Mapping forest and pasture cover of Western Rif (Chefchaouen)

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Abstract

Northern Morocco harbors the large-scale oak forests in the country, surrounded by an agricultural mosaic. The mountainous topography and the existing forest vegetation explain the strong predominance of grazing goats in these woodlands. Despite the socio-economic role and the predominance of pastoral activities, especially in Western Rif (Chefchaouen), there is little information about the current land cover mapping of forests and pasture. Mapping has become a central element of current natural resource management strategies to implement appropriate development policies. The objective of this study was to produce a land cover map of Chefchaouen in order to determine the forest and pastureland cover based on remote sensing data. This study allowed us to identify four types of pasturelands (forest, pasture mixed with forest, pasture, and pasture mixed with cropland). According to the classification results, forest, pasture, and cropland cover an area of 39, 3.9, and 3.1%, respectively. The largest cover land was recorded by pasture mixed with cropland (51.5%). The land cover results of the forest class agree with the statistics data reported in the official reports, except for the land cover of classes including pastures, because they have never been studied before. Overall, this research makes a contribution to know the current land cover types in Western Rif for future interventions in order to develop and manage forest and pasture areas.

Keywords: Forest – Pasture – Land cover – Remote sensing – Northern Morocco.

Cartographie du couvert forestier et pastoral du Rif occidental (Chefchaouen)

Résumé

Le Nord du Maroc abrite les plus grandes forêts de chênes du pays, entourées d'une mosaïque agricole. La topographie montagneuse et la végétation forestière existante expliquent la forte prédominance du pâturage de chèvre dans ces bois. Malgré le rôle socio-économique et la prédominance des activités pastorales, en particulier dans le Rif occidental (Chefchaouen), il existe peu d'informations sur l'actuelle cartographie de la couverture terrestre des forêts et des pâturages. La cartographie est devenue un élément central des stratégies actuelles de gestion des ressources naturelles pour mettre en œuvre des politiques de développement appropriées. L'objectif de cette étude était de produire une la couverture terrestre de la région de Chefchaouen afin de déterminer la couverture forestière et pastorale à partir de données de télédétection. Cette étude nous a permis d'identifier quatre types de pâturages (forêt, pâturage mélangé à la forêt, pâturage et pâturage mélangé à des terres cultivées). Selon les résultats de la classification, la forêt, les pâturages et les terres cultivées couvrent une superficie de 39, 3,9 et 3,1%, respectivement. La plus grande couverture terrestre a été enregistrée par les pâturages mélangés à des terres cultivées (51,5%). Les résultats de la couverture spatiale de la classe forestière concordent avec les données statistiques rapportées dans les rapports officiels, sauf pour la couverture des classes comprenant les pâturages, car ils n'ont jamais été étudiés. Dans l'ensemble, cette recherche apporte une contribution pour connaître les types de couverture terrestre actuels dans le Rif occidental pour des interventions futures afin de développer et de gérer les zones forestières et de pâturage.

Mots clés : Forêt - Pâturage – Couverture terrestre - Télédétection - Nord du Maroc.

رسم خرائط الغطاء الغابوي والرعوي للريف الغربي (شفشاون)

الشبلي يوسف والعثماني سميرة

ملخص

يعد شمال المغرب موطن لأكبر غابات البلوط في البلاد، محاط بفسيفساء زراعية .تفسر التضاريس الجبلية والنباتات الحرجية الحالية الهيمنة القوية لرعي الماعز في هذه الغابات .على الرغم من الدور الاجتماعي والاقتصادي وهيمنة الأنشطة الرعوية، خاصة في الريف الغربي (شفشاون) ، هناك القليل من المعلومات حول رسم خرائط الغطاء الأرضي الحالي للغابات والمراعي .أصبح رسم الخرائط عنصرًا مركزيًا في استراتيجيات إدارة الموارد الطبيعية الحالية لتنفيذ سياسات التنمية المناسبة .كان الهدف من هذه الدراسة هو إنتاج خريطة الغطاء الأرضي لشفشاون من أجل تحديد الغطاء الحرجي والمراعي بناءً على بيانات الاستشعار عن بعد .سمحت لنا هذه الدراسة بتحديد أربعة أنواع من المراعي (الغابات، المراعي المختلطة بالغابات، المراعي، والمراعي الممزوجة بأراضي المحاصيل) .وفقًا لنتائج التصنيف، تغطي الغابات والمراعي والأراضي الزراعية مساحة 39 ,3,9 و 3,1% على التوالي .تم تسجيل أكبر غطاء من قبل المراعي الممزوجة بأراضي المحاصيل .تتفق نتائج الغطاء الأرضي لفئة الغابات مع البيانات الإحصائية الواردة في التقارير الرسمية، باستثناء استخدام الغطاء المكاني للفئات التي تتضمن المراعي، حيث لم يتم دراستها مطلقًا. بشكل عام، يقدم هذا البحث مساهمة في معرفة أنواع الغطاء الأرضي الحالية في الريف الغربي للتدخلات المستقبلية من أجل تطوير وإدارة مناطق الغابات والمراعي.

الكلمات المفتاحية : غابة - مرعى - غطاء أرضي - استشعار عن بعد - شمال المغرب.

Introduction

Forest and pasture ecosystems provide extensive services for human well-being, including provisioning, regulation (e.g. carbon sequestration), and cultural services (Robles, 2009; Tinch and Mathieu, 2011).

In Morocco, pasturelands cover an approximate area of 53 million ha, extending over ten large ecological groups, which differ from each other by the floristic composition and the edaphoclimatic conditions. Morocco stands out from other countries in North Africa by the importance of its forest domain. Forest formations (including Alfa) are mostly state-owned and cover an area of approximately 9.6 million hectares, i.e. a coverage rate of 13.5% of the national territory (MAPMDREF, 2018). This forest area provides up to 1.5 billion forage units annually (Mhirit and Benchekroun, 2006). The number of livestock grazing in the forest year-round amounts to more than 8 million heads, i.e. 32% of the national herd (FAO, 2011).

In Northern Morocco, especially in the Western Rif (Chefchaouen), forest and pasture areas contribute highly to herd feeding. Livestock production is related to goat grazing in forest areas. According to Chentouf et al. (2011), goat farming contributes between 68% and 100% to the region's total agricultural income. These areas have also a very important socio-economic functions for rural populations (Chebli et al., 2020a). In 2016, almost 6 million dirhams were generated through the logging of Western Rif (HCP, 2018).

However, forest and pasture areas are under pronounced degradation and are seeing their productivity decrease due to the soil degradation by accelerated erosion, drought recorded during the last three decades, and anthropogenic activities (e.g. greenhouse gas emissions, pollution, tourism and urbanization) linked to the modes of use of these lands. In addition, they are undergoing changes marked by the disorganization of traditional management systems, the rise of individualism, the extension of clearing and cultivation, and sedentarization (Chebli et al., 2018). This situation, which is particularly worrying, requires the setting up of an evaluation system and a management strategy for these ecosystems.

The mapping, quantifying and monitoring of land cover (LC) is essential to understand the current state of the landscape. They have become an important aspect of the current strategies for managing natural resources and monitoring environmental

changes to support land use and environmental policies (Grecchi et al., 2014; Forejt et al., 2017). The use of satellite-based remote sensor data has been widely applied to receive cost-effective LC data over large geographic regions (Lunetta et al., 2006). Remote sensing and Geographic Information System (GIS) data sets are the keys to get continuous spatio-temporal information about LC and vegetation dynamics (Evrendilek and Gulbeyaz, 2008).

Despite the socio-economic role of forested lands and the predominance of pastoral activities in Western Rif, there is little information about the current spatial land cover of forests and pasture areas in a specific area such as that of Chefchaouen. Several studies about LC have focused only on urban growth, erosion, and carbon stocks (Sadiki et al., 2004; Mastere et al., 2013; Marraccini et al., 2015; Maanan et al., 2019). Only a study was delineated spatially the major LC types on a regional scale of Northern Morocco (Chebli et al., 2018), particularly forest and silvopastoral areas, and assessed LC changes and transition over a period of 30 years (1984–2014).

The goal of this study was to spatially delineate the current major LC types in the Western Rif of Northern Morocco, particularly forest and pastureland.

Material and methods

Study area

The study area (Chefchaouen) is located in Western Rif of Northern Morocco between 34° 46’ – 35° 26’ N and 4° 27’ – 5° 34’ W, on the massif of Jebala, over an area of 3,443 km². It is a part of the Tangier-Tetouan-Al Hoceima region. Chefchaouen is delimitated in the north-west by Tetouan, to the north-east by the Mediterranean over a length of 120 km, to the east by Al Hoceima, to the south-east by Taounate, to the southwest by Ouezzane and to the west by Larache (Figure 1). The Western Rif is characterized by its geographical location, as well as its climatic, geomorphological, and socio-economic context. The climate is characterized by rainy and cool winters from October to April and dry and hot summers from May to September. The local expression of this climate is strongly influenced by the altitude and proximity to the coasts. These influences divide the region into several bioclimatic zones of Mediterranean type (hyper-humid, humid, and sub-humid). In general, precipitation exceeds 700 mm/year and the torrential rainfall is the main cause of the violent floods

that affect the region. Temperature ranges from 3 to 14 °C in winter and from 18 to 38°C in summer (Chebli et al., 2018).

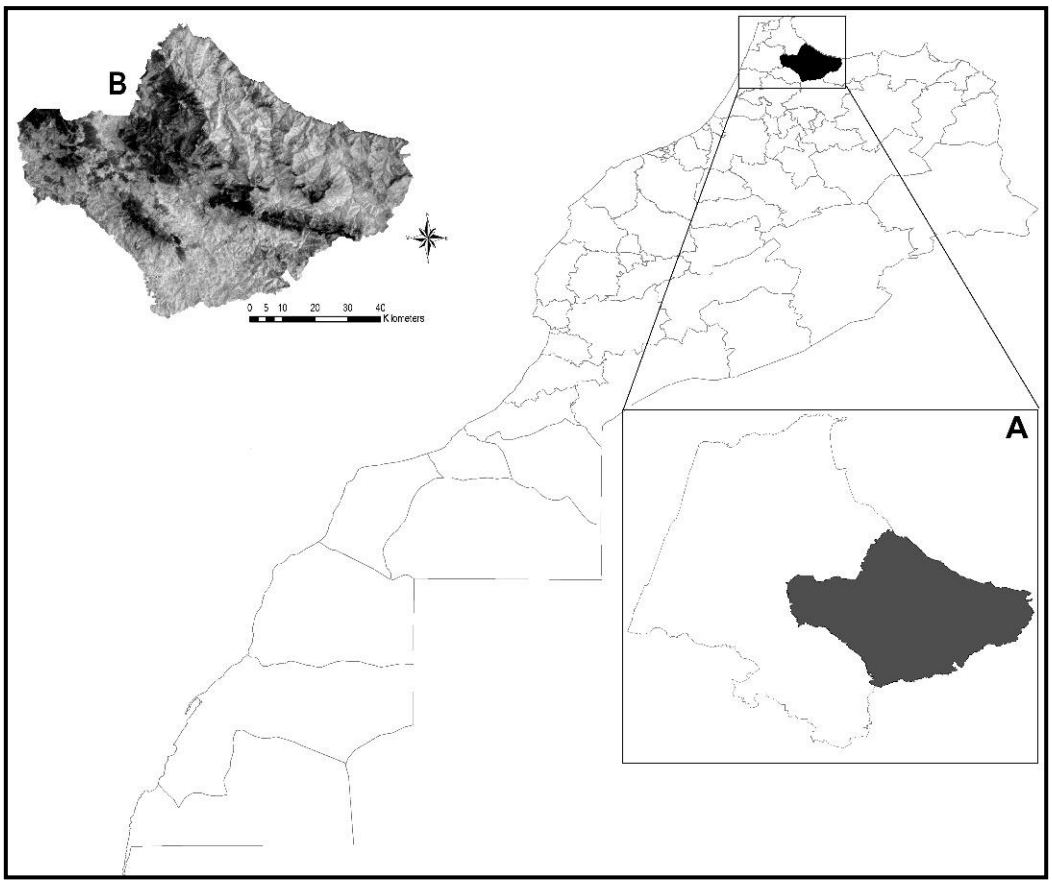

Figure 1: Location of the study area (A: Northern Morocco; B: Chefchaouen).

The population is about 457,432, i.e., 12.8% of the total population of the Tangier-Tetouan-Al Hoceima region and 1.3% of the national population. The provincial urbanization rate was 12.5% against 59.9% regionally, and 60.4% nationally (HCP, 2018). The study area is characterized by a rugged and tormented topography with a low level of mechanization and irrigation that handicap the development of agriculture and promote the emergence of traditional agriculture largely dependent on climate hazards. This traditional agricultural system combines subsistence cultivation (cereal crops), olive trees, and an extensive livestock system practiced by over 90% of the rural population. Most of the farms are small and family-run (Chebli et al., 2018). Land operated by farms is smaller than 5 ha, reflecting land fragmentation in most rural areas of Northern Morocco (DRATT, 2015). Livestock production is mostly related to the grazing of goats in forests and pasturelands.

Methodology and data acquisition

This study is based on spatial remote sensing and GIS data as well as non-spatial data available from various sources.

Remote sensing data and analysis

The available data are an image scene coming from the operational land imager/ thermal infrared sensor (OLI/TIRS) images, with 30m of spatial resolution on board of Landsat 8 satellite, at the dates of July 18th, 2019 (Figure 2). This date was chosen because the image scene was clear and nearly free of clouds (total cloud cover less than 10%) compared to other dates. A single satellite image was needed to cover the studied area. It was ordered from the United States Geological Survey (USGS) Earth Resources Observation and Science Data Centre (EROS). These images were acquired in Universal Transverse Mercator (UTM) projection system (zone: 30N, datum: WGS-84). Table 1 summarizes the characteristics of the Landsat image used for this study.

Table 1: Characteristics of the Landsat image used for this study.

Acquisition Date	Satellite	Sensor Identifier	Land Cloud Cover	Path	Row	Sun Elevation	Azimuth Angle
18, July 2019	Landsat 8	OLI_TIRS	0.03	201	36	66	118

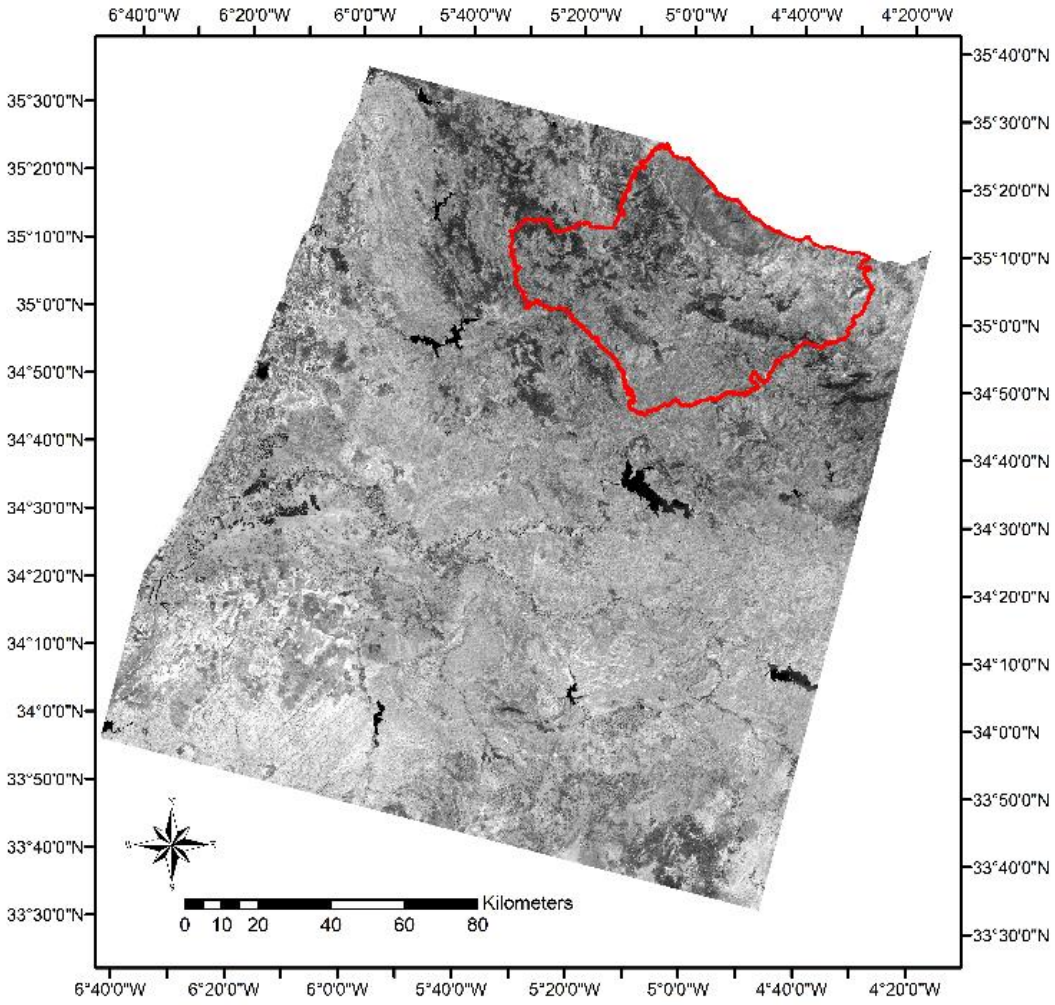

Figure 2: Landsat 8 OLI/TIRS scene of the studied area.

Based on our prior knowledge of the land cover from previous studies, the supervised classification approach was used in classifying the images, and the maximum likelihood classification (MLC) algorithm was applied. MLC is one of the most widely used in the classification of satellite imagery and the most effective method for supervised classification (Wasige et al., 2013; Tso and Mather, 2016). The method is based on the likelihood that each pixel belongs to a particular class. The basic theory assumes that these likelihoods are equal for all classes and that input bands are uniformly distributed. The method requires a significant calculation time and is based on a normal distribution of the data in each band in the classification. It tends to over-classify signatures with relatively large values in the covariance matrix (Vorovencii and Muntean, 2013). Image processing software has been used for geometric correction of satellite data, supervised classification, accuracy assessment of classification and final output maps etc. Accuracy assessment was performed by comparing differences

between observed points located on the ground and classified points yielded (Congalton, 1991). Based on Congalton et Green (1999), 320 reference pixels were randomly selected representing all land cover classes and compared by compilation of 200 systematic points from Google Earth Pro and 120 points located on the ground to check the accuracy of the classified maps. The accuracy assessment procedure was used to improve the classification accuracy of the classified images (Shalaby and Tateishi, 2007). We used the overall accuracy and the Kappa coefficient in order to evaluate the quality of the classified images.

Based on our prior knowledge of land use in the study area and the classification of the regional direction of agriculture (DRA) of Tangier, seven major land cover classes were used: (i) forest; (ii) pasture mixed with forest; (iii) pasture; (iv) pasture mixed with cropland; (v) cropland; (vi) built-up area; and (vii) water (Table 2; Figure 3). In addition to the land cover map, we focused on the forest class in order to produce a second more detailed map about the predominant kind of tree species that covered the forested land.

Table 2: Description of the land cover types considered in the study.

Land use types	Description
Forest	Continuous forest with trees and shrubs, maybe grazed as well (silvopastoral area)
Pasture mixed with forest	Grassland for grazing (rangeland) mixed with matorral (degraded forest)
Pasture	Grassland for grazing
Pasture mixed with cropland	Grassland for grazing mixed with cultivated areas
Cropland	Cultivated land for cereals, fodder crops, and arboriculture
Built-up area	Constructions and man-made structures
Water	Dams, ponds, and rivers

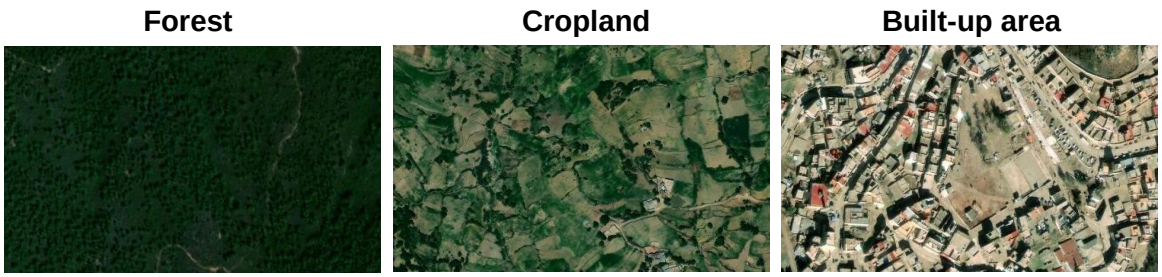

Figure 3. Example of land cover classes (USGS images of Chefchaouen).

Additional information

In addition to spatial data, quantitative and qualitative data were used to conduct this study. Overall, a review of existing quantitative data on forestry, pasture, and agriculture issues was conducted through statistical data and official reports obtained from national and regional administrations. This review was complemented by direct observations and some open interviews on the field with local farmers, that provided qualitative insights as to the use and history of forest and pasture resources. Due to the regional political context, the farmers are very prudent concerning the formal interviews (structured and semi-structured questions) about forest and pasturelands. In our case, open interviews constituted the only resort. This type of interview was based mainly on a direct discussion with farmers about the forest and pasture areas and grazing traditions.

Results and Discussion

Land cover analysis

The present study was conducted in order to analyze land cover in Western Rif of Northern Morocco using uniform 30 m spatial resolution Landsat image. Error matrix were used to assess the producer's and user's accuracy statistics and were summarized in Table 3. It should be pointed out that the producer's accuracy refers to the probability that the classifier has labeled an image pixel belong to a specific class given that the ground truth is in the same class. The user's accuracy refers to the probability that a pixel belongs to a specific class, given that the classifier has considered the pixel in the same class. Based on the accuracy assessment table, the lower values of the producer's accuracy are referring to the pasture mixed with forest and cropland classes. For the user's accuracy, the lower values were recorded with pasture class. All others mentioned producer's and user's accuracies values are above 80%. The confusion matrix highlighted a slight overestimation of the forest and pasture covers. Underestimation of cropland to the detriment of forested, and pasture to the detriment of pasture mixed with cropland was highlighted. Confusions between forest and cropland classes, and between pasture and pasture mixed with cropland introduced small commission and omission errors. Overall classification accuracy of the land cover map obtained from the supervised classification, assessed using the 320 reference points, was 85.3% and a kappa value of 0.82. According to Anderson et

al. (1976), an overall accuracy higher than 85% means that the study is good. In addition, Landis and Koch (1977) established a qualitative classification scale based on the values of the Kappa coefficient. These authors reported that a value of Kappa coefficient greater than 0.80 (i.e., 80%) represents strong agreement between the classified results and reference data.

Table 3: Error matrix and accuracy of land cover map.

	Forest	Pasture mixed with forest	Pasture	Pasture mixed with cropland	Cropland	Built-up area	Water	Total
Forest	**77**	2	1	1	9			90
Pasture mixed with forest	1	**8**	1					10
Pasture	2	2	**43**	9	3	1		60
Pasture mixed with cropland		2	3	**73**	2			80
Cropland	4	1	2	1	**42**			50
Built-up area						**25**		25
Water							**5**	5
Total	84	15	50	84	56	26	5	320
Producer's accuracy (%)	91.7	53.3	86.0	86.9	75.0	96.2	100	
User's accuracy (%)	85.6	80.0	71.7	91.3	84.0	100	100	

Note: Correctly classified samples are shown in bold.

Figure 4 shows the spatial distribution of land cover map of Western Rif for the year 2019. Forest covered 39.1% of the Western Rif territory (Figure 5). This forested land is mostly concentrated in mountainous areas. A similar result about the area of forest cover was reported by several data sources (official reports and regional statistics). According to the HCP (2018), forested lands cover an area of 135,076 ha which represents 39.2 % of the land cover of the studied area. Forests are dominated by natural deciduous trees, which constitute almost 2/3 with 72.2%. Table 3 suggests that, 9% of cropland was considered as forested land. This confusion between forest and cropland classes could be explained by the olive plantations expansion inside forest areas. That was also confirmed by Chebli et al. (2018), who studied the forest and silvopastoral cover changes in Northern Morocco.

As reported by Chebli et al. (2020b), and confirmed by direct observation and interview with local herders, the majority of forested lands in the study area are covered by heterogeneous vegetation composed mainly of three distinct groups of plant species: herbaceous (mainly grass and forbs), shrubs (strawberry tree (*Arbutus unedo* L.); spiny broom (*Calicotome villosa* (Poir.) Link); *Cistus spp*. inclusive of wrinkle-leaved (*C. crispus*), Montpellier (*C. monspeliensis*), and sage-leaved (C. *salviifolius*) rockroses;

tree heath (*Erica arborea* L.); topped lavender (*Lavandula stoechas* L.); common myrtle (*Myrtus communis* L.); broad-leaved phillyrea (*Phillyrea media* L.); lentisk (*Pistacia lentiscus* L.); kermes oak (*Quercus coccifera* L.); elm-leaf blackberry (*Rubus ulmifolius* Schott.); and trees (Oak species (*Quercus spp*.) inclusive of Algerian (*Q. canariensis* L.), holm (*Q. ilex* L.), and cork (*Q. suber* L.) oaks; and European olive (*O. europaea* var. *sylvestris* (Mill) Lehr).

Pasture mixed with cropland was the dominant class with 51.5%. Pasture (3.9%), cropland (3.1%), built-up area (1.4%), pasture mixed with forest, and water (0.1%) classes cover the rest of the study area (Figure 5). According to the recent regional statistics, cropland was estimated to 106,860 ha (31%), of which the private (Melk) lands are the most dominant with 99%. Irrigation concerns only 9,353 ha, reflecting a low irrigation rate of 8.8% (DSS, 2019). Underestimation of cropland cover (3.2%) compared to the ground truth could be explained by the presence of a new cover type that included pasture and cropland classes called pasture mixed with cropland. It should be noted that cereal crops are the most prevalent in the province of Chefchaouen since it occupies an area of 23,100 ha, or 21.6% of the study area despite the rugged nature of the relief. Legumes are cultivated on 3% of the cropland, i.e. an area of 3,220 ha (HCP, 2018). The acquisition date of satellite images (July) that coincides with the summer season (harvest season), might have affected the results, mainly for land reserved for annual crops, which are considered as pastureland (4%) or pasture mixed with cropland (2%). The rest of cropland areas are represented by tree plantations. These trees extend over an area of 52,013 ha (15.1%). The olive tree remains the most widespread with 83% of the areas devoted to this type of crop (HCP, 2018). According to the Table 3, 8% of cropland, mainly olive plantations, were confused with forested land. This confusion is due to the development of cultivation inside forest areas. As confirmed by Chebli et al. (2018) and by direct observation, the agricultural expansion is mainly developed inside forested land sheltered from local authorities. The direct transition of the forest to cultivated land is explained by the development of shifting cultivations (cannabis and cereal crops) requiring new cultivation fields (through clearing) inside forested land (Chebli et al., 2018). This trend has been also confirmed by Grovel (1996) and Aubert (2013).

Regarding to the pasture class, there is no available data about their current cover that could be due to considering pasture in official reports as fallow land and thus included as part of cropland. On the other hand, based on direct observation in the field, the pasture class is presented on the form of mixtures units, where the pasture is interspersed with cropland. These pasturelands are often located on rugged terrain (hill, rocky outcrops, etc.), where the natural vegetation based on *Chamaerops humilis* (dwarf palm tree), *Asphodelus microcarpus* (asphodel), and *Calicotome villosa* (spiny broom) have not been affected by cultivation. These spaces are in the form of small islets with a very small surface area (less than 20 ha).

Forest and pasture mixed with forested land are a part of the forest domain. The users of these forested lands, principally herders, are mainly concentrated around the forest, to guarantee permanent access to the grazing areas. The seasonal mobility of the goat herd is practically absent in the study area. The forest pasture is used throughout the year without taking into account the stocking rate. According to farmers' interviews, grazing goats start each day after milking and finished around sunset and sometimes a little earlier when herder is forced to go back home due to the rainfalls or due to the extreme heat. Grazing is practiced from mid-winter to mid-autumn. During winter, animals graze near to the farm, during a very limited grazing time not exceeding 3 hours per day. Thus, goat feeding comes from the tree branches, which are taken by delimbing. Herders take care of the delimbing and transporting the branches to the goat shed. This operation is carried out several times a day depending on the herd size and the duration of precipitation.

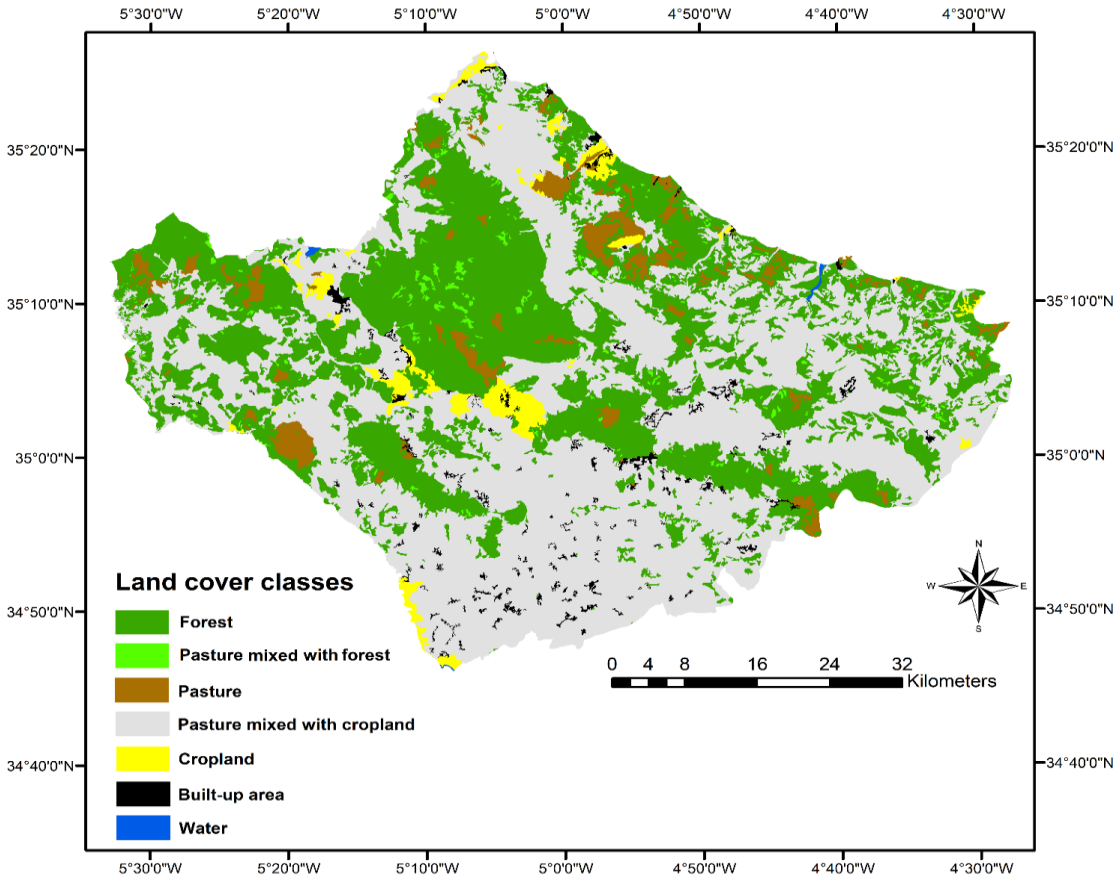

Figure 4: Land cover map of Western Rif (Northern Morocco).

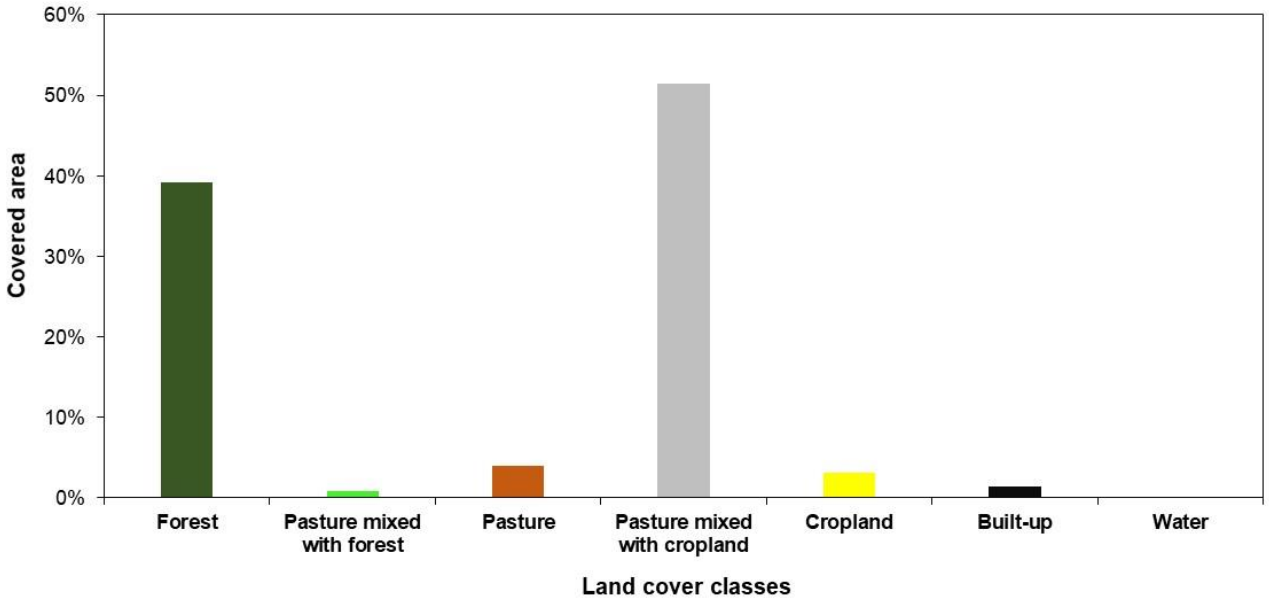

Figure 5: Spatial importance of land cover types of Western Rif (Northern Morocco).

Forest cover types analysis

Figure 6 shows the forest cover per class of tree species. To be noted that areas not classified as forest (non-forest land) are not included. The classification overall accuracy was 72.1%. The high confusion between tree species cover could explain this result. The results showed that oak trees class (42.2%) are the predominant forest cover for the study area (Figure 7). This forest type is mostly represented by two tree species: holm and cork oaks. Approximately 21% of the forest area is covered by thujas (*Tetraclinis articulate*). This forest tree is the most dominant species on the Northeastern side of the study area, where the complex cropland patterns and land mainly occupied by pasture mixed with cultivation areas and matorrals. The matorral is an intermediate type of the forest land. A part of the forest domain, it is considered as a degraded forested land, dominated mainly by shrubs and herbaceous strata (Benabid, 2002). As shown in the result of forest cover classification (Figure 7), this type of forest land occupied 13.6% of the forest area. Fuelwood extraction, shifting cultivation and tree delimbing for livestock feeding are the main drivers of forested land regression to matorral in Northern Morocco (Chebli et al., 2018). According to the DREFLCD-Rif (2017), matorral cover was estimated at 23.6% of forest area. Underestimation of matorral class could be explained by their high confusion with others land cover classes or their early transition to cropland and reforestation.

Pine (7.3%) and fir (Abies 3.5%) trees are concentrated in the middle of the study area, on the high altitudes. The cedar trees occurring at an altitude of 1,000–2,200 m in the study area, covers only 2.8 % of forested land (Figure 7). According to the last national forest inventory of 2006, pine, fir, and cedar trees covered 11%, 2%, and 2%, respectively (Mharzi Alaoui et al., 2017). The decrease of pines could be explained by the cover changes between 2006 and 2019. On the other hand, the fir increase is explained by the reforestation actions.

Reforestation areas were also detected and delineated. Their classification cover was estimated at 10.2% of the forested land. The reforestation actions are realized in degraded forests and explain why the matorrals represent the largest areas converted to reforestation in Northern Morocco (Chebli et al., 2018). According to DREFLCD-Rif (2016), reforestation covered 11.9 % of the forest area. The pine is largely used for

reforestation (95%), followed by cedar (1.4%) and oak cork (1.2%). The reforestation programs are carried out to preserve and develop this economic and ecological wealth and to fight against the degradation to which it is subject (human and animal pressure, fires). The slight underestimation of the reforestation is probably attributed to the confusion with other forest types.

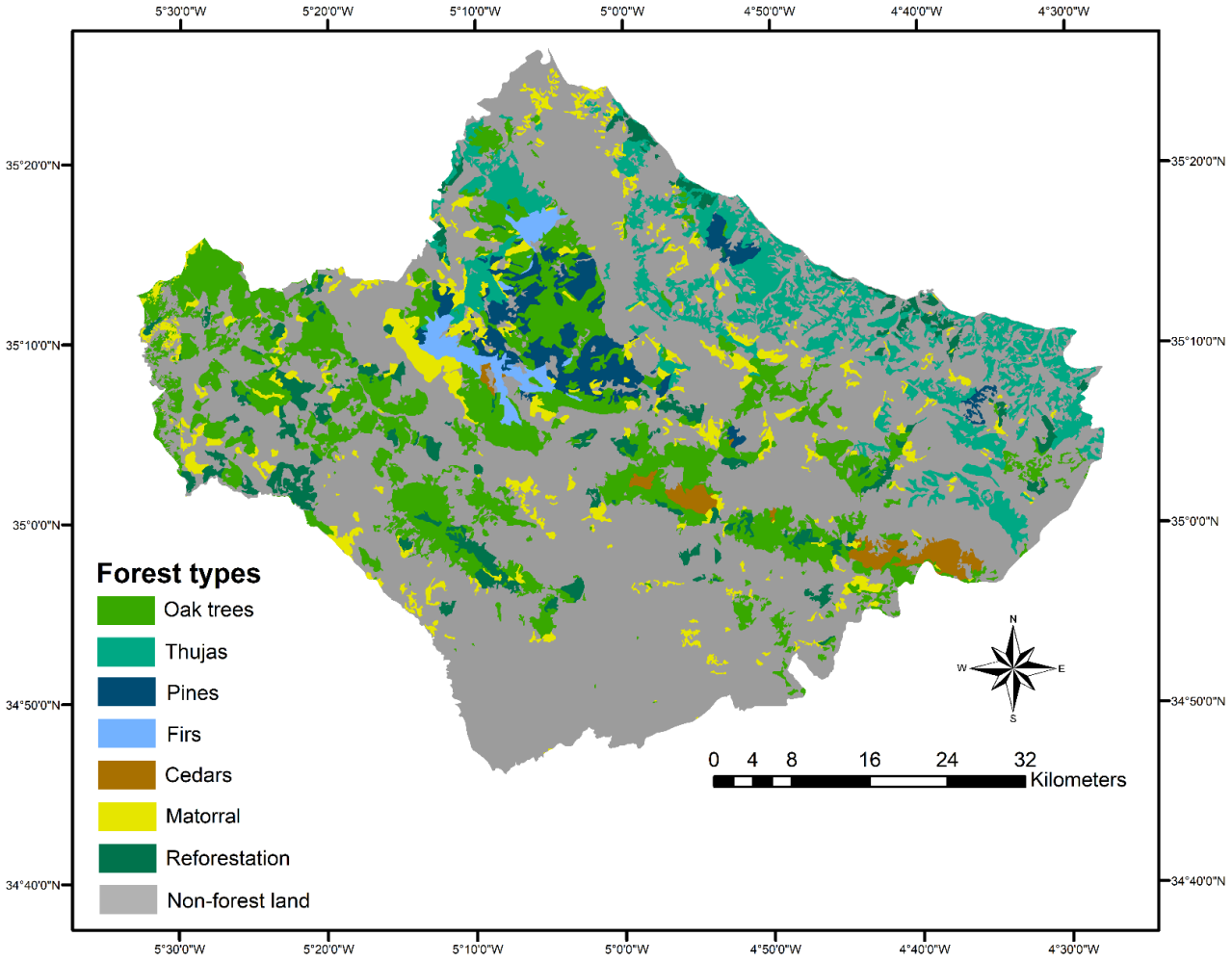

Figure 6: Forest types cover of Western Rif (Northern Morocco).

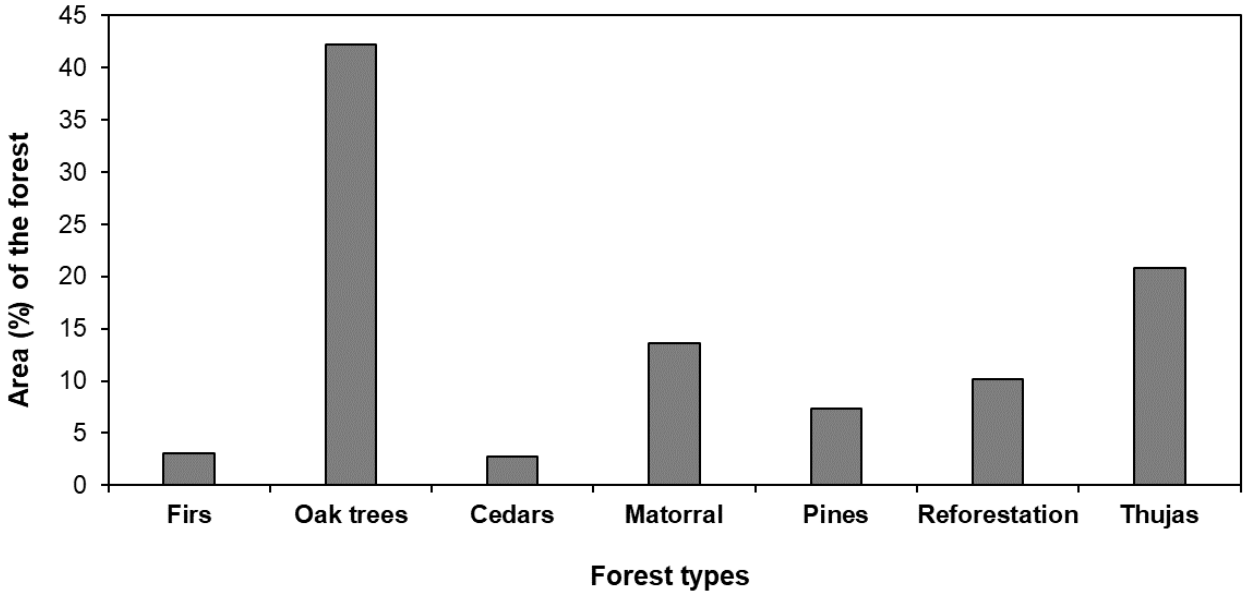

Figure 7: Spatial importance of forest cover types in Western Rif (Northern Morocco).

Conclusions

This study contributes to provide data about the current major land cover types in the Western Rif of Northern Morocco, particularly forest and pastureland, and the land cover of different forest types. To overcome this challenge, we adopted classification image approach to map land cover and forest types of Western Rif in Northern Morocco. This approach enabled us to delineate spatially different landscape of the study area. Our results demonstrated that the percentage of pasture mixed with cropland areas represents the largest cover of the total province area. The percentage of forested land was approximatively estimated at 40% of the total study area. This forested land is covered mainly by trees species (86.4%). The resulting land cover maps proved to be useful exploratory tools to evaluate the current state of forest and pastureland. They must be considered in future actions focusing on landscape management.

Finally, an integrated understanding of the impact of forest and pastureland change future scenarios on land management in the study area needs to be developed, taking into account the full complexity of these multifunctional lands, including social, environmental, and economic components.

References

Anderson J. R., Hardy E. E., Roach J. T. and Witmer R. E. (1976). A land use and land cover classification system for use with remote sensor data. Geological Survey Professional Paper. 964. p. 1–28. https://doi.org/10.3133/pp964.

Aubert P. M. (2013). Les évolutions de la politique forestière au Maroc : Entre réappropriation du modèle forestier français et idéalisation de la tribu. Revue Forestière Française. 4. p. 305–316. https://doi.org/10.4267/2042/53627.

Benabid A. (2002). Le Rif et le Moyen Atlas (Maroc) : Biodiversité, menaces, préservation. Conference paper at the mountains high summit conference for Africa. Nairobi: UNEP, May 2002.

Chebli Y., Chentouf M., Ozer P., Hornick J.L. and Cabaraux J.F. (2018). Forest and silvopastoral cover changes and its drivers in Northern Morocco. Applied Geography. 101. p. 23– 35. https://doi.org/10.1016/j.apgeog.2018.10.006.

Chebli Y., El Otmani S., Hornick J.L., Cabaraux J.F. and Chentouf M. (2020a). Pastoral production and use of forest rangelands in Western Rif. African and Mediterranean Agricultural (AFRIMED) Journal - Al Awamia. 128. p. 1–16. http://www.afrimed.ma/index.php/AFRIMED/article/view/3/2.

Chebli Y., El Otmani S., Chentouf M., Hornick J.L. and Cabaraux J.F. (2020b). Foraging behavior of goats browsing in southern Mediterranean forest rangeland. Animals. 10.p.1–19. https://doi.org/10.3390/ani10020196.

Chentouf M., Zantar S., Doukkali M.R., Farahat L.B., Jouamaa A. and Aden H. (2011). Performances techniques et économiques des élevages caprins dans le Nord du Maroc. Options Méditerranéennes. 100. p. 151–156.

Congalton R.G. (1991). A review of assessing the accuracy of classifications of remotely sensed data. Remote Sensing Environment. 37. p. 35–46. https://doi.org/10.1016/0034-4257(91)90048-B.

Congalton R. G., Green K. Assessing the accuracy of remotely sensed data: Principles and practices, CRC Press: New York, 1999, 183 p. In Grenier M., Labrecque S., Benoit M., Allard M. Accuracy assessment method for wetland object-based classification

DRATT (Direction Régionale de l'Agriculture de Tanger-Tétouan). (2015). Monographie de la région du Nord du Maroc. Rapports et données statistiques sur l'agriculture et l'élevage.

DREFLCD-Rif (Direction Régionale des Eaux et forêt et Lutte Contre la Désertification du Rif du Rif). (2016). Superficie des forêts reboisées et naturelles, province de Chefchaouen.

DREFLCD-Rif (Direction Régionale des Eaux et forêt et Lutte Contre la Désertification du Rif du Rif). (2017). Annuaire Statistique National.

DSS (Direction de la stratégie et statistiques). (2019). Structure de la SAU et nombre d'exploitations par province/préfecture au Nord du Maroc.

Evrendilek F. and Gulbeyaz O. (2008). Deriving Vegetation Dynamics of Natural Terrestrial Ecosystems from MODIS NDVI/EVI Data over Turkey. Sensors. 8. p. 5270–5302. https://doi.org/10.3390/s8095270.

FAO (Food and Agriculture Organization of the United Nations). (2011). Faostat. FAO Statistics Division. www.fao.org/faostat/en.

Forejt M., Skalos J., Pereponova A., Plieninger T., Vojta J. and Santruckova M. (2017). Changes and continuity of wood-pastures in the lowland landscape in Czechia. Applied Geography. 79. p. 235–244. https://doi.org/10.1016/j.apgeog.2016.12.016.

Grecchi R. C., Gwyn Q. H. J., Bénié G. B., Formaggio A. R. and Fahl F. C. (2014). Land use and land cover changes in the Brazilian Cerrado: A multidisciplinary approach to assess the impacts of agricultural expansion. Applied Geography. 55. p. 300–312. https://doi.org/10.1016/j.apgeog.2014.09.014.

Grovel R. (1996). La préservation des forêts du Rif centro-occidental : Un enjeu de développement de la montagne rifaine. Revue de Géographie Alpine. 4. p. 75–94. https://www.persee.fr/doc/rga_0035-1121_1996_num_84_4_3887.

HCP (Haut-Commissariat au Plan). (2018). Monographie provinciale de Chefchaouen. Direction Régionale de Tanger-Tétouan-Al Hoceima. HCP Edition. 109 pages. https://www.hcp.ma/region-tanger/attachment/1044497/.

Landis J. T. and Koch G. G. (1977). The measurement of observer agreement for categorical data. Biometrics. 33(1). p. 159–174. https://doi.org/10.2307/2529310.

Lunetta R.L., Knight F.K, Ediriwickrema J., Lyon J.G. and Worthy, L.D. (2006). Landcover change detection using multi-temporal MODIS NDVI data. Remote Sensing of Environment. 105. p. 142–154. https://doi.org/10.1016/j.rse.2006.06.018.

Maanan M., Karim M., Rueff H., Snoussi M. and Rhinane H. (2019). Modelling the potential impacts of land use/cover change on terrestrial carbon stocks in north-west Morocco. International Journal of Sustainable Development and World Ecology. 26 (6). p. 560–570. https://doi.org/10.1080/13504509.

MAPMDREF (Ministère de l'agriculture, de la pêche maritime, du développement rural et des eaux et forêts). (2018). Forêts en chiffre. Département des eaux et forêts.

Marraccini E., Debolini M., Moulery M., Abrantes P., Bouchier A., Chéry J. P., Sanz E., Sabbatinig T. and Napoleone C. (2015). Common features and different trajectories of land cover changes in six western Mediterranean urban regions. Applied Geography. 62. p. 347–356. https://doi.org/10.1016/j.apgeog.2015.05.004.

Mastere M., Van Vliet-Lanoë B. and Ait Brahim L. (2013). Land use mapping and its relation to mass wasting and gullying in North-Western Rif (Morocco). Géomorphologie: relief, processus, environnement. 19 (3). p. 335–352. https://doi.org/10.15201/hungeobull.65.3.6.

Mharzi Alaoui, H., Assali, F., Rouchdi, M., Lahssini, S., Tahiri, D. (2015). Analyse de l'interaction entre l'éclosion des feux de forêts et les types de bioclimat au nord du Maroc - cas de la région du Rif occidental. Revue Marocaine des Sciences Agronomiques et Vétérinaires, 3, 46–53.

Mhirit O. and Benchekroun F. (2006). Les écosystèmes forestiers et periforestiers : Situation, enjeux et perspectives pour 2025. Contribution au rapport sur le développement Humain. p. 393–483.

Robles A. B. (2009). The Mediterranean pastures and silvopastoral systems: basic concepts. In the Mediterranean pastures and silvopastoral systems: Basic concepts. AECID Edition. p. 59–69.

Sadiki A., Bouhlassa S., Auajjar J., Faleh A. and Macaire J.J. (2004). Utilisation d'un SIG pour l'évaluation et la cartographie des risques d'érosion par l'équation universelle des pertes en sol dans le Rif oriental (Maroc) : cas du bassin versant de l'oued Boussouab. Bulletin de l'Institut Scientifique. 26. p. 69–79.

Shalaby A. and Tateishi R. (2007). Remote sensing and GIS for mapping and monitoring land cover and land-use changes in the Northwestern coastal zone of Egypt. Applied Geography. 27. p. 28–41. https://doi.org/10.1016/j.apgeog.2006.09.004.

Tinch R. and Mathieu L. (2011). Marine and coastal ecosystem services: valuation methods and their practical application. United Nations Environment Programme - World Conservation Monitoring Centre. Biodiversity series. 33. 47 pages

Tso B. and Mather P. (2016). Classification methods for remote sensed data (2nd ed.). London: Taylor & Francis. http://doi.org/10.1201/9781420090741.

Vorovencii I. and Muntean M.D. (2013). Evaluation of Supervised Classification Algorithms for Landsat 5 TM Images, RevCAD 14/2013.

Wasige J. E., Groen T. A., Smaling E. and Jetten V. (2013). Monitoring basin-scale land cover changes in Kagera Basin of Lake Victoria using ancillary data and remote sensing. International Journal of Applied Earth Observation and Geoinformation. 21. p. 32–42. https://doi.org/10.1016/j.jag.2012.08.005.