palaestina Area*; The Israel Academy of Sciences and Humanities: Jerusalem, Israel, 2004.
- Zohary, M.; Feinbrun-Dothan, N. *Flora Palestina*; The Israel Academy of Sciences and Humanities: Jerusalem, Israel, 1966; Volume 1.
- Albert, A.; Petutschnig, B.; Watzka, M. Zur Vegetation und Flora Jordaniens. In *Reise Durch die Natur Jordaniens*; Waitzbaur, W., Albert, R., Petutschnig, B., Aubrecht, G., Eds.; Biologiezentrum der Oberösterreichischen Landesmuseen: Linz, Austria, 2003.
- Al-Jaloudy, M.A. *FAO Country Pasture Profile for Jordan*. Available online: <http://www.fao.org/ag/AGP/agpc/doc/Counprof/Jordan/Jordan.htm> (accessed on 15 November 2019).
- Kasapligil, B. Report to the Government of the Hashemite Kingdom of Jordan on an Ecological Survey of the Vegetation in Relation to Forestry and Grazing; UNESCO/FAO: Rome, Italy, 1956.
- Danin, A. Desert rocks as plant refugia in the Near East. *Bot. Rev.* 1999, 65, 93–170.
- Jensen, J.R. *Introductory Digital Image Processing: A Remote Sensing Perspective*; Pearson Education, Inc.: Glenview, IL, USA, 2016.
- Homer, C.; Dewitz, J.; Jin, S.; Xian, G.; Costello, C.; Danielson, P.; Gass, L.; Funk, M.; Wickham, J.; Stehman, S.; et al. Conterminous United States land cover change patterns 2001–2016 from the 2016 national land cover database. *ISPRS J. Photogramm. Remote Sens.* 2020, 162, 184–199.
- Abbas, A.M.; Al-Kahtani, M.A.; Alfaifi, M.Y.; Elbehairi, S.E.I.; Badry, M.O. Floristic diversity and phytogeography of Jabal Fayfa: A subtropical dry zone, south-west Saudi Arabia. *Diversity* 2020, 12, 345.

21. Zheng, J.; Fu, H.; Li, W.; Wu, W.; Zhao, Y.; Dong, R.; Yu, L. Cross-regional oil palm tree counting and detection via a multi-level attention domain adaptation network. *ISPRS J. Photogramm. Remote Sens.* 2020, 167, 154–177.
22. Gibbons, J.W.; Winne, C.T.; Scott, D.E.; Willson, J.D.; Glaudas, X.; Andrews, K.M.; Todd, B.D.; Fedewa, L.A.; Wilkinson, L.; Tsaliagos, R.N.; et al. Remarkable amphibian biomass and abundance in an isolated wetland: Implications for wetland conservation. *Conserv. Biol.* 2006, 20, 1457–1465.

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