Pastoral land use intensity and grazing damage in Al-Jabal Al-Akhdar, Libya

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Abstract: Extensive co-grazing in the Libyan Al-jabalAlakhdar region is a traditional anthropogenic stress but it has not been systematically evaluated at district level. Land cover of a 90,000 ha study area was mapped by remote sensing and GIS with field survey verification in order to classify land cover, calculate livestock numbers at each unit and evaluate the capacity of each unit. Evaluation of Actual Stocking Rate (ASR) is based on number of livestock, area over which livestock are spread and elevation of its number caused by importing forage. The livestock rates vary geographically so, to calculate a more spatially accurate ASR a raster grid used to give 217 units. The outcomes compared with Government records. Therefore the ASR is organised and presented in terms of frequency distributions for each land cover class. The ASR then adjusted by calculate the mass of supplemental forage which is about 50 kg 100 H^{-1} day^{-1} over a three-month period in a year. Calculation of sustainable stocking rate (SSR) depends on required annual biomass intake per animal (R), average fraction of the soil surface covered with annual plant species and edible shrubs (F), averaged palatable biomass after a dry season (P), and X which is a variable that considers both grazing efficiency, as animals do not eat 100% of plants. This study applied three different scenarios to evaluate the factor X. First proposal, the total edible biomass from the sample plots is multiplied by 0.5. Second scenario, X = 0.5 for the annual grass and X = 1 for the shrubs. Third scenario, the value of X is X = 0.5 for the annual grass and adjusted to consider the potential impact of plants palatability. The third scenario gives the best correlation with observed grazing damage at 0.92.

The new outcomes has not been attempted elsewhere, new procedure in calculation of ASR and SSR resulted in improved correlation with an index of environmental damage caused by grazing is presented. The biomass from grass decreases as from shrubs increases as the percentage of cover increases the total biomass is approximately constant at about 815 kg ha^{1}.

Keywords: land use intensity, grazing damage, Libyan Al-jabalAlakhdar region.

Introduction

The purpose of this research is to examine objectively the currently poorly substantiated belief that the grazing of sheep and goats is an inappropriate land use that is ultimately responsible for deterioration of vegetation cover in Al-Jabal Al-Akhdar, Libya. Nationally, the Barbary breed constitutes 95% of sheep (Akraim et al. 2008) and 90% of goats are the local (Mahali) breed, with this latter percentage likely to be higher in the study area (Ahtash et al. 2010). Small ruminant co-grazing can have positive impacts, particularly efficient

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anthropogenic use of available biomass (Animut & Goetsch 2008; Estell et al. 2012) in an environment that is subject to short term climatic variations. It may reduce fire risk and increase biodiversity as plants exploit animals as vectors of seed dispersal. Heavy grazing can however result in negative impacts such as significant reductions in cover, species richness and primary production, and an increase in less palatable or poisonous species (e.g. Gamoun 2014; Louhaichi et al. 2009). Various indicators of grazing impact have been identified (e.g FAO 1991) which benefit from the integration local expert knowledge. An understanding of how these relate to the intensity of land use is of interest as stocking rates are not under control of the landscape is not being promoted here, particularly as the relative importance of communal compared to managed systems for rangeland (e.g. Rowntree et al. 2004), knowledge the response of this and other semi-arid landscapes to a range of grazing intensities can only help inform sustainable land use. It is believed that developing an understanding of any spatial complexity is an appropriate first priority, whilst recognising the importance of temporal variations, and is an approach adopted by others (e.g. Ludwig et al. 2004).
The carrying capacity is the number of animals that can be placed on a pasture or rangeland for an entire season without harming it (Evlagon et al. 2012), i.e. when ASR/SSR <1. However in previous studies, there is little mention of how to quantify environmental impact and its relation to carrying capacity (Mysterud 2006; Pietikainen 2006; Nilsson 2001; Oba & Kaitira 2006). Consequently, the relationship between carrying capacity of the land or grazing pressure and degradation of the natural land needs to be quantified (Kosmas et al. 2011). This is of particular importance in this study. Currently, grazing is the primary land use, it is appropriate however to consider the natural areas as pasture land. It is an established fact that there are a number of measurements used to evaluate and assess the condition of the natural or modified vegetation cover in a specific area including ground-layer, trees and shrubs. Some of these measurements were suggested by important international agencies such as the (FAO 1991). The intensity of land use (in the study area grazing intensity), will be determined by evaluating the ratio of the actual stocking rate (ASR) (number of animals grazed within a particular area over a year), to the sustainable stocking rate (SSR) (number of animals that can be supported by the biomass produced on an area of land during a year). The aim of this paper is therefore to investigate whether the quality of management in the natural areas can be defined by intensity of grazing. This will be achieved by meeting the following objectives. Firstly, the intensity of land use from grazing animals will be determined for the land cover classes of natural land in the study area by establishing the actual and sustainable stocking rates. Secondly, this intensity of land use will be compared against the environmental damage observed in the field from grazing pressure.

Material& methods

Study area: The study area (Aljabal Alakhdar region) is located on the east side of Libya; it represents about 1% of the total area of Libya (Figure 1). The area study is located between longitudes 21° 13´ and 21° 40´ E, and between latitudes 32º 38´ and 32° 29´ N. Al-jabal Alakhdar represents about 1% of the country’s total area but it contains about 50% of its total plant species: 1,100 out of the 2,000 species found in Libya (Omar Al-Mukhtar University 2005).

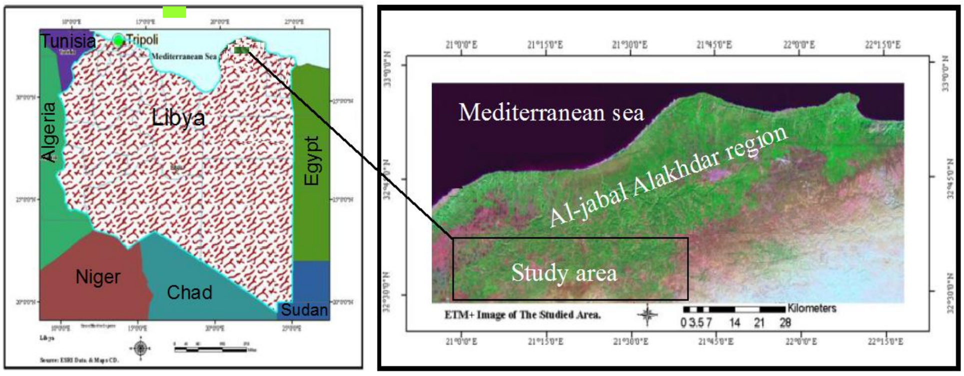


Figure (1). Map of Libya, with study area.

Many plant species are present in the study area, including trees, shrubs, grass. Some are annual and others are perennial or evergreen. The vegetation cover is exposed to degradation and some species have become almost non-existent because of human activities. All the vegetation cover in the study area can be considered drought-resistant and gives a high level of protection to the soil from water erosion; however, the majority of such cover is not fire-resistant (Omar Al-Mukhtar University 2005). There are a number of different types of trees in the study area, such as; *Ceratonia siliqua.*, *Juniperus phoenicea.*, *Cupressus sempervirens* L., *Olea europaea* Var., *Pinus halepensis* Mill., *Pistacia lentiscus.*, *Atemisia alba-alba.*, *Salvia fruticosa.*, *Thymus capitatus.*, *Arbutus pavarii.*, *Pitoranthos tortousus.*, *Solanum nigrum.*, *Ouercus coccifera.*, *Zizyphus lotus.*, *Lonicera japonica.*, *Sanguisorba officinalis.*, *Marrubium vulgare.*, *Peganum harmala.*
The Al-jabal Alakhdar region has more rainfall than other regions in Libya, with an average annual rainfall of 450 mm $yr^{-1}$and a maximum of 550 mm yr^{-1}. During the summer season (June, July and August), the temperature is about 30°C and precipitation is less than five mm. Drought during summer affects all vegetation cover and leads to a complete death of the annual grass. However, the remaining seasons have low temperatures and higher precipitation, particularly between November and March (Omar Al-Mukhtar University 2005). The total study area is about 90,000 hectares and contains the small agriculturally based towns of Marawah, Gandolla, Omar Al-Mukhtar, Al Bayyadah, Al Awylia and Taknis.

Data collection: A thematic map derived from the ERDAS IMAGINE. Land cover map of August 2015 had digital image processing. Optical imagery requires atmospheric correction or normalization, image registration, radiometric correction, and geometric correction (Coppin & Bauer 1996). In this case, geometric corrections (registration phase**,** radiometric correction and geometric corrections) of the image had already been carried out in Libyan Centre for Remote Sensing and Space Science (2016), so it was not applied. Interpretation of remote sensing was used in the study area to obtain appropriate classification schemes. An unsupervised classification method will use initially, followed by a supervised classification.
Field work: Data elaborating and final land unit map, all the data collected during the field survey were used to create a database and to integrate the overall accuracy, and a KAPPA analysis used to perform classification accuracy derived from error matrix analysis and correct the preliminary legend and land map (Viera & Garrett 2005). In addition, some photos were taken into account for describing land cover data in the study area. Overgrazing intensity is assessed using two methods. First, visual assessment of grazing damage is evaluated by field observation and depends on previous published information. Second, sustainable and actual stocking rates are calculated. The sustainable stocking rate (SSR) in a particular pasture depends on the total palatable biomass produced. This required annual

biomass, fraction including grazing efficiency and correction for biomass, averaged palatable biomass after dry season, and averaged fraction of the soil surface covered with palatable vegetation. These factors are calculated using the land use map (Figure 4), and field work. Actual stocking rate is calculated using number of animal for each region and using new method which is making grid/raster in GIS, questioned personally shepherds about the number of animals in the grid square compared with government record.

Method to calculate Actual Stocking Rate (ASR): Quantifying rangeland pressure is measured using actual stocking rates for different land covers. This requires knowledge of the actual stocking rate (ASR), graze and browse mass.

Method to determine the Sustainable Stocking Rate (SSR): The sustainable stocking rate (SSR) in a particular pasture depends on the total palatable biomass produced. This is the yield available for grazing and is crucial to meeting the needs of the grazing animals and is often evaluated in developed countries for stock management. Kosmas et al. (1999) present this in the form of the following equation:

$$SSR = X * P * F / R \qquad \text{(Equation 1)}$$

where: R is the required annual biomass intake per animal (kg animal^{-1} year^{-1}), F is averaged fraction of the soil surface covered with annuals, X is the fraction including grazing efficiency and correction for biomass not produced during the latest growing season (year^{-1}), P is the averaged palatable biomass after dry season (kg).

There are many ways to evaluate biomass, based on research objectives, the structure and variety of vegetation e.g. grass or shrubs, research funding, time availability and the researcher's skills (Mulonda 2011). Traditionally, to determine available biomass, plots of 2 m x 5 m are fenced off to exclude ruminants prior to the start of the growing season at 52 locations on all cover types (Figure 4). A 1 m x 1 m quadrat is employed to determine the fraction of ground covered by individual tree, shrub and annual plant species, apart from grasses which are treated collectively. The fraction of plant cover for each cover class is averaged from all plots of that class. Browse is harvested by clipping outward growing/available shoots produced in the current year at the end of the growing season (FAO 1991) with hedge shears from 15-25 mm above ground level to a height of 1.5m that corresponds to local goat browsing habits (as also observed by others e.g. Rogosic et al. 2006), generally to a depth of 50-100mm into the shrub. The foliage falls to groundsheets, where it is allowed to air dry for one week, as advocated by Gintzburger (1986) and then weighed by individual plant species in the field. Grasses are scythed as close to the ground level as possible and annual herbaceous plants (those dying completely or leaving no persistent woody stem above the soil surface at the end of each year and growing in the next season from seeds or surviving roots or tubers) are harvested similarly using a serrated knife and hand shears. The mass is determined directly on site by weighing (Cook & Stubbendieck 1986). Oven drying was not possible here due to due the quantity of sites and time constraints; the difference between dead standing grass mass in a hot climate and oven dried mass is also assumed to be minimal. These data were verified against agro-pastoral systems data.

Visual assessment of grazing damage: The grazing damage assessment was guided by Table 1 and a visit of 90 locations in the filed Figure (4), from 15th June to 20th October 2017.
Table 1. Classification of exploitation of the natural area by grazing based on field evidence (Abdalrahman et al. 2017).

Utilization And classification	Key species Degree of use	Effect of grazing on annual plants , trees/shrubs and soil
Light to non-use	≤ 20%	Annual plants: grazing is not apparent from a distance of 5m. On close inspection, a few plants of the most palatable species show evidence of light use; grazed height on such plants > 15cm tall and grazed patches are small or not present. Trees/shrubs: little or no use of palatable species; with close inspection, a few plants show evidence of light use (grazed heights less than 15cm measured from the ground). Soil: no trampling paths on the soil.
Conservative	21-40%	Annual plants: varying degrees of grazing ; grazing focused on small patches of 10-50 cm in diameter whilst other areas are untouched Trees/shrubs: grazing evidence is not seen from a distance of 7m, grazed height 5 to 15 cm measured from the ground, no use of less palatable species . Soil: no trampling paths on the soil.
moderate	41-60%	Annual plants: varying degrees of grazing ; some grazed patches of 50 to 100 cm in diameter. Trees/shrubs: grazing evidence is not seen from a distance of 10m, grazed heights 16 to 25cm measured from the ground, light use of less preferred species. Soil: light trampling and some bare ground patches.
heavy	61-80%	Annual plants: all palatable plants show obvious grazing from 10m distance. Less preferred species have received some use. No ungrazed patches and plants. Grazed patches 100 to 200 cm in diameter. Shrubs: shrubs received obvious grazing that can be seen from a distance of 10 m. grazed heights 25 to 35 cm measured from the ground Soil: many trampling paths and obvious bare ground patches can be seen from a distance of 10 m.
Severe	> 80%	Annual plants and Shrubs: no ungrazed patches, bare patches there is consumption nearly to the ground. Shrubs: obvious *consumption* with broken branches. Grazing is noticeable from a distance of 15-20m. Soil: obvious livestock trailing and trampling paths that can be seen from a distance of 15m.

The following are examples of characters of land condition suffered from overgrazing, obtained during the fieldwork and used to describe the intensity of land use in the classification from Figure 2, a to Figure: (2, f).

Figure: (2, a). Visual assessment of a small Mastic tree for grazing damage (high land use intensity. Land cover class = H, 32° 34' 1" N, 21° 18' 23" E

Figure: (2, b). Animal paths indicating high land use intensity. Land cover class = B, 32° 31' 42" N, 21° 30' 29" E

Figure: (2,c). Severe: complete denudation of small Mastic tree (<0.4m) through over grazing. Land cover class = F, 32° 30' 41" N, 21° 24' 56" E.

Figure: (2, d). Heavy: consumption of 70% of *Santonica Wormseed* shrub of low height from overgrazing (<0.25m). Unpalatable Caper shrub to the left. Land cover class = D, 32° 33' 57" N, 21° 43' 24" E

Figure: (2, e). Moderate grazing effects on grass, on trees/shrubs grazing evidence is not seen from a distance. Land cover class = H, 32° 36' 3" N, 21° 24' 48" E

Figure: (2, f). Conservative; grazing focused on small patches, on trees/shrubs, grazing evidence is not seen from a distance. Land cover class= H, 32° 34' 57" N, 21° 19' 4" E

Figure: (2). Field observation of grazing intensity.

Results and Discussion

Land cover map: Mapping the variability of land cover 2015 was created with six classes; forest (as woodland with varying proportions of coniferous trees and shrubs is known locally), shrubland, bare soil, irrigated land, rain-fed crops, and urban areas. The classification accuracy of the map using a random sample of 298 pixels was selected for land cover map (Ediriwic-krema & Khorram 1997; McGwire et al. 1996; Congalton 1991). The result pointed out that an overall classification accuracy of around 91.6 %. The agreement of a Kappa index was about 0.90 (Table 2). Slightly poorer agreement was obtained for shrubs. This may be due to difficulty in differentiating between small trees and large shrubs.

Table 2 : Accuracy assessment of the 2015 land cover map produced from Landsat data.

	Reference data							
Classified data	Bare soil	Rain-fed	Shrubs	Forest	Irrigated	Row total	User accuracy (%)	Kappa*
Bare soil	**69**	4	0	0	0	73	94.5	0.91
Rain-fed	1	**68**	2	3	0	74	91.9	0.89
Shrubs	1	1	**16**	1	1	20	80.0	0.80
Forest	0	1	1	**93**	4	99	94.0	0.91
Irrigated	1	0	2	0	**29**	32	90.3	0.89
Colum total	72	74	21	97	34	**298**		
Accuracy (%)	94.4	91.9	76.2	95.9	85.3			

Note: Number of pixels correctly classified: 275; overall classification accuracy: 91.6%. *Overall Kappa index of agreement: 0.90.

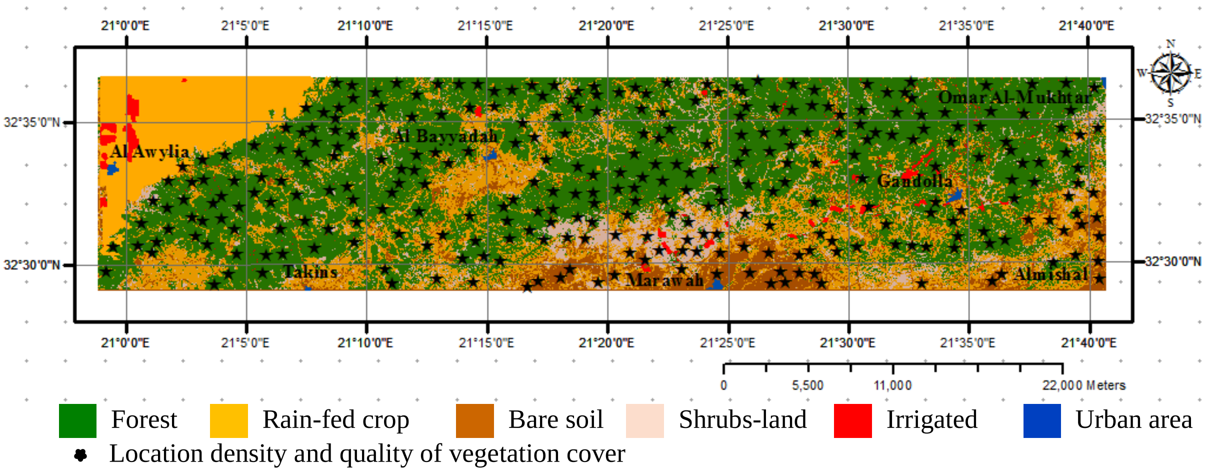


Figure: (3). Classification of land cover for study area in 2015.

The thematic map (Figure 3) illustrates that 52% of the study area is forest(as wood land with varying proportions of coniferous trees and shrubs is known locally) and shrubland, with 9% identified as bare soil from heavy grazing of grasses in an open cover. Agricultural cropland constitutes 33% of the area.

Instead of these six main landscape classes, consideration of the requirement of the assessment of grazing damage means a more detailed understanding of the land cover is required. A total of 300 locations (Figure 3) were selected by stratified random sampling for quality control purposes. Being guided by the FAO (1991) land use classification system (Di Gregorio & Jansen 2000; Jensen 1996), each class is defined by the percentage of tree and shrub cover, with the remaining percentage belonging to annual plants and grasses. Eleven land classes were eventually used (Figure 4).

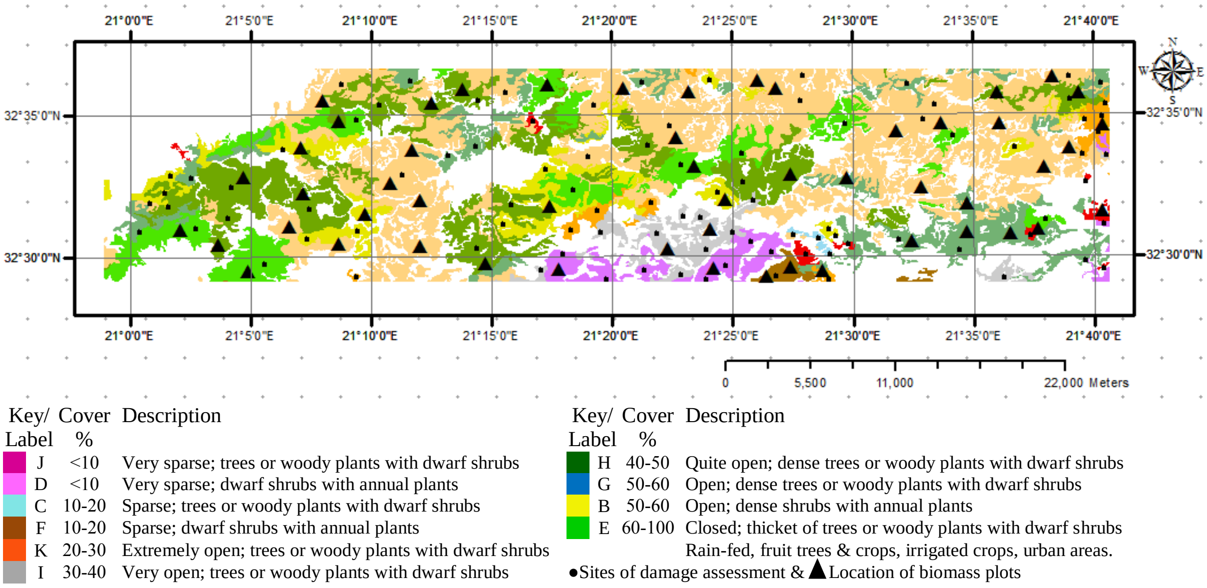


Figure (4). Natural land use map for study area in 2017.

Agricultural crop land excluded from the natural use map (Figure 4) because it plays no part in grazing activities. The shrubland of the thematic map largely corresponds to a very open 10-20% cover (Class F) of dwarf shrub cover with the remaining percentage consisting of annual plants (annual plants and grasses), as in other classes. The thematic bare soil primarily corresponds to classes D and K in Marawah: a sparse cover of <10% dwarf shrubs with annual plants and an open cover of 20-30% trees or woody vegetation with dwarf shrubs respectively.

For the former, the study area is divided using a raster grid to give 217 units of grazing land (Figure 5). A real stocking rates were averaged over each unit, accounting for any partial use by a flock or if used by more than one shepherd. Then the obtained (ASR) is compared with animal population given by Agricultural ministry (2017). During calculation of stocking rates, it is important to determine forage supplements levels in terms of quantity and duration per head to obtain the most accurate results.

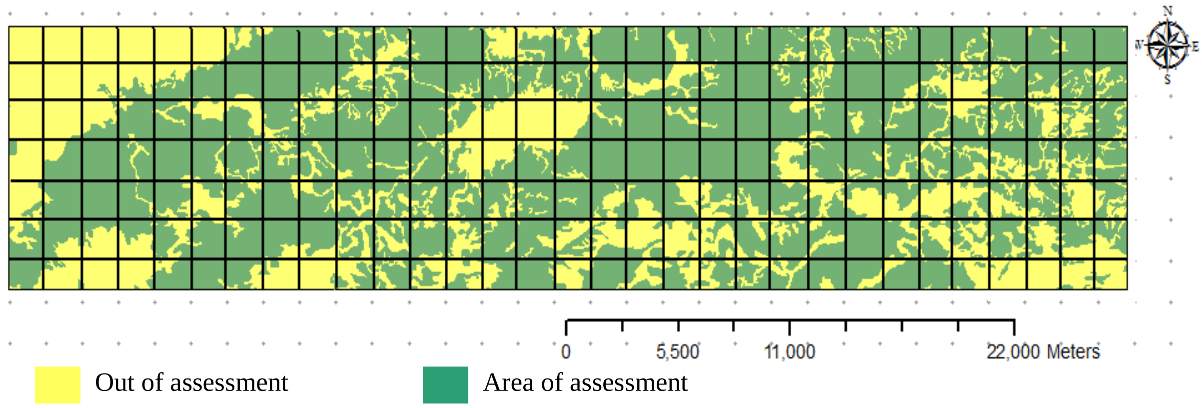


Figure (5). Grid cell division of the study area to measure actual stocking rates.

Actual Stocking Rate: The frequency distributions may be influenced by a number of different socio-economic factors such as wealth and interest in sheep farming, proximity to markets for disposal of stock and the purchase of supplemental forage, the desire to employ foreign nationals as shepherds or to keep livestock husbandry as a family business. The regional differences illustrated in vegetation cover map (Figure 4), therefore the actual stocking rate (ASR) is organised and presented in terms of frequency distributions for each cover class (Figure 6).

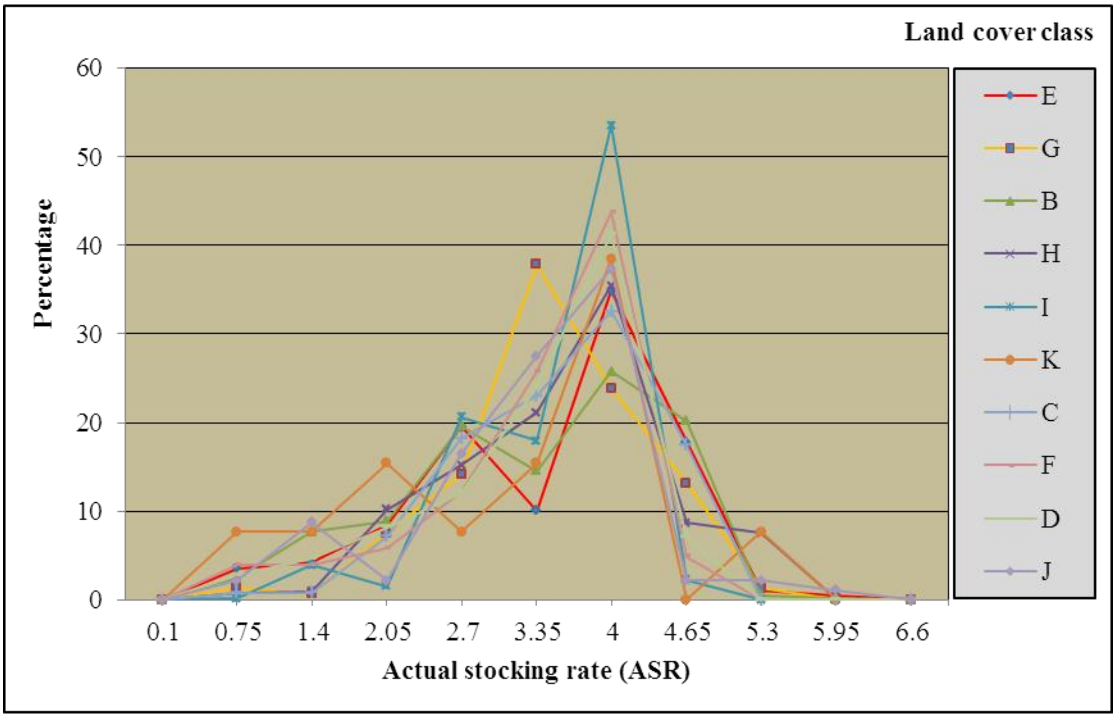
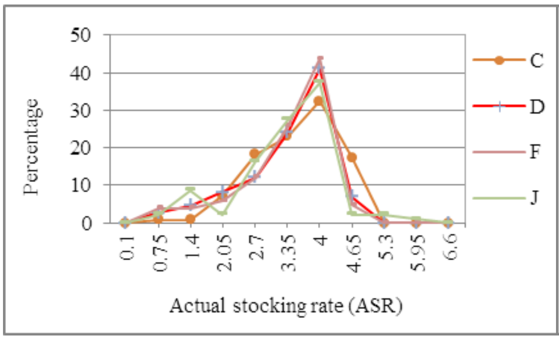
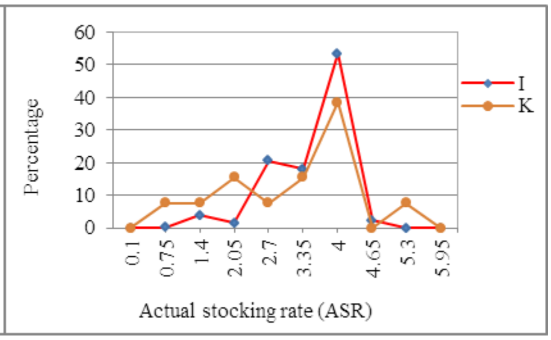


Figure (6). Actual stocking rate of sheep and goats from survey of shepherds.

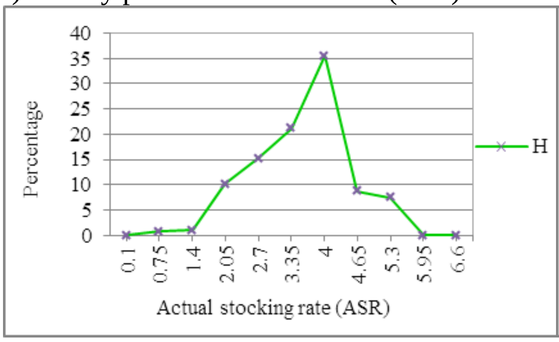
From Figure 6, it can be seen that about 20% of the land has less than 2.7H ha^{-1}, the vast majority of land has 2.7- 4.6H ha^{-1} and less than 10% of the land has more than 5H ha^{-1}. The majority of the land cover classes have similar animal frequency distributions.

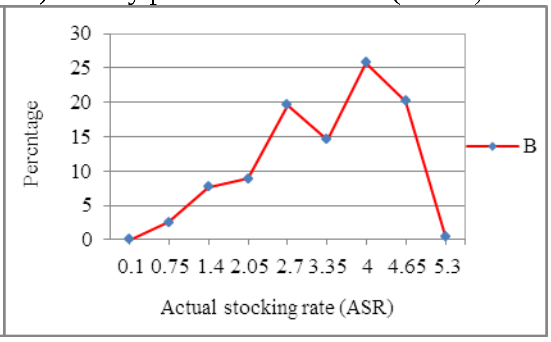
The Figure 6 has been divided into six sub graphs in Figure 7 to depict and illustrate the classes. The ASR is organised and presented as new frequency distributions for each cover class (Figure 7i- vi). The Land cover classes C, D, F and J are only found in Marawah (Figure 4) and have similar distributions of actual stocking rates (Figure 7i); these areas are treated as marginal land either surrounded by more intensively used agricultural cropland or near to agricultural land. Class K also only appears in Marawah. The difference between the distributions for classes G and H is attributed to the presence of the more unpalatable *Phoenician juniper* and the limited availability of water resources in the former (Figure 7v and iii). Although the percentage of cover for classes B and G are similar, the higher mean stocking rate and skew of class B (Figure 7v and iv) may be caused by an abundance of small roads, water resources and widespread low density housing. The lower mean and skew of the stocking rate for the highest cover class E (Figure 7vi) may be attributable to unpalatable *Phoenician juniper*. and Mediterranean cypress (*Cupressus sempervirens)* whose presence may explain the long tail towards lower stocking rates.



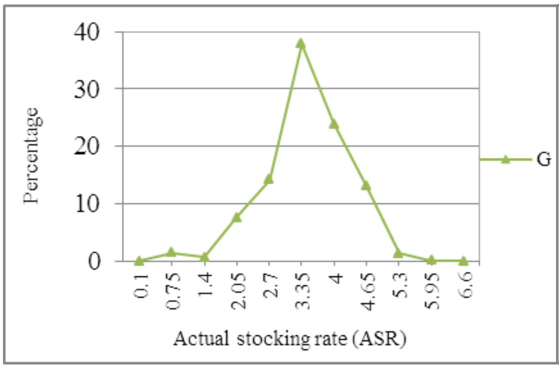


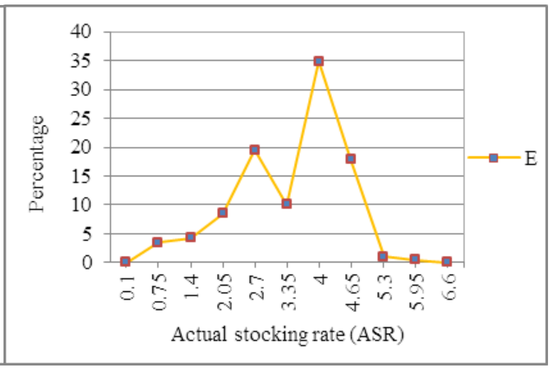
i) Woody plant & shrub cover > (20%)   ii) Woody plant & shrub cover (20–40)%





iii) Woody plant & shrub cover = (40-50)%   iv) Woody plant & shrub cover = (50-55)%





v) Woody plant & shrub cover = (55-60)%   vi) Woody plant & shrub cover < (60%)

Figure 7. Comparison of the actual stocking rates in different land cover classes.

The total number of animals measured in each district (or scaled up if only part of a district's area is covered by the study area) compares well with Government records (Figure 8).

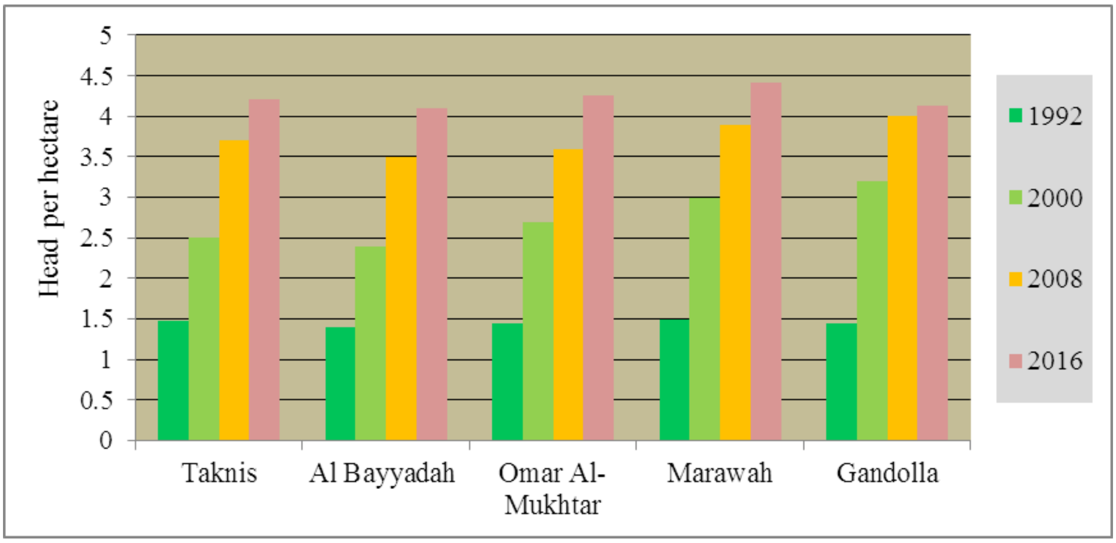


Figure 8. Number of goats and sheep in the study area between 1992 and 2016 (Agricultural ministry 2017).

The number of animals in the study area has increased beyond the normal pasture capacity level, which estimates is about 4-5 animals per hectare with less than 15 hours of grazing a day in the whole year. This change can be seen by the average stocking rates for each region in the study area (Figure 8). So it is common that shepherds and breeders start to use other sources of concentrated feeds and external feed supplements. Shepherds confirmed that supplemental feed, such as wheat and barley grain with additional minerals, is supplied during the winter to reduce the impact of animals on the natural cover.

Adjusted Actual Stocking Rate (AASR): The required biomass per animal per year, R, is 187.5 kg H^{-1} yr^{-1} (FAO 1991). This requirement from each area of land will be reduced by the mass of any supplemental forage imported by a shepherd for his animals. This is generally about 50 kg 100 H^{-1} day^{-1} over a three-month period in the winter. For one animal, the required natural biomass, rnb, is therefore

rnb = R - forage supplement (Equation 2)

To identify how much pressure the animals are exerting on the land, the stocking rate that the natural land has to support is therefore adjusted using equation 3 to account for this additional forage provided by the shepherds, with typical values used for an example calculation given in Table 3.

Adjusted actual stocking rate (AASR) = ASR * rnb/R (Equation 3)

Table 3. Typical Livestock feed requirements, forage supplement and required natural biomass.

Supplemental forage mass	0.5 kg $Head^{-1}$ day^{-1}
Time	90 days yr^{-1}
Forage supplement	45 Kg H^{-1} yr^{-1}
Required biomass	187.5 Kg H^{-1} yr^{-1}
Required natural biomass (rnb)	142.5 Kg H^{-1} yr^{-1}
Division factor to alter existing ASR calculation	1.32

It was found that about 90% of shepherds provided supplemental forage for their animals. No obvious variation with land cover class was noted. The impact of adjusting ASR is an overall reduction in the actual grazing pressure on the land (Figure 9), as livestock consumes fewer plants.

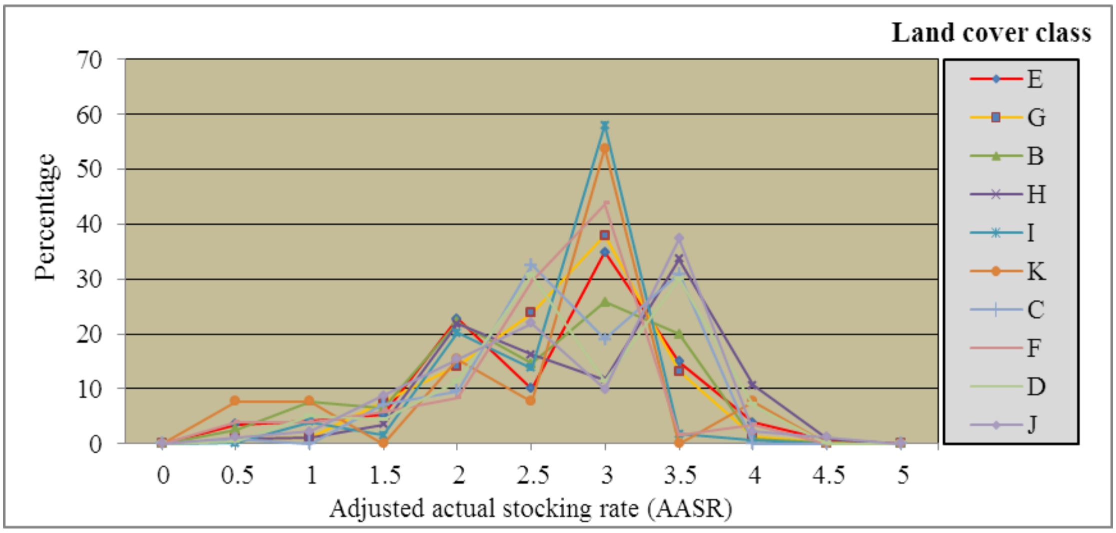


Figure (9). Variation of adjusted actual stocking rate with land cover class.

Due to the high popularity of this measure in the sample of shepherds, all stocking rates are therefore reduced by a factor of 0.76 (the quotient of animal dry matter requirements), (R) minus the annual feed supplement and R, where R = 187.5 kg H^{-1} yr^{-1}; FAO, 1991) to give an adjusted stocking rate (AASR). The majority of land has an AASR of 2.5-3.5 H ha^{-1}, with about 10% and 20% of land having greater than 3.5 H ha^{-1} and less than 2 H ha^{-1} respectively.

Adapting Sustainable Stocking Rate (SSR_P): The application of the SSR method in the study area has revealed new outcomes, which indicates to a direct relationship between SSR and percentage of plants cover and SSR value ranging between 1.94 and 2.19. Classes B, G and H have a vegetation cover more than 40% also they have a high sustainable stocking rate, C, F, D and J have a vegetation cover less than 20% also they have a low sustainable stocking rate (Figure 10).

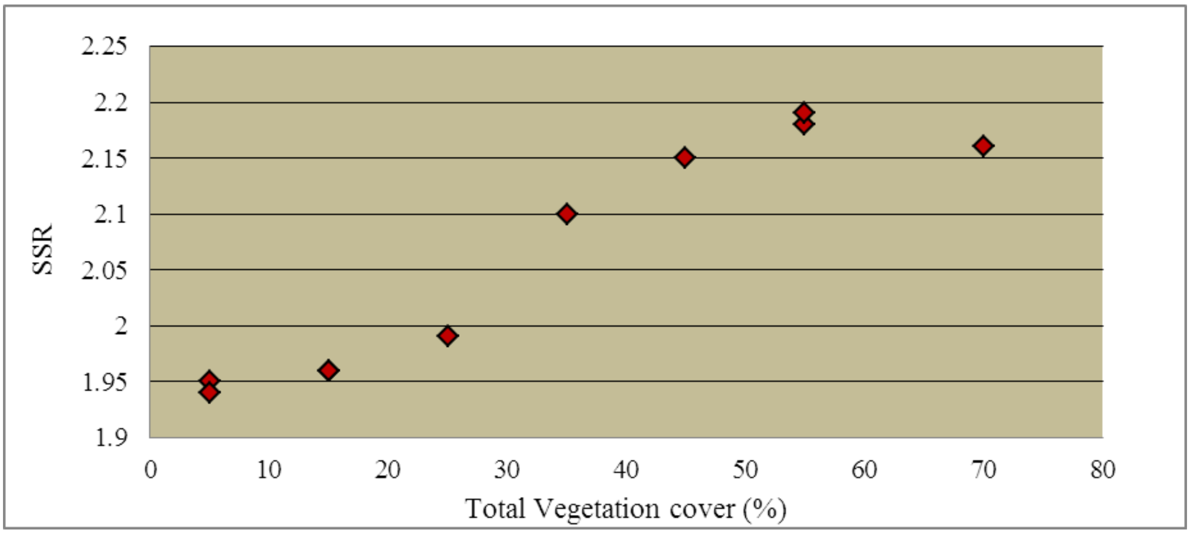


Figure (10). Relation of percentage vegetation cover and sustainable stocking rate for the study area.

A factor X accounting for both grazing efficiency and a correction for biomass not produced during the latest growing season and the reciprocal of the animal dry matter requirements (R). Adapting the sustainable stocking rate (SSR_P) equation by including both annual plants and trees/shrubs in the edible biomass and the preferential consumption of any plant defined by its palatability, for *i* number of species the sustainable stocking rate may be expressed for each cover class as:

$$SSR_p = \frac{1}{R}\left(\sum_{i=1}^{n} palatability_i \times X_i \times P_i \times F_i\right) \qquad \text{(Equation 4)}$$

Kosmas et al. (2011) propose X = 0.5 per year for grazed land; similar to the common rule for planning an appropriate level of pasture utilization of "take half, leave half" or a 50 per cent use of annual primary forage production which accounts for the loss incurred from plant damage due to trampling and other factors such as insect or wildlife damage (FAO, 1991). For shrubs, X might reasonably vary from 0.5 to 1; the latter may be more appropriate due to the methodology of harvesting shrub biomass and because shrubs respond morphologically to grazing pressure rather than being trampled.

Actual and sustainable stocking rates

The total number of sample plots is relatively large, they are but a small sample of the total study area; it is to be expected that fewer plant species were observed in the sample plots compared to those identified by shepherds with respect to palatability, and the fraction of ground covered by each plant species (F) also varies with the percentage of shrub and tree cover (P) (Figures, 11 and 12).

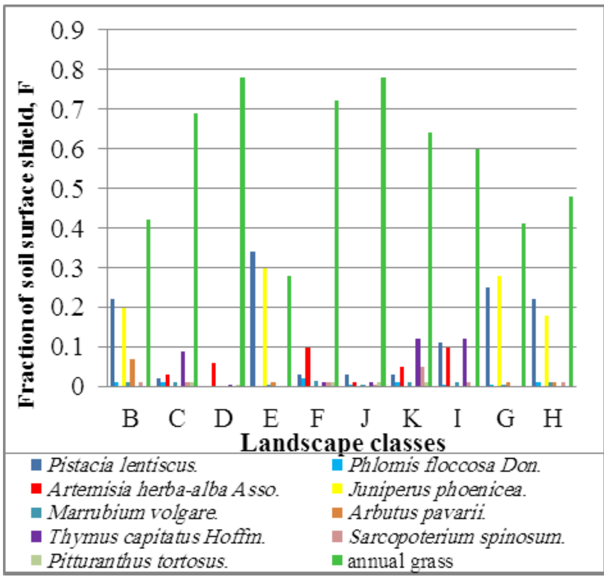


Figure (11). Fraction of soil surface shielded by plant types from sample plots for different land cover.

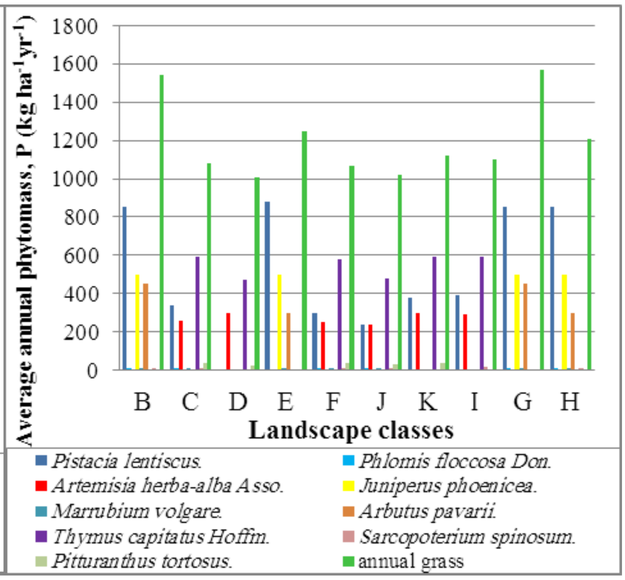


Figure (12). Average biomass by plant type from sample plots for different land covers.

The product of average edible biomass (P) and fraction of the soil surface covered (F) by shrubs and by grass separately varies with change in land cover (Figure 13). This is a new outcome from this research for the study area and has not been attempted elsewhere over such a wide area and over different cover types. The biomass from grass decreases as that from shrubs increases as the percentage of cover increases. When both forms of biomass are added together, the total biomass is approximately constant at about 815 kg ha^{-1}.

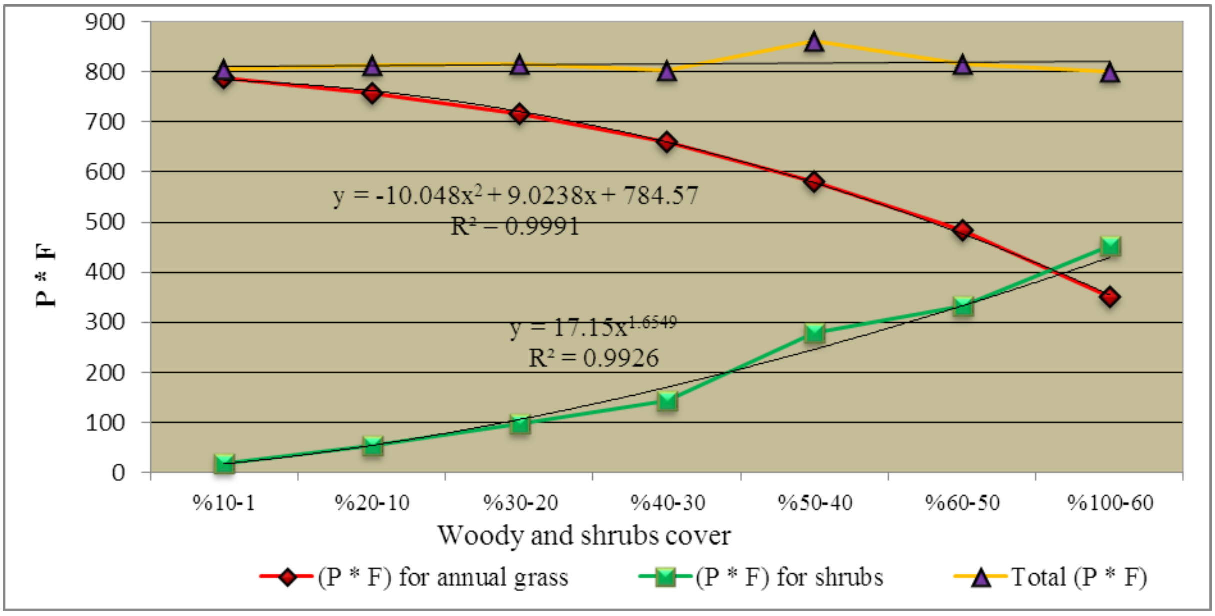


Figure (13). Land cover and product of the average edible biomass (P) and fraction of the soil surface covered (F).

A simple non-linear relationship to quantify the reduction in total standing dry mass is established using regression (Figure 13). The offset is set to the average annual total mass. A good correlation coefficient is obtained. Using this with the relationship for consumable dry matter with rainfall presented by Catchpole & Wheeler (1992) gives a similar value of 884 kg $ha^{-1}yr^{-1}$.

A list of available plants in the study area was prepared and classified on a scale of zero to one in terms of their palatability to sheep and goats (Table 4). In the absence of comprehensive local information, consultation with scientific experts (Yagoub & Baboo pers. comm. 2010) and shepherds who identified as being discerning expert practitioners, often with knowledge amassed over many generations; a random sample of 200 shepherds throughout the study area were interviewed to establish annual average values of palatability, asking them to consider frequency and extent of consumption. The plant species identified are the most frequently encountered and relevant to pastoralism, although others have identified a greater variety (e.g. Hegazy et al. 2011; El-Barasi et al. 2011; Gimingham & Walton 1954).

Table 4. Available plants in the study area and their overall degree of palatability to sheep and goats.

Name of plant	Palatability	Name of plant	Palatability
Trees		Levant Horehound	0
Carob	0.2	*Plantago major*	0
Phoenician juniper	0.01	*Rhus tripartita*	0
Mediterranean cypress	0	*Phyllarea angustifolia*	0
Wild Olive tree	0	*Vibrnum tinus*	0
Canary Islands Pine (*Pinus halepensis*)	0	**Annual grass**	
Shrubs		*Matthiola longipetala*	1
Mastic tree	0.65	*Cynosurus coloratus*	1
Santonica Wormseed	0.6	*Echinochloa colona*	1
Three-lobed sage	0.6	*Hordium marinum*	1
Thyme	0.5	*Lamarckia aurea*	1
Strawberry Tree	0.3	*Lolium loliaceum*	1
Pitturanthus tortosus	0.1	*Lolium rigidum*	1

Name of plant	Palatability	Name of plant	Palatability
Solanum nigrum	0.1	*Stipa capensis*	1
Ouercus coccifera	0.015	*Bromus rubens*	1
Lotos (*Ziziphus*)	0.01	*Bromus madritensis Lioyd*	1
Lonicera etrusa	0.01	*Cynara cornigera Lindely*	0.8
Burnet	0.01	*thistle (thorny plants)*	0.8
Common Horehound	0.01	Thistle (*Carduus carlinoides)*	0.8
Peganum harmala	0.01	*Carduus nutans*	0.8
Ephedra alata	0	*Thapsia garganica*	0.7
Globularia alypum	0	*Chamomilla aurea*	0.7
Jerusalem Sage, Phlomis	0	*Asphodelus microcarpus*	0.6
Rhamnus lyciodes	0	*Malva sylvestris*	0.6
Phyllarea latifolia	0	*Cuscuta planifolia*	0.6
Cistus parviflorus	0	*Urginea maritima*	0
Caper (*Capparis spinosa*)	0	*Paronychia arabica*	0

Three different scenarios were applied to evaluate the grazing efficiency factor X required to calculate sustainable stocking rate (Figure 14). the adoption of the second scenario causes an rise in available biomass as the cover increases from trees and shrubs increases, a factor which shepherds would have exploited if true, but is not evident from the measured data (Figure 5) and thus this scenario is not explored further. Incorporation of varying efficiency of consumption and palatability is the most accurate estimate of the useful annual productivity of the rangeland for sheep and goats. This latter result is a similar outcome to that obtained if palatability is ignored and a uniform value of X = 0.5 is employed- a fact that may be useful if a rapid estimation of sustainable stocking rate is required.

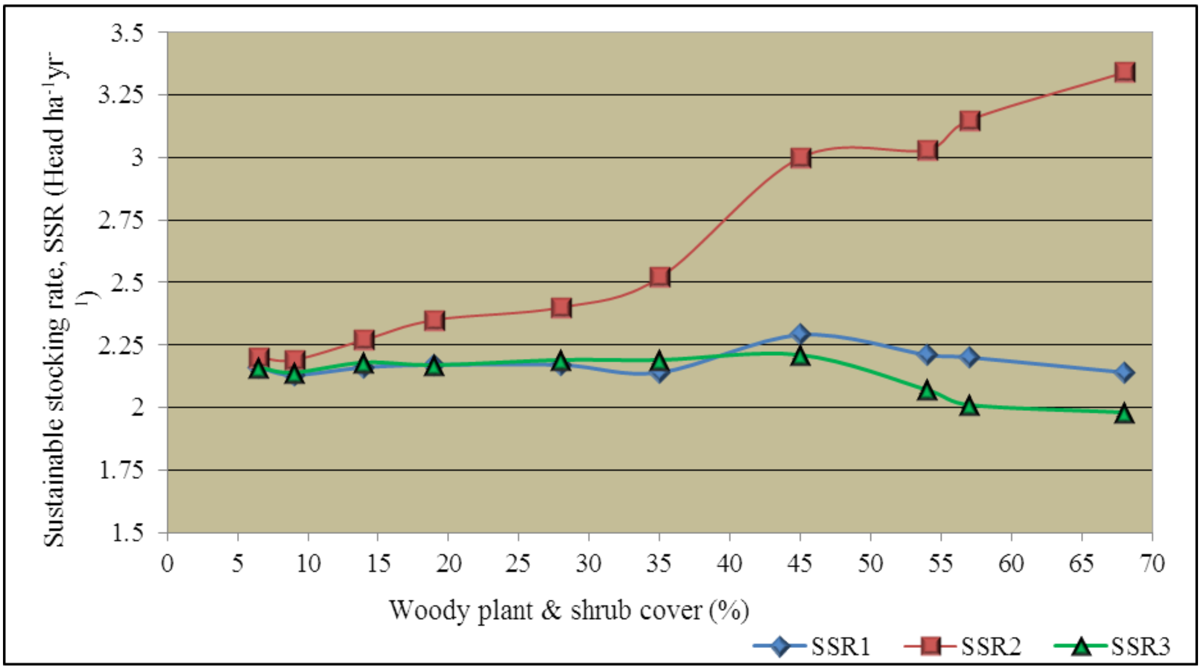


Figure 14. Comparison of sustainable stocking rates using three scenarios of grazing efficiency: SSR1- palatability = 1, X=0.5; SSR2- palatability = 1, X_{annual} = 0.5, $X_{tree/shrub}$ = 1; SSR3- palatability from Table 4, X_{grass} = 0.5, $X_{tree\ and\ shrub}$ = 1.

To forecast risk of grazing damage description of grazing intensity are compared to the field measurements of grazing damage over different land cover types (Figures 15a-b).

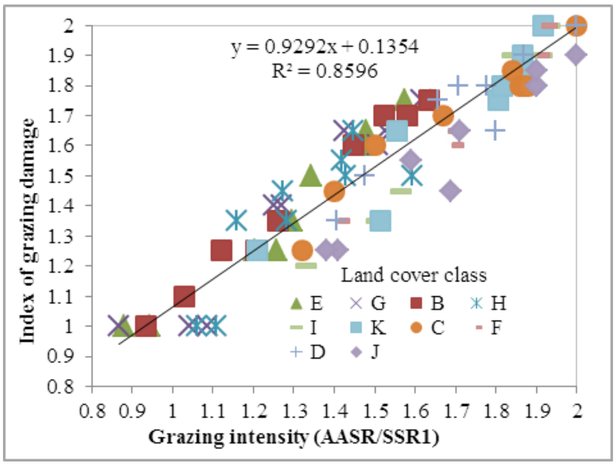


Figure 15a. Grazing intensity (SSR1, X=0.5) and index of grazing damage.

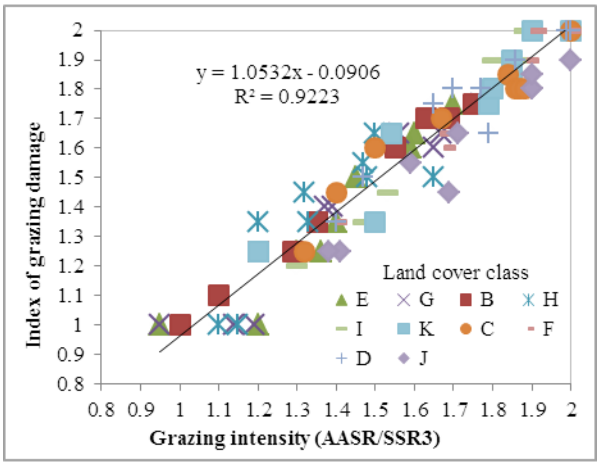


Figure 15b. Grazing intensity (SSR3; X_{annual}=0.5, $X_{tree/shrub}$=1×plant palatability) and index of grazing damage.

Adoption of palatability in the assessment of grazing intensity has resulted in the best correlation co-efficient (Figure 15b). For Scenario 1 (Figure 15a), land with a greater shrub cover tends to appear above the linear regression line (e.g. classes B and E), whilst land with sparse shrub cover appears below it (e.g. classes J and K), whereas in the third scenario (Figure 15a), such differentiation is not apparent. In the third scenario, the data are mixed together. There are no previously published data on the relationship between grazing damage and grazing intensity, and so this is an important contribution of this research. The form of the relationship was not known, and the closeness of the data to a straight line confirms it is a linear relationship. It can also be inferred that inclusion of policy enforcement for calculation of management quality index is not necessary to evaluate the impact of the intensity of land use in natural areas subject to grazing pressure as a good linear relationship has been obtained. As the third scenario of grazing efficiency gives the best correlation with observed grazing damage, the distributions of grazing intensities for all land cover classes are compared (Figure 6):

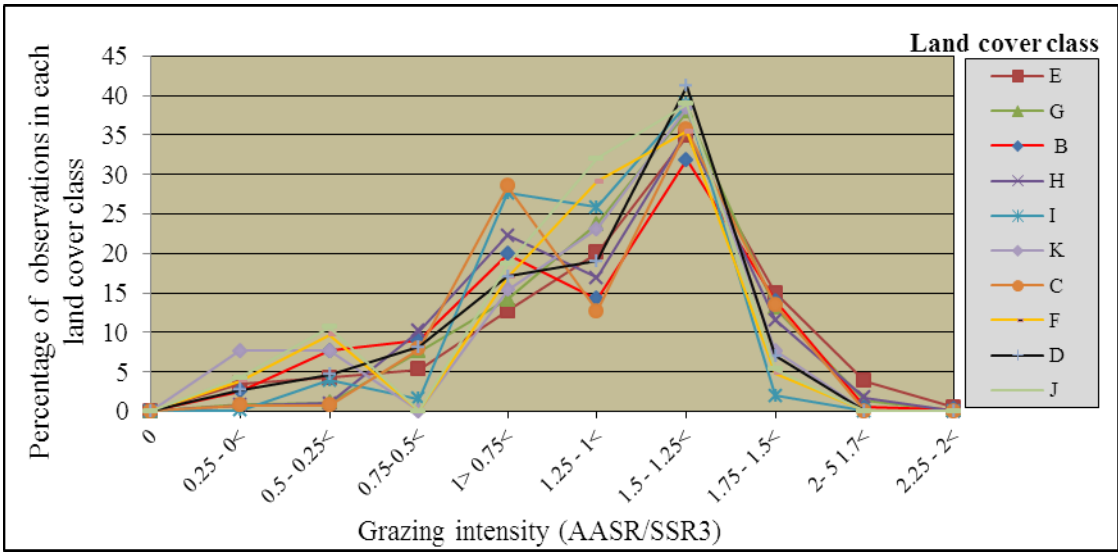


Figure 16. Variation of grazing intensity using grazing efficiency scenario 3 for different land cover classes.

When the ratio of AASR/SSR is less than 1, there is likely to be no long-term damage from this grazing pressure. The peak grazing pressure for all land cover types is the same and given by an AASR/SSR of between 1.25 and 1.5. The shape of the distribution is now similar for each land cover class; compared to the greater variability in the actual stocking rates recorded (Figure 6).

The relationship between AASR/SSR3 for different cover types is very good, but is based on only one year of dry biomass calculations, which should ideally be increased to annual growth from at least three and preferably seven years. This is because the quantity of biomass is of course dependent on growing conditions for the preceding year for example rainfall intensities, frequencies and time of occurrence in relation to plant growth. In addition, the influence of plant palatability to sheep and goats is appropriately based at present on the opinions of shepherds and local experts. This factor could be investigated further by controlled grazing experiments in the field. This could also investigate the temporal relationship between grazing intensity and loss of cover. The index of environmental damage from grazing has been shown to be a potentially rapid and accurate method of assessment of the impact of human activities in natural areas.

Conclusion

A standard equation for co-grazing has been improved and applied for the Al-Jabal Al-Akhdar region which precisely demonstrates complex land cover. Land cover map 2015 has been produced and identified using remote sensing from a satellite image, the study area has been visited to first confirm the accuracy of the land cover map. The result pointed to an overall classification accuracy of around 90%. GIS has been used to identify the new land use classes and it was necessary to visit a total of 300 locations were selected by stratified random sampling for quality control purposes. An extensive and comprehensive reference databased on, actual stocking rates, sustainable stocking rates, supplementary feed, and plant palatability was created and independently verified.

An extensive survey has allowed actual stocking rates to be recorded, which can be adjusted if supplementary feed is provided and plant palatability is identified. Sustainable stocking rates are identified from numerous sample plots of edible biomass and on different land cover classes. A new linear relationship is established between grazing intensity and observed grazing damage over all cover types, with the best correlation occurring when plant palatability is considered. This research clearly identifies the pressure exerted on the environment can be predicted from stocking rates. This provides the evidence to encourage environmental managers and planners to plan strategies to combat grazing damage and may be used for future regional studies.

Acknowledgements

Sincerely thankful to the experts and the employees for their efforts and advices to change the way of approaching the problem wherever required.

المستخلص: الرعي في نطاق مفتوح عبارة عن إجهاد تقليدي للأراضي الرعوية بمنطقة الجبل الأخضر من ليبيا والى الأن لم يتم تقييمه بشكل منهجي منظم على مستوى المنطقة. تم إنتاج خريطة غطاء أرضي بمساحة 90.000 هكتار بواسطة الاستشعار عن بعد ونظام المعلومات الجغرافية ثم التحقق الميداني لدقة الخريطة وذلك لغرض تصنيف الغطاء الأرضي وكذلك أيضا تقسيم المنطقة إلى وحدات لحساب عدد الحيوانات داخل كل وحدة وقدرتها الاستيعابية. تم تقدير معدل التخزين الفعلي (ASR) بحساب عدد الماشية ، مع مراعاة اختلاف أعداد الماشية جغرافيًا من منطقة إلى أخرى داخل الإقليم ، لذلك تم حساب ASR بطريقة أكثر دقة تعتمد التوزيع الجغرافي المكاني عن طريق تقسيم المنطقة باستخدام شبكة نقطية إلى 217 وحدة رعوية ومقارنة العدد الكلي بالسجلات الحكومية. كذلك أيضاً قدرت كمية الأعلاف

المضافة والتي تبلغ حوالي 50 كجم/ 100هكتا ر/ يوم خلال فترة ثلاثة أشهر في السنة وتم إدراجها من ضمن حسابات معدل التخزين الفعلي . اعتمدت هذه الدراسة في حساب معدل التخزين المستدام (SSR) على كمية الكتلة الحيوية السنوية المطلوبة لكل حيوان (R) ، نسبة تغطية سطح التربة بأنواع نباتية سنوية وشجيرات صالحة للأكل (F) ، ومتوسط الكتلة الحيوية المستساغة بعد موسم الجفاف (P) ، و X وهو متغير يأخذ في الاعتبار كفاءة الرعي اعتمادا على أن الحيوانات لا تأكل 100٪ من النباتات . طبقت هذه الدراسة بثلاثة سيناريوهات مختلفة لتقييم العامل X ,الاقتراح الأول وهو مجموع الكتلة الحيوية الصالحة للأكل مضروبة في 0.5. الاقتراح الثاني وهو X = 0.5 للعشب السنوي و X = 1للشجيرات، الاقتراح الثالث X = 0.5 للعشب السنوي وحساب معدل الاستساغة للشجيرات. وخلصت هذه السيناريوهات إلى أن الاقتراح الثالث كان الأفضل بمعدل ارتباط 0.92 مع مؤشر الضرر البيئي الناتج عن الرعي.

ساهمت هذه الدراسة في إضافة جديدة لم تتم تجربتها من قبل في حساب ASR و SSR. وكذلك تحصلنا على علاقة عكسية بين معدل إنتاج الكتلة الحيوية لكل من العشب و الشجيرات وكانت الكتلة الحيوية الكلية ثابتة تقريبًا عند حوالي 815 كجم \هكتار.

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