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THE EFFECT OF PLANTING, PROTECTION AND FERTILIZATION APPLICATIONS ON VEGETATION, SOIL PROPERTIES, SOIL LOSS AND SOIL WATER CONTENT IN CENTRAL ANATOLIA DEGRADED RANGELAND

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Abstract: Soil and vegetation degradation is a serious problem in grasslands in Central Antolian Region of Turkey. Soils and vegetation in this region are highly degraded due to uncontrolled heavy grazing. Measures should be taken to restore the degraded grasslands to effectively combat desertification in these regions. This study was conducted to evaluate treatments; fertilized + planted + protected from grazing (A), Fertilized + protected from grazing (B), protected from grazing (C), and grazed (D) on forage quality and some physical and chemical properties of degraded grassland soils in Karakuz of Sivas, Turkey. Results showed that structural stability, aggregation index, electrical conductivity (EC), pH, $CaCO_3$, potassium (K) and SOM contents were unaffected; and hydraulic conductivity, bulk density, soil extractable P content, CEC, penetration resistance, dry grass yield, and cover percentage were affected significantly by treatments. Runoff and soil loss were not observed in any of the treatments during the five year study period. Fertilizers decreased the diversity (number of species) while it increased the forage quality and yield. During study period, 31 species vanished and 14 new species appeared in fertilized parcels.

Key words: Grassland management, soil properties, forage quality, desertification, water content

1. INTRODUCTION

Land degradation is a widely observed serious environmental problem in Turkey. In order to make reliable rangeland management decisions, we have to have a high level of knowledge of varieties in hydrological processes in rangeland ecosystems, thus different degrees of degradation is crutial. In order to obtain a better rangeland management, plant growth patterns, production and their influence levels on water and ecosystem degradation have to be studied in detail.

Heavy grazing pressures causing rapid degradation are observed more in ecologically sensitive arid and semi-arid rangelands. Efficient management of soil is the key ingredient in order to maintain a management of sustainable utilization of the drier rangeland areas is efficient soil-water management (Snyman, 1998; Dube, 1999; Oesterheld et al., 2001; Flemmer et al., 2002a,b). Prennial grasses' survival and production in arid and semi-arid rangelands are generally limited by water and nutrients (Ghebrehiwot et al., 2006). Thus, it is crutial to have a better understanding of plant growth patterns, productivity and their relation to the water availability (Flemmer et al., 2003; Wiegand et al., 2004; Snyman, 2005). Such drier areas exhibit a considerable temporal variability of water availability (Snyman, 1999; Busso et al., 2003) and vegetation dynamics (Snyder & Tartowski, 2006; Fernández, 2007; Rodriguez et al., 2007; Swemmer et al., 2007).

Vegetation productivity is low in nutrient deficient rangeland soils, and these further results in reduced organic matter content and nutrient cycling. Fertilizer application to rangeland increases plant productivity. In Turkey, soil degradation observed have numerous causes including over-grazing, drought and erosion. Erosion caused many of the rangeland soils to lose fertility and quality, by carrying away nutrients and soil particles. Soil erosion results in a soil to have decreased water holding capacity and water availability to plants, which further stimulates the soil degradation

(Rostagno, 1989). These areas continue to lose nutrients, water holding capacity, herbaceous cover, and soil particles by means of erosion once they become degraded (Ayoub, 1998). Infertility of rangeland soils is an explanation for eroded rangelands falling short of their production potential. Various cultural practices application on rangelands creates a potential to enhance soil properties including increased soil organic matter, increased extractable P, and increased soil moisture.

Recovery of soil C and plant nutrients are key to restoration of degraded rangelands (Martinez et al., 2002). The ultimate target of range management is to obtain increased plant growth and litter production, thus leading to increase soil C and nutrient contents (White et al., 1997). Inorganic fertilizers can be efficient to improve rangeland and soil quality. Also protection and revegetation applications may improve rangeland and soil quality in these degraded areas.

In Turkey, grassland degradation has increased since 1950, and approximately 12 million hectares of grassland converted into farmland. So, the grassland which was land use type changed has been rapidly degraded and most of them was abandoned. To avoid of the rapid degradation of pastures, some measures to be taken in recent years. For this purpose, grassland area is determined by measurements of cadastral to prevent land use changes in the expense of pastureland. Various projects are carried out for grassland improvement. In these works, there are several planting, fertilizing and protection facilities but not enough research activities.

The objective of this study was to determine some measures to restore degraded soils and vegetation in grasslands of semi-arid regions in Central Anatolia of Turkey. To do this, fertilizer application, plantation, conservation and their combinations were compared during five years of study period. It was hypothesized that application of these cultural practices could restore degraded soils and vegetation in the study area.

2. MATERIALS AND METHODS

2.1. Study Site

This study was conducted at natural grassland parcels in Karakuz village, located in Sivas region of Central Anatolia. The elevation at study site is 1411m and means annual precipitation is 306.4 mm year-^{1}, 84.2% of which falls between October and May. The mean annual temperature is 9.4^{o}C (DMI, 2009). The landscape has rolling hills while the study site had a slope range of 15% to 20%. The predominate vegetation species are *Graminea* and *Fabaceae*. The other vegetation types are steppe and meadow. The areas <10% slopes are mainly under cultivation. Wheat, sugarbeet, and cover crops make up the main part of the agriculture, while wheat is the dominant agricultural crop in the study area. The natural grassland mostly degraded due to heavy grazing. Soils texture is sandy loam, field capacity varied from 23.29% to 25.55%, wilting point from 14.60% to 15.43%, and hydraulic conductivity from 31.02 cmh^{-1} to 83.22 cm h^{-1}. The soils of the study area are moderately permeable, has low available water capacity, moderate water erosion hazard, moderate runoff, and a mean available rooting depth of 70 cm.

2.2. Experimental Design

This study was conducted at four parcels named A, B, C and D, each representing a treatment. In this study, *Agropyron cristatum*, *Sanguisorba minor* and *Hedysarum pogonocarpum* species were used for planting. In treatment A; a mixture of 20% *Agropyron cristatum*, 40% *Sanguisorba minor* and % 40 *Hedysarum pogonocarpum* was sown in lines with 50 cm intervals oriented along slope, in April 2004. At this parcel 0.25 Mg ha^{-1} composed fertilizer (20-20-0) (N-P-K) was applied at planting.

In treatment B; the plot was fenced to protect from grazing and 0.25 Mg ha^{-1} composed fertilizer (20-20-0) was applied. No planting was performed at this parcel. In treatment C, the plot was fenced against grazing and no fertilizer was applied. In treatment D; the plot was allowed to grazing and no fertilizers was applied. No harvesting was done at any parcels in the first year of the study. All the parcels were harwested at the same time in June in 2005, 2006, 2007, and 2008.

2.3. Methods and Techniques

Soil samples were taken at each parcel from 0-0.2 m depths every year in June. Prior to mixing each sample, which were stored in a plastic container, and pulverizing to pass a 2-mm sieve, stones and large plant roots or debris are removed by air drying. Then the soil samples were analyzed for soil organic matter (SOM) by Walkley-Black procedure (Nelson & Sommers, 1982), soil pH in 1:2 soil:water suspension (McLean, 1982), $CaCO_3$ content with a pressure calcimeter (Nelson, 1982), EC was measured in saturation extract (Richards, 1954), available phosphorus was determined by the Olsen method (Olsen et al., 1954), available K was extracted from the soil by ammonium acetate and measured with a flame photometry (Black, 1965), and cation exchange capacity was determined by saturating the soil samples with sodium acetate (Rhoades, 1982). Soil saturated hydraulic conductivity was measured in saturated undisturbed cores (Black, 1965). The soil penetration resistance (PR) was measured with a cone penetrometer at 0 – 10 cm depth (Bradford, 1986). Bulk density was measured by the core method (Blake & Hartge, 1986). The aggregation index was determined by wet-sieving method of Yoder. In the method, mean diameter weight of aggregate was subtracted from the mean diameter weight of primer particle (Yoder, 1936; Tuzuner, 1990). Structure stability was determined by water and mechanically dispersed samples in Bouyocous cylinder. These readings were done in 40 seconds using a hydrometer (Yoder, 1936; Tuzuner, 1990). Soil water content was determined gravimetrically after oven drying at 105°C and converted to mm water in soil by equation 1 (Richards, 1954). Soil samples were sampled to determine water content from 0 – 0.1, 0.1 – 0.2, 0.2 – 0.3 and 0.3 – 0.5 m soil depths. The soil sampling to determine soil moisture could not be carried out in the very dry times, the snow-covered days and very wet periods.

$$P_d = Pw * \rho k * d / 100 \quad (1)$$

Where, P_d is water (mm), P_w is gravimetric soil moisture (%), ρk is bulk density (g/cm^3), d is soil depth (mm).

The grasses were harvested from 5-6 cm height; they were dryed in the oven at 60°C until a constant weight was reached (Tosun & Altın, 1981). Canopy cover was determined by Quadrat Methods (Genckan, 1992). Botanic composition was determined by Braun-Blanquet method (1964), at the beginning of the research and at the end of the 5 years of experiment.

In 2004, four 5 m by 10 m runoff plots were set by 5 m apart and parallel to the slope. Runoff plots were bordered with a 20 cm high soil dich to keep precipitation and runoff within the plots. Each plot had a water catchment and container tank (0.56 m diameter and 1.00 m deep) at the lower end of the slope to catch runoff and sediment. A tipping bucket rain gauge connected to a data logger from year 2004 to year 2008 was used to collect the hourly rainfall data.

2.4. Statistics

The research was carried out in four grassland plots without replication. Parcel sizes were 5 X 10 m with a uniform slope of 15%. Soil samples and plant properties were measured with randomly selected ten different locations of each plot. Differences in soil and plant properties were analyzed with one-way ANOVA and means were grouped with LSD test when the variation was significant at 0.05 probability.

3. RESULTS AND DISCUSSION

3.1. Soil loss and soil water contents

During the study period the minimum rainfall was recorded 243.7 mm in 2007 and the maximum rainfall was 347.5 mm in years of 2007 and 2008 respectively. The average rainfall for 5 year experimentation was 314.2 mm (Table 1). No runoff and soil loss was recorded in any of plots.

Table1. Rainfall amount and soil water content in the study area (2004-2008)

Years	Rainfall, mm	Soil water content in 0-0.5 m soil depth, mm (Pd)			
		A	B	C	D
2004	305.9	291.16	279.94	308.08	323.12
2005	347.3	430.06	434.49	440.99	463.38
2006	331.7	313.06	343.02	372.42	375.76
2007	243.7	371.36	398.16	415.82	428.05
2008	342.4	239.59	241.30	267.53	268.89
Mean	314.2	329.05	339.38	360.97	371.84

Periodical soil moisture studies (five times in a year) were carried out in order to determine the applications' effect to soil moisture content and the results are given in Table 1. The plots covering different research topics are listed according to the soil moisture values. Amount of soil water accumulated in parcels D, C, B and, A in decreasing order. Since the amount and intensity of precipitation was low and the soils were continuously dry, no runoff was observed during the study. Therefore, effect of treatements on runoff was not clear. Since no water was lost by runoff and deep percolation the differences in moisture accumulation among treatments were resulted from differences in evapotranspiration.

The greatest vegetation development was observed at parcel A where soil water content was lowest and the least vegetation was observed at treatment D where water content was greatest at the harvest.

Table 2. Descriptive statistics of some soil and grassland properties at the treatment plots (n=10)

Variable	Min	Max	Mean	Median	#SD	#CV	Min	Max	Mean	Median	#SD	#CV
	A (Fertilized, planted and protected from grazing plot)						B (Fertilized and protected from grazing plot)					
$^{\#}K_s$	5.01	5.980	5.356	5.33	0.29	5.41	4.580	5.520	5.25	5.33	0.28	5.26
#BD	0.91	1.410	1.198	1.20	0.17	14.19	0.970	1.520	1.20	1.16	0.21	17.63
#SS	8.97	13.61	11.71	11.35	1.48	12.64	10.51	13.01	11.57	11.17	0.95	8.21
#AI	0.01	0.48	0.10	0.05	0.14	140.0	0.020	0.280	0.09	0.08	0.07	80.00
#EC	0.59	0.733	0.698	0.707	0.04	5.73	0.632	0.799	0.690	0.675	0.06	8.70
pH	7.41	7.71	7.57	7.58	0.10	1.32	7.48	7.64	7.56	7.55	0.05	0.66
$^{\#}CaCO_3$	2.20	4.40	3.18	3.10	0.86	27.04	1.80	4.80	3.22	2.95	1.10	34.16
#P	6.79	35.98	14.71	11.79	8.69	59.08	5.60	17.19	9.48	9.00	3.32	35.02
#K	111.3	318.0	146.3	129.0	61.6	42.11	104.6	163.61	140.04	141.52	21.67	15.47
#SOM	1.26	1.68	1.513	1.55	0.13	8.59	1.34	2.27	1.76	1.71	0.315	17.90
#CEC	42.02	69.10	59.07	59.91	7.82	13.24	33.39	74.37	59.94	61.17	10.23	17.07
#DGY	317.0	1728.00	1016.00	904.00	414.00	40.75	408.0	1500.0	969.00	1014.00	401.00	41.38
#CP	52.75	98.00	73.40	70.75	15.55	21.19	18.75	99.25	74.67	86.88	29.29	39.23
	C (Protected from grazing plot)						D (Grazed plot)					
$^{\#}K_s$	3.89	5.52	4.87	4.94	0.47	9.65	3.99	5.23	4.67	4.71	0.38	8.14
#BD	1.12	1.75	1.55	1.64	0.20	12.90	0.66	1.81	1.38	1.42	0.33	23.91
#SS	8.66	13.62	11.48	11.05	1.49	12.98	9.00	13.84	11.97	11.45	1.56	13.03
#AI	0.02	0.72	0.12	0.07	0.21	175.00	0.02	0.09	0.05	0.06	0.02	40.00
#EC	0.568	0.710	0.66	0.675	0.05	7.58	0.408	0.763	0.63	0.657	0.10	15.87
pH	7.11	7.69	7.48	7.55	0.20	2.67	7.23	7.67	7.51	7.54	0.14	1.86
$^{\#}CaCO_3$	2.20	5.20	4.03	4.60	1.16	28.78	1.80	5.90	4.19	4.40	1.27	30.31
#P	1.20	3.60	2.24	2.20	0.86	38.39	2.39	4.40	3.27	3.19	0.75	22.94
#K	98.10	771.60	192.30	121.80	205.00	106.6	104.6	188.88	140.28	143.89	25.79	18.38
#SOM	1.10	2.40	1.49	1.33	0.44	29.53	1.20	2.16	1.68	1.63	0.37	22.02
#CEC	59.45	91.88	69.05	63.14	10.95	15.86	59.45	72.46	63.14	61.80	3.70	5.86
#DGY	210.0	1397.00	563.00	478.00	345.00	61.28	176.4	656.00	376.30	360.40	173.00	45.97
#CP	23.75	68.25	43.35	43.00	13.73	31.67	5.75	77.00	51.90	54.87	22.82	43.97

#SD: Standart deviation, CV: Coeficient of variation, K_s: Saturated Hydraulic conductivity (cm h^{-1}), BD: Bulk density (g cm^{-3}), SS: Structure stability (Dimensionless), AI: Aggregation Index (mm), EC:Electrical conductivity (mmhos cm^{-1}), $CaCO_3$ (%), P:Phosphorous (ppm), K: Potassium (ppm), SOM: Soil organic matter (%); CEC: Cation exchange capacity (me $100g^{-1}$); DGY:Dry grass yield (kg ha^{-1}); CP:Cover percentage (%).

3.2. Soil and grassland properties

At the end of the five years, the effect of the applications on the soil properties was evaluated. For this purpose 80 soil samples, collected from (0-0.2 m), were analysed in 2008. The descriptive statistics for soils of the treatments are given in table 2.

Differences in soil and grassland properties were analyzed with one-way ANOVA and means were grouped with LSD test if the variation was significant. The applications did not cause a significant difference in structural stability (SS), aggregation index (AI), EC, pH; and $CaCO_3$, K and SOM concentrations. However, significant differences were observed in saturated hydraulic conductivity (K_s), bulk density (BD), available P concentration, CEC, penetration resistance (PR), dry grass yield (DGY) and cover percentace (CP) (Table 3).

In treatments A and B, fertilizer applications would result in a better root growth. Therefore, the increased K_s in these treatments were attributed to increased root growth by P fertilizers and decreased compaction in these grazing prevented parcels. In these treatments, fertilizer application increased plant available P content, significantly. Similar to K_s, BD was significantly affected by treatments ($P<0.01$). Lowest BD occurred in treatments A and B, and highest in treatment C. Unexpectidly, greatest BD was observed in treatment C, instead of D, and this was attributed to greater OM content in treatment D. We also attributed this to the fact that the bulk density samples would be taken from uncompacted locations by chance in treatment D. Li et al., (2011) were found similar results in the northern Loess Plateau where vegetation has naturally recovered. They have been detected significant improvements in soil physical properties, including decreases in bulk density and increases in hydraulic conductivity. The residual effect of P fertilizer was still significant in treatment B after five years (the P fertilizer was applied in B only one time at the beginning of experiment).

Table 3. Effect of treatments on soil properties and dry grass yield in the study area

	#K_s	#BD	#SS	#AI	#EC	#pH	#$CaCO_3$	#P	#K	#SOM	#CEC	#PR	#DGY	#CP
A	5,36[a]	1,20[a]	11,71[a]	0,09[a]	0,698[a]	7,57[a]	3,18[a]	14,7[a]	146,3[a]	1,51[a]	59,08[a]	1013,2[a]	1016,0[a]	73,40[a]
B	5,25[a]	1,20[a]	11,58[a]	0,08[a]	0,691[a]	7,56[a]	3,22[a]	9,5[b]	140,0[a]	1,76[a]	59,94[a]	1131,4[a]	969,0[a]	74,67[a]
C	4,87[b]	1,55[b]	11,48[a]	0,11[a]	0,664[a]	7,47[a]	4,03[a]	2,2[c]	192,3[a]	1,48[a]	69,05[b]	793,1[b]	563,0[b]	43,35[b]
D	4,67[b]	1,38[ab]	11,97[a]	0,05[a]	0,626[a]	7,50[a]	4,19[a]	3,3[c]	140,3[a]	1,68[a]	63,15[ab]	1514,4[c]	376,3[bc]	51,90[ab]

#Ks:Hydraulic conductivity (cmh^{-1}), BD;Bulk density (gcm^{-3}), SS:Structure stability (Dimensionless), AI:Aggregation Index (mm), EC:Electrical conductivity ($mmhoscm^{-1}$), $CaCO_3$ (%), P:Phosphorous (ppm), K:Potassium (ppm), SOM: Soil organic matter (%); CEC: Cation exchange capacity ($me100g^{-1}$); PR: Penetration resistance (KPa); DGY: Dry grass yield ($kgha^{-1}$); CP: Cover percentage (%).

That significant difference occurred between treatment A and B (Table 3), where same amounts of phosphorus fertilizer was applied, would be caused by better root activity at the former that increased the amount of available phosphorus content. Grater P content in treatment D than in C was attributed to P addition by grazing animals in the soils in the former, suggesting that a controlled grazing may be a good practice to maintain a nutrient levels in grassland soils.

Greater CEC in the parcel C than the others may be attributed to relatively high OM content combained with a slightly different clay content in the former (the experiment was set an area uniform in texture, however, by geostatistical concept, some spatial variation in soil texture is always expected).

Soil compaction is one of the most important soil quality indicators. Expectidly, gratest soil compaciton ocurred in treatment D. However, penetration resistance (PR) was always smaller than critical value of 2000 kPa, in which root growth of many plants is restricted. Greater PR at A and B than C was attributed to soil compaction caused by field crude while fertilizer application and grass planting.

Table 4 shows the canopy cover (CP) and dry grass yield (DGY) from 2005 to 2008. In treatments A and B, DGY decreased gradually by time due decreasing effect of applied fertilizer, suggesting that the fertilizer application may be repeated at least once in every two years to maintain the yield at reasonable level. Greatest four-year mean DGY occurred in treatment A and least in D.

In a due to that planted species out competed some native species, decreasing the DGY slightly. However, these outcompeted native species were mostly undesired ones by grazing animals. Therefore, replanting increased the forage quality. Compared to treatment B, DGY was slightly higher in A due to that planted species increasing the DGY slightly.

There was a tremendous difference in DGY between C and either A or B, and this suggested that protecting against grazing may not be enough to increase quality and yield of pastures in the study area, but some fertilizers and/or replanting may be necessary. In treatment D, mostly parennial plants were dominated and DGY was far below the A and B but close to C trials.

Surface coverage (CP) was always greater in A and B than C and D. Interesetingly, in general, CP and DGY did not agree. In all treatments, the DGY was almost independent from CP. In 2007, insufficient precipitation (Table 1) affected treatment B more serious than the other treatments (Table 4), resulting in tremendous decrease in CP compared to teament A. This suggested that the planted species in treatment A were adapted successfully to the drouhgt conditions.

The fertilizer application increased the pasture quality as high pasture quality species outcompeted the native ones. The diversity at the parcels was measured by Braun-Blanquet (1964) first in July 2005 and second in 2008. The results showed that the number of species decreased from 60 to 38; from 64 to 44, from 57 to 48 and from 39 to 26 in treatments A, B, C, and D, respectively.

Table 4. The temporal change of the dry grass productivity and canopy coverage

Treatment	2005		2006		2007		2008	
	#DGY	#CP	#DGY	#CP	#DGY	#CP	#DGY	#CP
A	-	90	2600	83	1781	92	1016	73
B	-	75	1543	83	1133	58	969	75
C	-	75	509	50	631	48	563	43
D	-	60	202	25	574	42	376	52

#DGY: Dry grass yield ($kgha^{-1}$); CP: Cover percentage (%).

In fertilized A and B plots, although the number of species decreased, high forage quality species such as *Graminea* and *Fabaceae* reappeared, increasing the pasture quality. These good quality species outcompeted poor quality species, increasing the forage quality. In treatment C where fertilizers were not applied, protection against grazing resulted in an increased number of species. Species *Astragalus – Artemisia* were dominant in this parcel, while *Gramineae* and *Artemisia* were the dominant species at parcels A and B, respectively. The treatment D occurred with lowest number of species due to grazing. This parcel was rich in species not preferred by grazing animals.

4. CONCLUSIONS

Restoration of degradaded grasslands in Central Anatolia of Turkey is important to combat desertification in these regions. The soils in the region are mostly low in organic matter content, slightly alkaline to alkaline, and are shallow to very shallow at steep to very steep localities. Soil texture varies from sandy to clayey and precipitation ranges from 240 to 350 mm/year in the study region. We studied effect of treatments; conservation + fertilization (A), conservation + fertilization + plantatiton (B), conservation (C), and grazing as a control (D) on soil properties, forage quality and yield, and richness and diversity of vegetation at a representative location in Sivas province of Turkey. During the 5 years of experimentation (from 2004 to 2008) precipitation ranged from 243.7 to 347.5 mm/year.

Conservation decreased penetration resistance, and fertilizer application increased soil organic matter content, dry grass yield (DGY), and soil surface coverage, significantly. Treatment A resulted in a slightly higher DGY than treatment B as planted species outcompeted some greater biomass producing native ones. Both A and B decreased diversity in vegetation. However, this decrease in diversity resulted in an inceased pasture quality as some low forage quality species vanished. The results showed that the fertilizer application should be repeated once in every two years to maintain a good forage quality and yield and that protecting against grazing may not be sufficient to enhance forage quality and yield but also fertilizers should be applied to ensure a good forage quality and yield. Only protecting application against to grazing may not be sufficient to improve grassland quality.

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