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An Approach for Analysis of Integrated Components on Available Forage in Semi-Arid Rangelands of Iran

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Abstract: This study describes the components of available forage in Vahregan watershed, Central Iran and highlight issues relating to forage endowment and environmental dynamics. In this study, proper use factor and palatability models and their components use to develop the model of available forage and measure it. The components climatic, topography, land systems, vegetation, land use and grass and shrub species composition changes were analyzed using GIS. In this study source of information are herders, land and livestock owners, research institution and personal field inspections. Responses to the questionnaires were obtained from local government offices and research on rangelands and analyzed in parallel with the results of detailed interviews with pastoralists. The results of the completed overall model of available forage showed that of the 18346.2 hectares in the range area only 8.36% of the rangeland is in good condition and the rest are in fair (13.8%), poor and very poor (77.82%). About 16812.85 ha (91.64%) of the rangeland area shows a downward trend, only 1533.35 ha (8.36%) upward trend. About half of the rangeland is not favorable for domestic livestock grazing. The range condition situation and its trend in consideration of soil and slope properties in this study indicates that the rangeland in Vahregan is a fragile production system, sensitive to soil erosion and rangeland degradation, so for a long time sustainable exploitation should be goes to minimize land degradation in the future, proper management and sustainable exploitation should be implemented in the future

Key words: Available forage model · Palatability · Proper use · GIS · Central rangeland · Iran

INTRODUCTION

Range and rangeland are defined as those areas of the world, which by reason of physical limitations-low and erratic precipitation, rough topography, poor drainage, or cold temperatures-are unsuited to cultivation and which are a source of forage for free-ranging native and domestic animals, as well as a source of wood products, water and wildlife [1]. More recently, authors define rangeland as "uncultivated land that will provide necessities of life for grazing and browsing animals [2]. Or expanded: Rangeland is a type of land that supports different vegetation types including shrub lands such as deserts, chaparral, grasslands, steppes, woodlands, temporarily treeless areas in forests and wherever dry, sandy, saline, or wet soils and steep topography preclude the growing of commercial farm and timber crops [3]. Heady and Child make passing reference to a definition based on use, such as livestock grazing, livestock summer range and deer winter range. Giles (1984) describes rangelands as tracts of land used for grazing by domestic livestock or wildlife, where natural vegetation is the main forage resource. They may be used for ranching, as where animals graze on private land, or for three other systems of extensive grazing: nomadic pastoralist, transhumance or sedentary pastoralist [4].

The fundamental challenge of grazing management is to optimize, simultaneously, the interception and conversion of solar energy into primary production and the efficient harvest of primary production by livestock [5]. Grazing management involves the manipulation of kinds and classes of livestock, stocking rate, grazing season and grazing intensity to optimize these two opposing processes and maximize livestock production per unit area on a sustainable basis [6]. The managerial task of optimizing primary production and efficient forage harvest is further complicated by climatically induced variation in plant production and the widespread

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occurrence of selective grazing [5]. Worldwide, at least 40 million pastoralists depend on natural grazing for their livelihood; most are subsistence herders and more than half are in Africa. Rapid increases in human and livestock populations this century, have contributed to increasing grazing pressures, particularly in arid and semi-arid environments [7-10]. The disappointing record of development programs forced a re-interpretation of grassland ecosystems, their dynamics and development opportunities. This has led to a re-evaluation of concepts such as desertification, overgrazing, land degradation and an assessment of whether, in some grazing lands, no form of development is possible. The scientific community now acknowledges that the exploitation of spatial and temporal variability within grazing lands is a key factor for their sustainable use. With traditional, pastoral peoples, this has long been appreciated, as transhumant and nomadic systems show. The re-interpretation of rangeland ecosystems is often referred to as the "paradigm shift." This shift has led to a revised approach to rangeland development, based on a more complete understanding of grazing-based livestock production systems, including their limitations and dynamics and a greater role for local people in participatory planning. The "new perspective," and the recent availability of innovative data collection and analysis tools, provides powerful new aids to improving the protection and management of grazed environments [11].

In temperate and cold latitudes, such as the Vahregan district, the forage production year is distinctly cyclic and plant growth is concentrated in a limited growing season, during which time temperature and soil moisture are usually conductive to plant growth. Range and most pasture vegetation is highly heterogeneous and dynamic across space and time and grazing animals can select diets much different from the average of what is available to them [12]. This study describes components of pastoral rangeland system in Vahregan, Central Iran and highlight issues relating to forage endowment and environmental dynamics. It shows an integrated approach to land and forage resource assessment that facilitates quantification of the rangeland resource, understanding of resource component inter-relationships and prediction of environmental impact and appraisal of development options. The output of the rangeland changes constantly due to the tremendous influences of many interacting factors. The technique described has been successfully applied in a PhD thesis and is designed to overcome shortcomings of traditional methods of available forage assessment estimation [13].

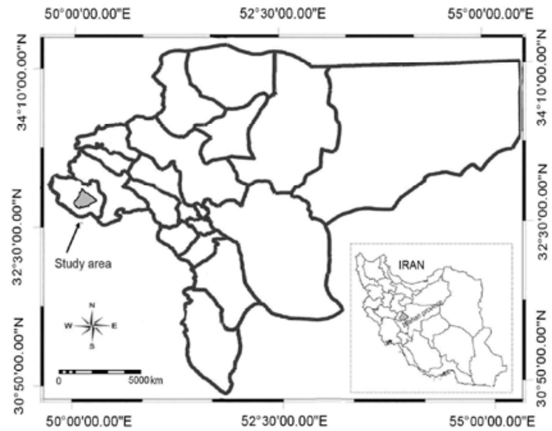

Fig. 1: Location of study area within the Vahregan District

The above definitions imply that any uncultivated ground is suitable for grazing. No criteria concerning ecological, vegetative, wildlife or aquatic communities' abilities to sustain large-scale herb ivory are established. Under these definitions, accessibility to grazing animals is the determinant of suitability [14,15].

Determination of available forage for domestic livestock grazing, although politically and pragmatically complex, is a viable tool for improving range condition. Determination of available forage should be used if for no other reason than that it hasn't contributed to present poor ecological range condition.

Procedure

Study Area: The study area is located in the Vahregan catchments in the Isfahan Province, in the Central of I. R. Iran. The area under the study (50°, 00´-50°, 12´E and 32°, 56´-33°, 48´N) is a 25,012.4-hectare plain. Its elevation range is from 2,200 to 3,135 meters (Mean 2,578 meters above sea level) (Figure1).

The climate is semi arid with an average annual rainfall of 542 mm/yr., falling mainly in the autumn and winter. The average minimum and maximum temperatures are 3.1°C and 16.7°C (Mean annual temperature is about 10 degrees Celsius). The Vahregan's rangelands contain 10 vegetation types including 3 shrub communities, 1 grassland community, 1 forb community and 5 botanical compositions shrub, forb and grassland communities (Table 1).

Sheep and goats were the two main sources of animal production. In Vehregan, the rangeland area is negatively affected by inappropriate land management practices, e.g. overexploitation. Uncontrolled exploitation of the vegetation of the rangelands has an effect on the forage quality because of the transition from a plant community

Table 1: Vegetation communities in Vehregan rangelands

Number	Vegetation type	Area (ha)
1	*Agropyron trichophoum*	206.46
2	*Astragalus brachycalyx*	1,857.68
3	*Astragalus brachycalyx-Agropyron trichophorum-Erngium billardierii*	1,293.84
4	*Astragalus adscendens*	6,676.61
5	*Astragalus brachycalyx-Eryngium billardierii*	1,759.61
6	*Astragalus adscendes-Agropyron trichophorum*	1,533.35
7	*Astragalus brachycalyx-Dorema ammoniacum*	183.74
8	*Eryngium billardierii-Serratula latifolia-Astragalus adscendens*	850.97
9	*Ferula ovina*	2,931.52
10	*Astragalus brachycalyx-Silene conoidea*	1,052.42
Total rangeland area	18346.2	

with a higher nutritive value to one with lower nutritional value. Overstocking and extended grazing periods are current characteristics of inappropriate management practices in the study area. In this study, 182 plant species in ten major vegetation types were identified in highland rangeland in Vahregan in negative and poor trend and condition.

Identification and Selection of Development Options: A study questionnaire was used for identification of local environmental and managerial constraints of rangeland to facilitate the relevant list of component issues and the subjective ranking of their importance. The component issues include factors that affect topography, edaphic conditions, plant species choice and rangeland management. Responses to the questionnaires were obtained from the local government offices and research conduction on rangelands and analyzed in parallel with results obtained from detailed interviews with pastoralists. In general, opportunities for rangeland improvement through plant species introduction has more potential in the more humid zones, whereas grazing management is the primary option in semi-arid areas, but an important aspect across all zones.

Geographical Information System (GIS) technology with different software packages like ARCVIEW, ILWIS, MICROSTATION and EXCEL were used to interpret the data, in association with detailed land use surveys is a valuable tool for modeling and analyzing land systems and therefore useful in development planning and management [16]. The following components were analyzed using GIS: topography, land systems (landform, climate, soil type, soil depth and soil texture), vegetation, land use and grass species composition changes. In this study, a visual scoring method of the available dominant species to report the vegetation cover map, botanical composition and forage production in 10 vegetation types (VT) in the Vahregan region. The results were used in order to develop a model of available forage and its components, including the Proper Use Factor (PUF) model and the palatability (PL) model and a hardcopy of the map, developed from the digitized calculation of the VT found in the rangeland. Overlay of integrated areas of VT and PUF, were shown by utilizing GIS Arc/view features.

Proper use (PUF) is defined as the degree of utilization of the current year's growth that, if continued, will achieve management objectives and maintain or improve the long-term productivity of the site. PUF varies within season and systems of grazing [17]. Season, rainfall, soil erosion, slope types, vegetation types, rangeland condition and trend, palatability and management are all factors that can included as components for the available forage model (Figure 2).

Rangeland Forage Types, Condition and Dynamics: Vegetation classes, along with distribution information, are an adjunct to general land use data sets. This information is necessary to characterize the study area, ascertain rangeland condition and assess proper use factors. For each vegetation class, information included; floristic composition, area, altitude range, rainfall range, temperature range, soil type, edaphic factors and the occurrence of palatable and unpalatable plants. Floristic composition and vegetation class information, in effect, summarized the spatial environmental variability of the area. The principal forage parameters required are; yield, utilization and quality. Values of each of these parameters reflect the inter-and intra-year variability of forage supply typical of many rangelands, particularly in arid and semi-arid environments.

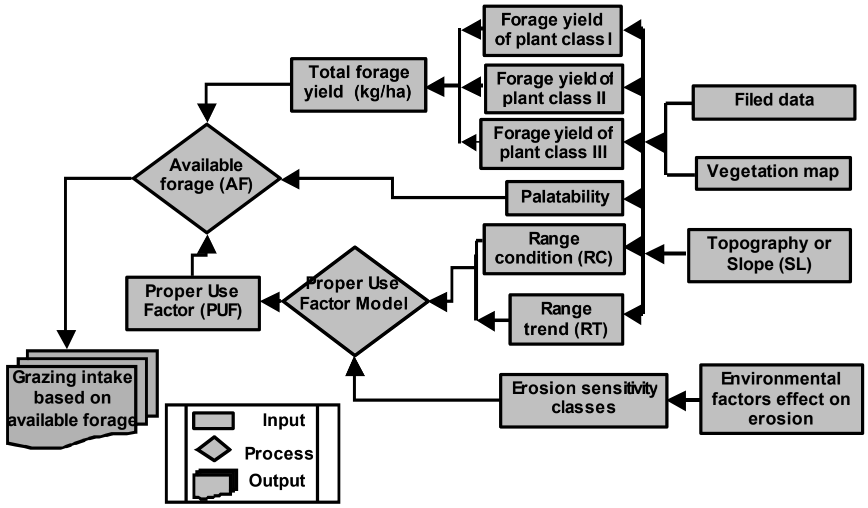

Fig. 2: Conceptual model of forage production and available forage (AF) under highland Range Production System

Rangeland condition and dynamics are major issues in the assessment of grazing land for sustainable use. This is especially true in relation to ecological thresholds, such as; responses of the system to changes in grazing pressure, seasonality of production and the level and impact of inter-year variability of climate on system productivity [11]. Information on the seasonality of forage supply can be used to assess the nature of forage resources and feed balances, particularly in relation to livestock forage requirements. General information on grassland growth patterns was obtained from Badjian *et al*., (2007) [18]. Details, such as patterns and trends of rangeland and the occurrence of forage deficits were obtained from interviews with pastoralists. Rangeland condition (RC) is a value-laden term, often associated with particular models of rangeland change or particular modes of measurement. Sometimes, RC is assumed to exist in some absolute form and assessments are designed to capture it, or at least to approximate it as closely as possible. The differences amongst definitions are significant and reflect perceptions of how and why change occurs under use and the objectives of the assessment [19]. The term is simply a concept, comparing the level of specific indicators such as vegetation cover, production, composition or soil erosion at a particular location with the assumed potential for that attribute within that vegetation type or compared with other locations.

Range trend (RT) is the direction of change in condition or state of the rangeland. However, a true representation of trend has rarely been measured successfully by comparing data over time [20]. RT in this study was categorized as up, down and fair trend classes and illustrated in detail in Badjian *et al*., (2007) [18]. Estimates at a single point in time of 'apparent trend' have depended on current measures of plant composition, plant age, distribution, vigor, litter accumulation and soil surface condition [21].

So range condition of a site based upon the above four factors is then determined by totaling the condition scores for all species present. The numbers obtained (0% to 100%) can be divided into 4 classes:

- Excellent Condition = 76 to 100% of the climax community
- Good Condition = 51 to 75% of the climax community
- Fair Condition = 26 to 50% of the climax community
- Poor Condition = 0 to 25% of the climax community [22].

Available forage (AF, kg/day) for livestock was calculated as:

$$AF = \sum (Y + (P/PUF)) \quad (3)$$

Where; Y= yield (kg/ha), P = palatability and PUF = proper use factor [23]. PUF was determined by combining information on range condition (RC), range trend (RT) and soil erosion sensitivity [13] (Figure 3).

The coefficient rates including consideration of RT and RC for PUF and the requirement to leave 50% of the forage for regeneration and soil conservation [24] are shown in Table 2.

Because livestock is the major user of primary production in the semi-arid and arid regions, degradation has always been attributed to this sub-sector [25].

Table 2: Coefficient rates of palatability and proper use factor for calculation of available forage

Soil Erosion sensitivity (SE)	Range condition (RC)	Range trend (RT)	Proper Use Factor (PUF)
Low and Medium	Good or Excellent	Up or Static	50
Low and Medium	Good or Excellent	Down	40
low	Fair	Up or Static	40
Medium	Fair	Up or Static	35
Medium	Fair	Down	30
High	Fair	Up or Static	30
High	Fair	Down	25
Medium	Poor	Up or Static	30
Medium	Poor	Down	25
High	Poor	Up or Static	25
High	Poor	Down	20

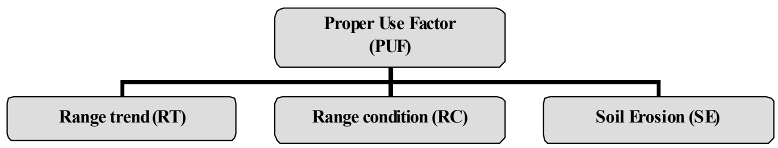

Fig. 3: Conceptual model of Proper Use Factor (PUF) based on Range Condition (RC), Range Trend (RT) and Soil Erosion sensitivity (SE)

United Nations Environmental Program (UNEP) singled out human impact and, specifically, livestock grazing as being the cause of the irreversible degradation, which prevailed during the past two decades [26]. Most of Iran's rangeland is in a class lower than poor condition (very poor). So the first class of rangeland condition (Excellent) is no longer seen. Sheep are less intimidated by steeper terrain than cattle and tend to prefer upland grazing sites. Sheep used all slopes regardless of steepness, but when terrain was especially rough, the animals mostly trailed through the area, making little use of the available forage. Sheep utilization was relatively uniform on all side slopes less than 45%, but utilization was reduced by 50-75% on the steeper slopes. The un-herded sheep tended to use the same bedding grounds on the ridge tops with up to 70% forage removal but with significantly less forage use on the mid slopes and bottomlands [27].

Soil Erosion Conditions: The characteristics and distribution of soil erosion provide substantive information relating to land use patterns and highlight edaphic constraints to rangeland. This information is also necessary to assess suitability of plants proposed for introduction. Historical land use data allows for the analysis of trends in land use and land capability. The main sources of land use and class data are universities and research institutions and land users.

The soil erosion properties were used in this study as one of the main factors of PUF. The relationship between soil erosion and species in rangeland was determined by the local knowledge of nomads and consultation with Isfahan Institute of Research Forest and Range (IIRFR). Soil erosion was categorized in four groups based on the definitions from Amiri (2010) in details [28]. Soil depth, type, texture, gravels, structure, rocky outcrops and groundwater were the characteristics used to categorize each group (Figure 3).

For creating erosion sensitivity classes, the slope map and EPM model were used to calculate erosion potential (Figure 4). According to this model;

$$Z = Y.Xa\,(\Psi + I^{0.5}) \quad (1)$$

Where; Z is the erosion severity index, Y is the sensitivity of soil and bedrock to erosion, Xa is the land use index, Ψ is the erosion index of the watershed and I is the average gradient of the slope. Sensitivity to the erosion sub-model for each vegetation type was created by integrating range condition, land use, slope, erosion potential, soil characteristics and geology. Sensitivity to erosion was then classified as shown in Table 3.

Topography or Slope (SL): Holechek (1988) [30] provided the first formal procedures for adjusting grazing capacity for slope and distance from water and his reductions are

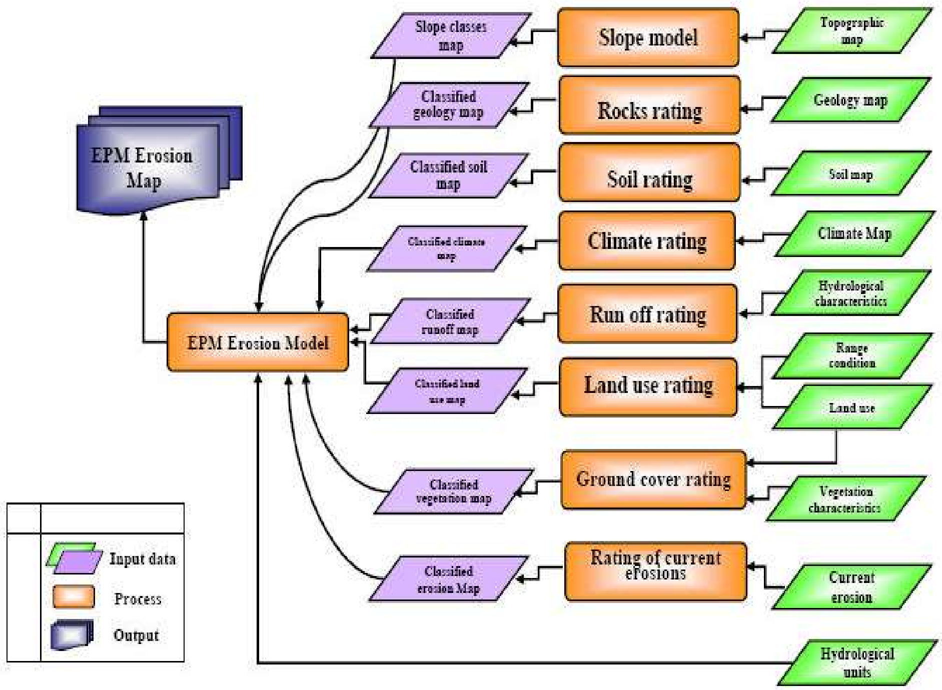

Fig. 4: EPM Model for Soil Erosion [28]

Table 3: Classes of sensitivity to erosion [29]

Symbol	Range of Z	classes
1	< 0.2	Low
2	0.2-0.7	Medium
3	0.7-1	High
4	>1	Very High

well supported by previous and present research like Valentine (2003) [31]. Most recently, the United States Department of Agriculture-Natural Resources Conservation Service has adopted Holechek's guidelines. His guidelines involve no reduction for 0-10% slopes, 30% reduction for 11-30% slopes, 60% reduction for 31-60% slopes and 100% reduction for slopes over 60%. At the very least, 50% of the above-ground biomass needs to remain each season, to ensure that the plant community remains viable and can regenerate itself and remain resilient, even in the face of drought [19].

In this study, upon consideration of the Holechek guidelines, the coefficient rates of slope as a factor of PUF were defined and shown in Figure 4.

Estimation of Proper Use Factors and Palatability: Two forms of utilization information are required for rangeland: proper use factors (optimal or recommended levels of use) and current levels of use. Differences between the forms of utilization indicate under or overexploitation of the grazing. Such information was obtained from pastoralist interviews and field visits. Estimates of proper use factors incorporate grazing efficiency (the proportion of total herbage that livestock can harvest), carry-over losses between time of forage growth and consumption, forage losses due to trampling and fouling during period of consumption and the maximum proportion of forage that can be grazed without causing rangeland deterioration [32, 33].

The estimation of proper use factors for rangelands is a complex process and carries the risk of misinterpretation due to generalization. Indicative values for a range of rangelands are presented in Table 4. Such values are influenced by local conditions and differences in livestock species, vegetation, soil erosion and the timing of grazing use relative to the forage growth season.

Based on SRM (1991) [24], if a pasture is continuously grazed for the grazing season, PUF will be approximately 50% (i.e., take half and leave half); if the pasture is in a planned grazing system, “proper” use may be 60%. In the current study PUF is determined by the available forage from a maximum 50% of key species on key grazing areas [33]. Forage availability (AF) is affected by integrated topography factors (SL), soil erosion properties (SE), rangeland condition (RC) and rangeland trends (RT). The factors illustrated in Figure 2 follow the coefficient rates and minimum rate of the PUF model stated by Amiri and Arzani (2010) [34].

Table 4: Relationship between slopes, soil, range trend and range condition with vegetation types in Vahregan

VT	Range condition	Range trend	Soil erosion	Slope group	Area / ha
1	Fair	Downward	2	2,3	206.46
2	Poor	Downward	2,3	1,2,3	1,857.68
3	Fair	Downward	1,2	2,3	1,293.84
4	poor	Downward	1,2,3	2,3	6,676.61
5	Poor	Downward	1,2,3	1,2,3	1,759.61
6	Good	Static	2,3	1,2,3	1,533.35
7	Fair	Downward	1,3	2,3	183.74
8	Fair	Downward	2,3	2,3	850.97
9	Poor	Downward	1,2,3	2,3,4	2,931.52
10	Poor	Downward	2	1,2,3	1,052.42
Total					18,346.2

$$PUFsp = f \text{ (Min. rate of one of: RC, RT, SOP, SL)} \quad (2)$$

Where; PUFsp is the proper use factor of the given species.

The cumulative PUFsp consider as PUF in estimation of available forage (AF). Integrated VT and PUF were studied using GIS based on digitalized maps and information was stored for later analysis. The coefficient rates of integrated factors were used to obtain new maps of integrated PUF.

Palatability is defined here as the relative attractiveness of plants to a grazing animal, whereas preference is the act of selection of specific plants by the animal. Animals select one type of forage over another based on smell, feel and taste. Texture, leafiness, fertilization, dung or urine patches, moisture content, pest infestation, or compounds that cause forage to taste sweet, sour, or salty may therefore influence palatability (PL). The visual estimation for yield determination is made midway during mob grazing of the plants by sheep/goats. The determination of palatability is based upon the leaving of 50% of the forage for regeneration and soil conservation [24]. Therefore, the maximum palatability rating belongs to class one under good-fair rangeland conditions (50%) and the minimum belongs to class three under poor-very poor rangeland conditions (15%). For this purpose, the species found in VT labeled in palatability classes, under consultation with the Iranian range management specialists [34]. Figure 3 shows the integration of the forages palatability with consideration of RC.

Estimation of Available Forage (AF) Model: The term AF, refers to that portion of the forage production accessible for use by a specified kind or class of grazing animal [24]. It is the consumable forage stated in digestible dry matter per land unit area, which removes by grazing livestock without damage to the forage plants. In this study, the PL model was compared with the PUF model to show the lowest coefficient rate for calculation of AF.

$$Afsp = PUFsp \text{ (if PUF< PL)} * Pspi * Svt \text{ (kg DM/ha)} \quad (3)$$

or

$$Afsp = PLsp \text{ (if PL <PUF)} * Psp * Svt \text{ (kg DM/ha)} \quad (4)$$

Psp is the production of expected species of each species class in the VT, AFsp is the available forage of expected species and Svt is the area of VT [34].

These equations show the important role of PUF as a forage index and PL as a limiting factor for range grazing (Figure 3). Therefore, the amount of AF is conditional and based on the minimum coefficient rate of PUF or PL. This is due to the limitations and sensitivity of range production to degradation in arid or semi arid regions. Estimation of AF by plant species, the consumption by the animal and the contribution of the forage to the animal's diet should be synchronized with each other in the same period [31, 35].

To measure the forage production area, the digitized land use map of Vahregan was overlaid the digitized species production VT map. Furthermore, the VT map was overlaid on the PUF component areas, to show the amount of forage production in specific unit area accompanied with the available forage (AF).

RESULTS

Digitized Features of Proper Use Factor and its Attributes: Figure 5 shows the digitized features of the slope (Figure 5-1), soil erosion (Figure 5-2), vegetation types (Figure 5-3), rangeland trend (Figure 5-4) and condition (Figure 5-5) with their areas in Vahregan. About 10 different vegetation types with 18,346.2 ha have been

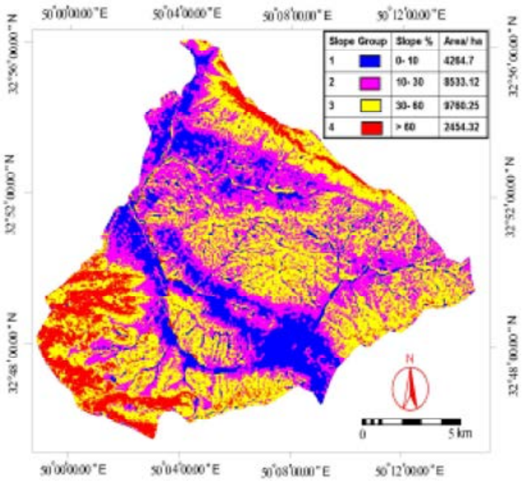

Fig. 5.1: Slope properties in Vahregan

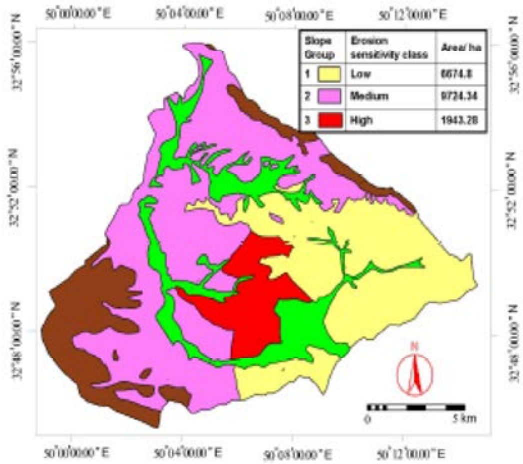

Fig. 5.2: Erosion class properties in Vahregan

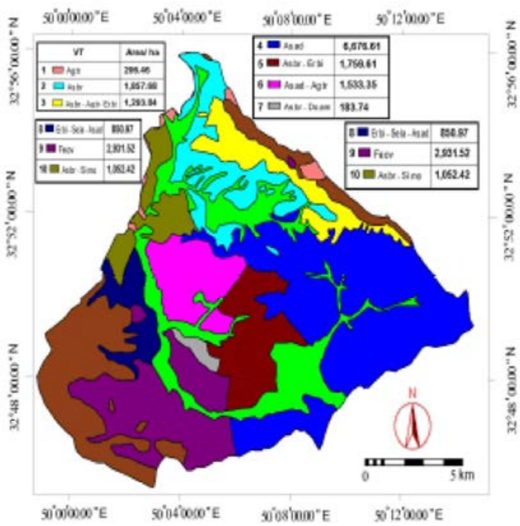

Fig. 5.3: Vegetation type of Vahregan watershed

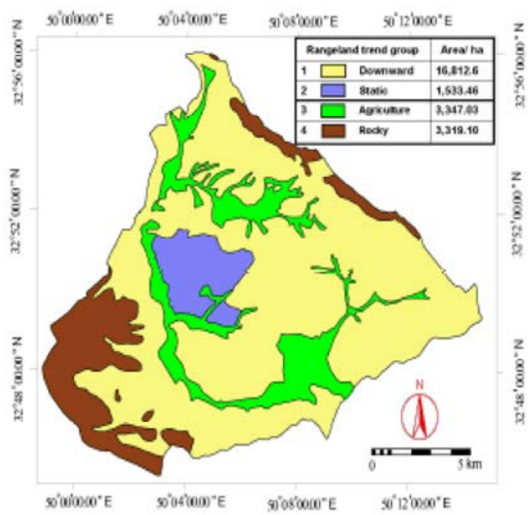

Fig. 5.4: Rangeland Trend (RT)

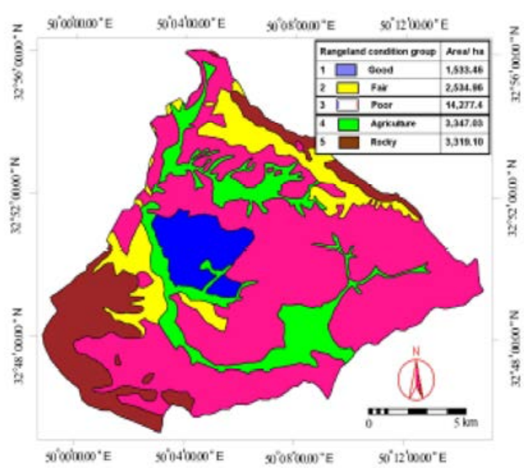

Fig. 5.5: Rangeland condition

Fig. 5: Features and attributes of Proper Use Factor (PUF) for measurement of available forage (AF) in Vahregan

Table 5: The forage production of vegetation types (VT) among the botanical compositions

	Vegetation Types, kg/ha									
Botanical groups	1	2	3	4	5	6	7	8	9	10
PG	303.4	24	82.5	15	84.8	3.6	28.2	31.62	24.76	4.8
PF	218	66.8	121.5	78.6	283.7	181.5	361	92	416.6	256
AL	-	-	7.02	-	-	-	-	0.8	-	-
PL	7.14	-	9.9	5.1	4.6	1.03	1.1	4.06	-	-
SL	20.3	-	8.6	13.5	15	30.5	9.3	6.97	-	-
S	52.9	389	215.6	281.4	192.2	207.3	199.6	163.2	84.6	21.3
Total	601.74	479.8	445.12	393.6	580.3	423.93	599.2	298.65	525.96	282.1

Perennial Grasses (PG), Perennial Forbs (PF), Annual Legumes (Al), Perennial Legumes (PL), Shrubs-likes (SL) and Shrubs (S)

defined in Vahregan rangelands. A rangeland in Vahregan covering 18,346.2 ha of the land area and have an important role in incoming production by feeding domestic livestock. The total area of land area was 25,012.39 ha.

These species in VT belong to six botanical compositions Perennial Grasses (PG), Perennial Forbs (PF), Annual Legumes (Al), Perennial Legumes (PL), Shrubs-likes (SL) and Shrubs (S). Table 5 shows 10 VT forage productions among the 6 botanical compositions. This Table indicates that the VT1, VT7, VT5, VT9 and VT2 with 501.74, 599.2, 580.3, 525.96 and 479.8 kg/ha respectively are the most productive VT in Vahregan.

Figure 5 also indicates that only 1533.46 ha (8.3%) of the rangeland is in good, 2534.96 ha (13.8%) in fair condition and the rest are in poor (77.8%). The area of the rangeland is situated at a long distance from the village and the watering points, which makes it less attractive to grazing animals and shows a positive trend (up) and good condition.

Property features of the 7 hydrological units and the area categorizes into three groups based on erosion sensitivity class with their coefficient rates (Figure 5-2) indicates that most of the rangeland area has the erosion sensitivity class “group 2” (9724.34 ha). This group is characterized by shallow to relatively deep soil with low infiltration rate (Figure 5-2).

Group 1 is located at the east of the plain and is low soil erosion with suitable infiltration rate. Group 3 high soil erosion and sensitive to soil erosion, with very low depth and low infiltration rate, around village and water point that is trampled by intensive domestic livestock. Group 2 cover 38.9% of the Vahregan rangeland, so special soil management techniques are needed to inhibit soil erosion in order to allow for a sustainable exploitation of the rangeland.

Slope type properties are included in the study area (25012.39 ha) and agriculture area (3347.03 ha) with defined located on slope range from zero to >10% steepness. Group 2 and 3 covers 73.1% cropland with a slope of 10-60%. Among the four slope groups, group 3 (30-60% slope) covers most of the Vahregan central area with its 9,760.25 ha. Only a small part of the Vahregan contains slopes >60% (Figure 5-1).

Table 4 is the integrated results of the digitized feature of VT featuring of soil erosion classes, slope type, rangeland condition and rangeland trend(s). The results indicate that most parts of the VT are located three soil erosion classes with their affects. VT 1 and 10 cover only one soil erosion class and other VT are scattered on all erosion groups (soil erosion) so it can be concluded these VT have a minimum and maximum relationship with soil erosion properties, respectively. The all VT are found on all slopes, VT 2,5,6,9 and 10 on three of them and the rest are found on either 1 or 2 slopes. Slope group 3 has the maximum frequency and slope group 4 has the minimum frequency based on their area. The results stated in Table 4 also indicate the impact of the slope type properties on the VT forage production.

Of the VT area, 13.8% is in fair condition, 77.8% in poor condition with the most negative range trend and 8.3% have good rangeland condition with a permanent range trend.

DISCUSSION

Continuous use of the Vahregan rangeland is not only detrimental to animal production and vegetation cover, but also reduces the stability of soil and increase soil erosion which affects range degradation and threatening the production and available forage of these rangelands.

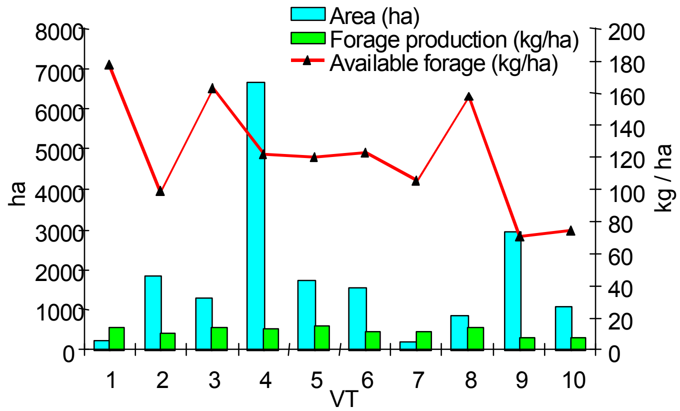

Fig. 6: Forage production and available forage of vegetation types in Vahregan

Factors such as soil erosion properties (10 soil types in 3 groups), topography or slope properties (0->60% slope steepness in 4 groups), range trend and range condition properties (10 vegetation types in 6 groups) were used in the PUF, while palatability of the vegetation and rainfall affect the forage availability and its utilization by animals. Data in Figure 6 shows the mean forage production and available forage of 10 vegetation types. The data in this figure is the results of combining PUF components, palatability and environmental factors on 10 vegetation types.

The results indicate that vegetation types 3 and 8 have the most productive species in presence of PUF components.

Soil erosion classes, rangeland trend, condition and topography are sustainable components of a vital production system such as Vahregan and have an important role in range management. They are used for estimation of PUF and PL models, calculation of forage production and available forage. This study indicates that rangeland in Vahregan is a fragile production system, sensitive to soil erosion and rangeland degradation. Therefore, a special range management plan should be developed to allow for a sustainable exploitation of the rangeland. Except in some parts of Vahregan most factors acted the same effect on forage production and available forage

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